THE 2025-26

Radiology UPDATE

A 20-hour Comprehensive and Clinically Relevant Review of Key Imaging Topics Across Multiple Subspecialties of Radiology.

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David R. Victor, JD
CEO

Dear Registrant:

Advancements in imaging technology, evolving diagnostic criteria, and the integration of artificial intelligence continue to reshape the field of radiology. Staying clinically current is essential to providing accurate diagnoses and optimizing patient outcomes. ***The 2025-26 Radiology Update*** is designed to provide you with the latest insights and evidence-based approaches in diagnostic imaging.

This comprehensive 20-hour course features expert-led lectures from a wide array of imaging disciplines including: body imaging, neuroradiology, head and neck imaging, pediatric radiology, cardiothoracic radiology and artificial intelligence. Their presentations include topics ranging from Cholangiocarcinoma Imaging Updates, to HRCT Evaluation of Interstitial Lung Disease, Pediatric Trauma Imaging, AI and Quantitative Neuroimaging, Spinal Pathology and more.

To help you assess your level of comprehension, we have included brief self-evaluation quizzes within this syllabus. These tests are included in this syllabus and are identified by the black edges of the pages on which they are featured.

Your feedback is invaluable in shaping future iterations of this program. Please take a moment to complete the evaluation questions provided for each lecture. Additionally, we encourage you to engage with our expert faculty—your inquiries and insights contribute to a dynamic learning experience.

We also invite you to take advantage of the collaborative nature of this course. The diversity of participants provides an opportunity to exchange knowledge and perspectives with fellow radiologists and imaging specialists.

Thank you for your participation. I hope you find ***The 2025-26 Radiology Update*** both educational and rewarding.

Cordially,
American Educational Institute, Inc

David R. Victor, Esq.
CEO

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COURSE OBJECTIVES

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After completing ***The 2025-26 Radiology Update*** you should have acquired the knowledge that will better enable you to better:

- Appreciate for the diagnostic and treatment value of **cholangiocarcinoma imaging.**
- Improve the interpretation of spinal imaging through a **compartmental approach to pathology**, enhancing the ability to localize lesions, differentiate neoplastic, cystic, vascular, and degenerative processes, and communicate findings using standardized reporting systems.
- Improve recognition of imaging findings associated with **pediatric non-accidental trauma**, including musculoskeletal injuries, high-risk abdominal findings, and neuroimaging features, to aid in timely and accurate diagnosis.
- Understand **thoracic aorta disease imaging**.
- Understand MRI findings for **pancreatic disorders and diseases**.
- Enhance understanding of the role of **artificial intelligence in neuroimaging** to improve the detection, diagnosis, and monitoring of neurological conditions
- Improve the ability to recognize and interpret imaging findings in **pediatric genitourinary emergencies**, including urinary tract infections, obstructive uropathies, ovarian and testicular torsion, and other non-traumatic, non-oncologic conditions.
- Understand the rationale for as well as limitations and risks of **LDCT lung cancer screening**
- Understand **inflammatory bowel disease** and its imaging
- Understand the evolving role of **artificial intelligence in the imaging enterprise**, including its applications in workflow optimization, radiology reporting, quality assurance, and clinical decision support.
- Enhance the ability to recognize and interpret imaging findings in **neonatal emergencies**, including intracranial hemorrhage, respiratory distress, cyanosis, and bowel obstruction, to facilitate timely diagnosis and intervention.
- Understand HRCT evaluation and imaging manifestations of **Interstitial Lung Disease**
- More effectively utilize imaging techniques to diagnose **benign liver lesions.**
- Understand imaging findings for **diffuse liver disease and malignant liver lesions.**
- Understand **temporal bone anatomy** on CT and improve recognition of key pathologies to aid in accurate diagnosis and clinical decision-making.
- Understand the appropriate clinical application and current use criteria of **CMR and CTC evaluation of heart disease**
- Understand the role of MRI in **prostate** management
- Utilize imaging to identify female infertility caused by **GYN abnormalities and cancers.**
- Improve the ability to **recognize and differentiate incidental head and neck findings** on imaging, ensuring appropriate follow-up and management.
- Improve the understanding of **parathyroid imaging**, including anatomy, localization techniques, and the role of CT in preoperative planning for primary hyperparathyroidism.

All learning objectives above address IOM/ACGME core competencies.

THE 2025-26

Radiology UPDATE

FACULTY DISCLOSURES

The individuals listed below have control over the content of ***The 2025-26 Radiology Update***. None of them have a financial relationship with an ineligible company.

David R. Victor, Esq., CEO, American Educational Institute
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Summer L. Kaplan, MD, faculty member
Robert M. Marks, MD, faculty member
Wende N. Gibbs, MD, faculty member

The following faculty members of ***The 2025-26 Radiology Update*** have a financial relationship with an ineligible company:

Lawrence N. Tanenbaum, MD, FACR, AIdoc, Subtle, Icometrix – consultant. Fuji, Guerbet – speaker
Paul M. Bunch, MD, Guerbet – medical advisor

All lectures presented by speakers with relevant financial relationships have been peer reviewed. All speakers with financial relationships have attested that clinical recommendations they make are evidence-based and free of commercial bias.

Robert M. Marks, MD

Robert M. Marks, MD is a board-certified diagnostic radiologist and a professor of radiology at the University of San Diego. His clinical expertise is in body imaging of the abdomen and pelvis. His research interests include liver imaging including hepatocellular carcinoma diagnosis and surveillance. Prior to joining UC San Diego Health, he served as chief of abdominal imaging and program director of the body imaging fellowship at Naval Medical Center San Diego.

Dr. Marks previously served as a US Navy flight surgeon through two deployments. He completed fellowship training in body imaging at Naval Medical Center San Diego and residency training in radiology at Naval Medical Center Portsmouth.

He is a member of the Society of Abdominal Radiology, American Roentgen Ray Society, Radiological Society of North America, and American College of Radiology. He has been a manuscript reviewer for multiple journals including Abdominal Radiology, the American Journal of Roentgenology, and Radiographics.

You may contact Dr. Marks with any questions or comments by email at rmarks@health.ucsd.edu.

Cholangiocarcinoma Imaging Update

Robert M. Marks, MD

Disclosures

- Guerbet LLC

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Goals and Objectives

1. Understand recent updates for cholangiocarcinoma
2. Describe the process for creating the lexicon for CCA with a pictorial review
3. Review mimickers of CCA
4. Understand new reporting templates for CCA

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Cholangiocarcinoma

- CCA is a bile duct cancer
  - Intrahepatic cholangiocarcinoma
    - Second order or more proximal bile ducts
  - Extrahepatic cholangiocarcinoma
    - common bile duct or primary confluence

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Intrahepatic Cholangiocarcinoma

- 10% of all primary liver malignancies
  - second most common primary liver malignancy
- iCCA can also be classified based on morphological features
  - mass-forming
  - periductal infiltrating
  - intraductal

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Intrahepatic Cholangiocarcinoma

- More recent classifications of iCCA based on histologic features and genetic mutations
  - Small duct and large duct
- Classifications of iCCA has prognostic implications
  - Help guide treatment decisions
    - Surgical approach, resection, locoregional therapy
    - Systemic therapy (chemotherapy, immunotherapy)

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Risk Factors

- CCA: Asia > Western countries
- Conditions that lead to cholestasis and chronic inflammation
  - epithelial proliferation, increased risk of mutagenesis
- Chronic inflammation of the biliary epithelial microenvironment
  - inflammatory bowel disease, cirrhosis, viral hepatitis, chronic liver fluke infection
- Conditions leading to the increased systemic production of compounds that are mutagenic to the biliary epithelium
  - Fatty liver disease

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Precursor lesions for iCCA

CCA occurs through the dysplasia-carcinoma sequence

- 4 known precursor lesions

1. Biliary intraepithelial neoplasia
   - Often detected at margin of iCCA
     - Not detectable on imaging
     - Worse prognosis

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Precursor lesions for iCCA

2. Intraductal papillary neoplasm of the bile duct
   - villous or polypoid papillary mass that variably secretes mucin, produces a cast-like filling defect within the bile ducts, and obstructs and distends the involved segments of the biliary tree
   - Precursor of Intraductal CCA

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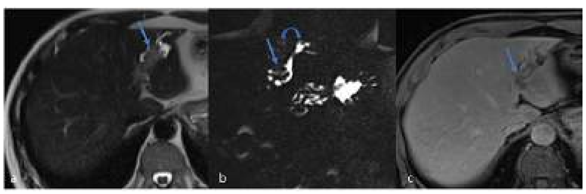
IPNB



El Homsi, M., Alkhasawneh, A., Arif-Tiwari, H. *et al.* Classification of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04732-8

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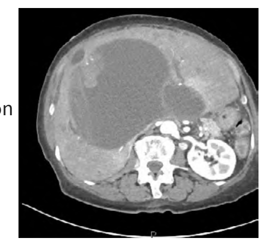
Precursor lesions for iCCA

3. Intraductal tubulopapillary neoplasia
   - Rare
   - Similar to IPNB, but no mucin production
4. Biliary mucinous cystic neoplasm
   - Previously a biliary cystadenoma
     - Ovarian stroma



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SAR DFP on CCA

- The Society for Abdominal Radiology (SAR) Disease Focused Panel (DFP) on cholangiocarcinoma was established in 2023
- Overarching Goal: To better detail the application of imaging (CT, MRI, PET-CT, PET-MR, molecular imaging) in the diagnosis, staging, and treatment response of Cholangiocarcinoma
  - A major goal was a lexicon specific for CCA

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Why a lexicon for CCA

- The Liver Imaging Reporting and Data System (LI-RADS) is a system was developed to standardize HCC diagnosis and treatment response assessment high-risk patients
- The LI-RADS M category is meant for lesions that are probably or definitely malignant, but not necessarily HCC
- LI-RADS M has many terms that pertain to CCA and metastatic disease

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LR-M Criteria

Targetoid, definition

Targetoid mass, imaging appearance on various phases or sequences

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Why a lexicon for CCA

- Lack of standardized terminology specific for CCA
  - Patients that do not fit LI-RADS population
  - Isolated findings specific for all types of CCA, both intra and extrahepatic
- Goal of Lexicon: Develop a lexicon specific for CCA that complements the LI-RADS M category terms

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Lexicon Development

- 11-member team from DFP
- Identified terms not included in LI-RADS M
- Once team agreed upon terms
  - Definitions, applicable modalities, synonyms, and comments

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Lexicon Development

- Once Lexicon team approved the lexicon
  - Sent to entire 49-member roster of the DFP for suggestions and edits
- Put to vote on April 28, 2024
- Each term needed 90% approval by the DFP
- 39 members voted
  - 2 surgeons, 2 pathologists, radiation oncologist, IR
- The entire Lexicon reached the 90% threshold

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15 Terms

1. **Intraductal**
2. **Mass-forming**
3. **Periductal infiltrating**
4. **Intrahepatic CCA**
5. **Distal CCA**
6. **Large Duct CCA**
7. **Small Duct CCA**
8. **Perihilar CCA**
9. **Dominant Mass**
10. **Intrahepatic Metastases**
11. **Satellite Nodules**
12. **Dilated upstream bile ducts**
13. **Hepatic Capsular Retraction**
14. **Lobulated Margins**
15. **Necrosis**

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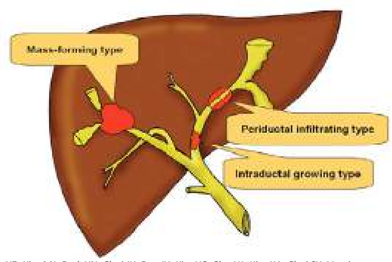
Morphological classification of ICC



Chung YE, Kim MJ, Park YN, Choi JY, Pyo JY, Kim YC, Cho HJ, Kim KA, Choi SY. Varying appearances of cholangiocarcinoma: radiologic-pathologic correlation. Radiographics. 2009 May-Jun;29(3):683-700. doi: 10.1148/rg.293085729. PMID: 19448110

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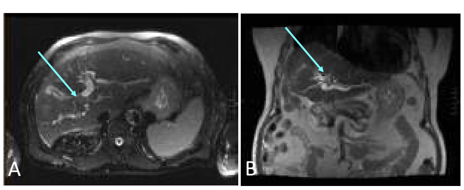
Intraductal

- Describes a morphologic growth pattern with a polypoid or papillary intraductal mass, often with biliary ductal dilatation
- According to the 5th edition of the World Health Organization (WHO), this morphologic growth pattern is considered a malignant transformation of intraductal papillary neoplasm of the bile duct (IPNB)



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Intraductal

- Typically grow slowly
- Favorable prognosis compared to other morphological sub-types

Chung YE, Kim MJ, Park YN, Choi JY, Pyo JY, Kim YC, Cho HJ, Kim KA, Choi SY. Varying appearances of cholangiocarcinoma: radiologic-pathologic correlation. Radiographics. 2009 May-Jun;29(3):683-700. doi: 10.1148/rg.293085729. PMID: 19448110

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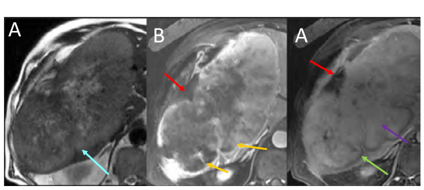
Mass Forming

- Describes a morphologic growth pattern as a space occupying hepatic mass
- Most common growth pattern
  - 65%-80% of all cases
- Often has targetoid imaging appearance (center and periphery of mass have different imaging characteristics)



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Mass Forming

- Worse prognosis than intraductal CCA
- Vascular encasement is common
  - Intravascular tumor thrombus is rare
- On histology
  - Viable tumor cells at periphery
  - Fibrosis, necrosis, and scant tumor cells in center
    - Leads to the targetoid imaging appearance

Han J K et al. Radiographics 2002;22:173-187

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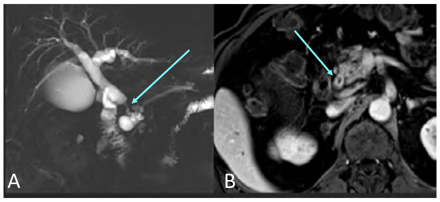
Periductal Infiltrating

- Tumor growth along bile ducts without mass formation
- Seen as periductal thickening, enhancement, or signal abnormality
- Can also see an abnormally dilated or narrowed duct with dilated upstream bile ducts.
  - o Spreads along the Glisson sheath of the portal triad
- May have an infiltrative, spiculated, non-smooth, or irregular appearance



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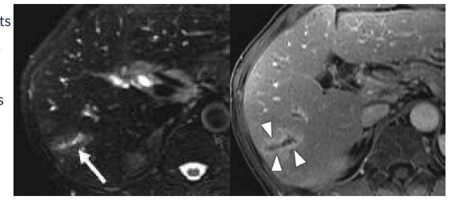
Periductal Infiltrating

- Relatively rare as iCCA
  - Large ducts > small ducts
  - Most causes of perihilar CCA
    - Becomes mixed mass forming/periductal infiltrating if allowed to grow



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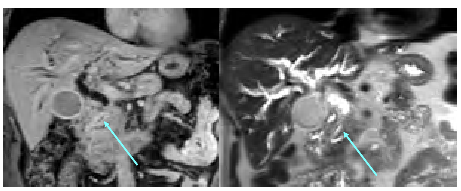
Periductal Infiltrating

- Worse prognosis than intraductal CCA
  - Extends beyond bile duct
    - Hepatoduodenal ligament
      - Neurovascular and lymphatic spread
    - Also spreads to adjacent organs
      - Precludes resectabiltity



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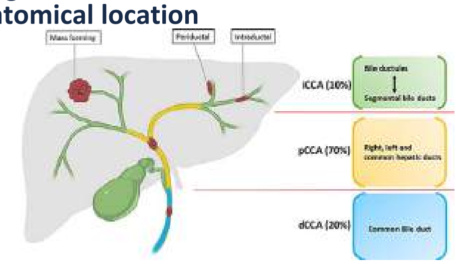
Cholangiocarcinoma can be classified based on anatomical location



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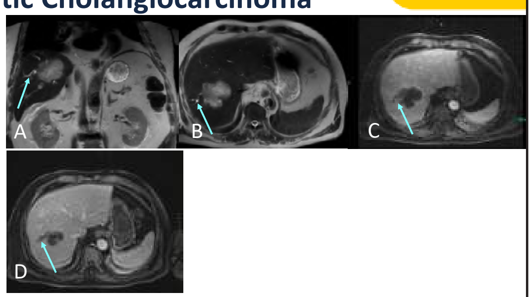
Intrahepatic Cholangiocarcinoma

- Arises within and/or proximal to second order bile ducts
- This is typically an intrahepatic mass forming CCA
  - o 80% of the time
    - Periductal infiltrating /intraductal less common



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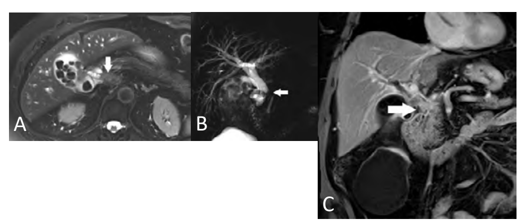
Distal Cholangiocarcinoma

- Tumor that arises in CBD, distal to cystic duct insertion
- May cause stenosis of the duct
- Periductal infiltrating/mass forming most common



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Distal Cholangiocarcinoma

- Tumor that arises in CBD, distal to cystic duct insertion
- May cause stenosis of the duct
- Periductal infiltrating/mass forming most common
- Poor prognosis
  - 50% recurrence 5 years after resection

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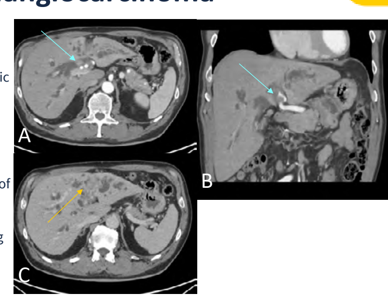
Perihilar Cholangiocarcinoma

- Also known as a Klatskin tumor
- Arises from common hepatic duct, main biliary confluence, or first order intrahepatic bile ducts
- Presents with dilated upstream bile ducts
- Periductal infiltrating 70% of cases
  - o Leads to mixed periductal/mass forming as it grows



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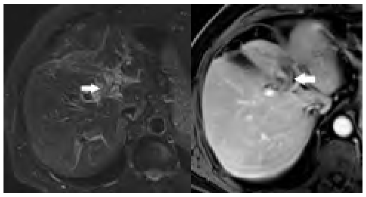
Perihilar Cholangiocarcinoma

- Median survival time 13-37 months
- Surgical resection is most curative
- Tumor staging
  - Bismuth-Corlette (BC) system
    - Describes proximal tumor involvement, used by surgeons
  - The American Joint Committee on Cancer staging system
    - Based on pathology and used for prognosis
  - Memorial Sloan-Kettering Cancer Center system
    - Adds vascular involvement



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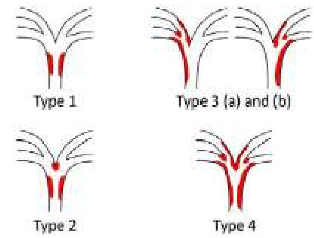
Perihilar Cholangiocarcinoma

- Bismuth-Corlette (BC) system
  - Provides pre-operative assessment of longitudinal growth
    - Type 1: CBD only
    - Type 2: Involves biliary confluence without intrahepatic ductal involvement
    - Type 3: Extends to right or left intrahepatic duct
    - Type 4: Extends to both intrahepatic ducts
  - Surgical goal: resection with negative margins



Ku, D., Tang, R., Pang, T., Pleass, H., Richardson, A., Yuen, L. and Lam, V. (2020), Survival outcomes of hepatic resections in Bismuth-Corlette type IV cholangiocarcinoma. ANZ Journal of Surgery, 90: 1604-1614. https://doi.org/10.1111/ans.15531

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Classification by Histology

- CCA can be classified by location into large or small duct and histological features
  - Prognosis

Large Duct

Small Duct

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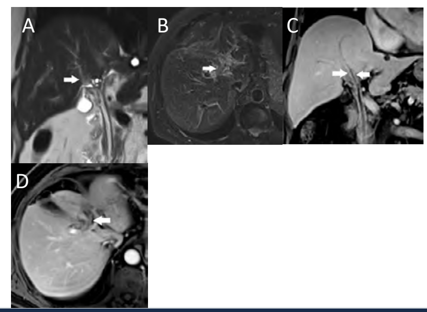
Large Duct Cholangiocarcinoma

- Subtype of intrahepatic CCA that arises in large intrahepatic bile ducts, in a perihilar or central location.
- Usually of periductal infiltrative or intraductal morphologic growth pattern
- Histology: large to midsize tubular or papillary proliferations of tall columnar epithelium that produce mucin
- Perineural, vascular, lymphatic invasions more than small duct CCA



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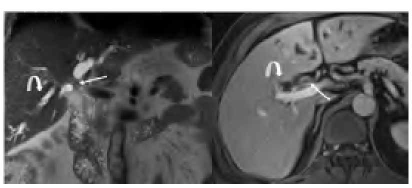
Large Duct Cholangiocarcinoma

- Associated with:
  - PSC
  - liver flukes
  - hepatolithiasis
  - choledochal cysts
- Worse prognosis than small duct CCA



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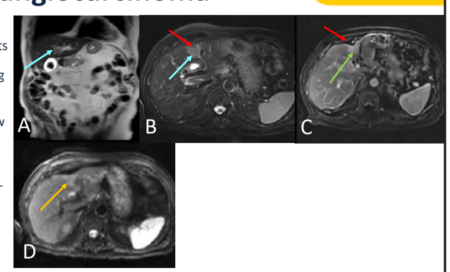
Small Duct Cholangiocarcinoma

- Subtype of intrahepatic CCA that arises in small intrahepatic bile ducts
- Most commonly has a mass-forming morphologic growth pattern
- Histology: non-mucin-producing low columnar, cuboidal, or spindle shaped cells
  - Express c-reactive protein and N-cadherin
- Commonly in peripheral location
- Small duct CCA has a better prognosis than large duct CCA



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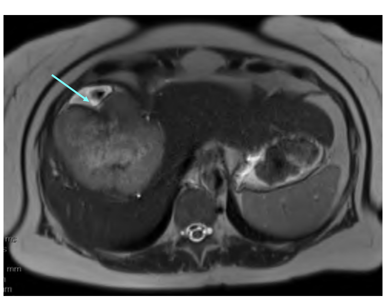
Small Duct Cholangiocarcinoma

- Risk factors
  - Similar to HCC
    - Viral hepatitis
    - Non-biliary cirrhosis
      - No precursor lesion



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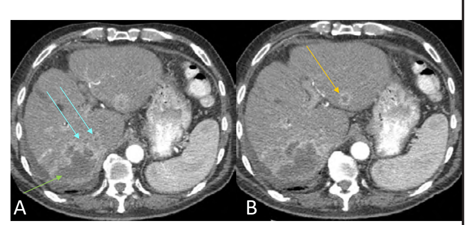
Dominant Mass, Intrahepatic Metastases, and Satellite Nodules

- The **dominant mass** is the largest intrahepatic mass forming CCA when there are multiple hepatic masses
- **Intrahepatic metastases** are smaller intrahepatic masses within a *different* segment(s) when there is a larger dominant mass.
- **Satellite nodules** are smaller intrahepatic lesions within the *same* segment as the dominant mass
- Intrahepatic mets worse prognosis than satellite nodules



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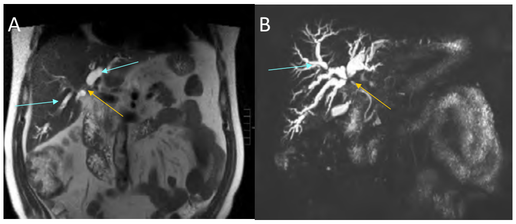
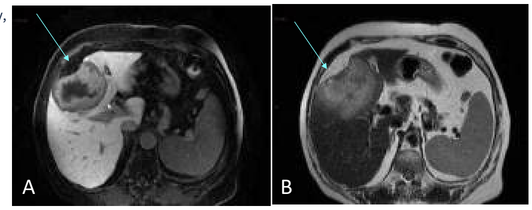
Dilated Upstream Bile Ducts

- Dilatation of bile ducts peripheral to a CCA due to obstruction of the bile duct
- Seen with all morphological types of CCA



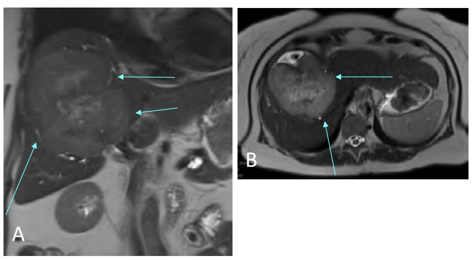
Hepatic Capsular Retraction

- Focal irregularity, flattening, or concavity of the normal convex liver capsule
- Most often associated with mass forming CCA
- Desmoplastic reaction and prominent tumoral fibrous stroma



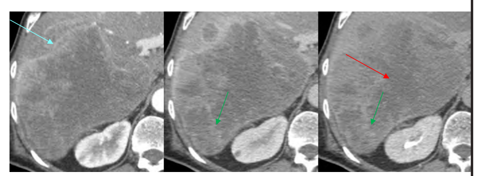
Lobulated Margins

- Non-smooth or irregular peripheral border of a mass with an outward appearance of lobules associated with mass forming CCA
- May represent microvascular invasion of dominant mass



Necrosis

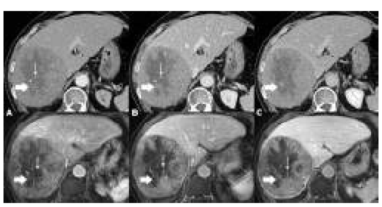
- Cell death causing liquification resulting in area(s) of non-enhancement within the mass
- On CT, it appears as areas of non-enhancement with low attenuation within a mass
- On MRI, it appears as areas of non-enhancement within a mass with or without T2-hyperintensity



Preliminary data suggests a favorable prognostic role of necrosis in CCA

Mimickers of CCA

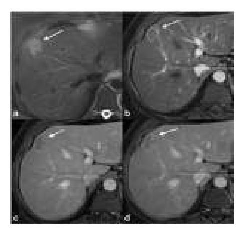
- HCC
  - Variants of HCC
    - Poorly Differentiated
    - macrotrabecular-massive
    - scirrhous HCC
  - May have peripheral enhancement
  - LI-RADS M



Chiow, S.M., Khoo, H.W., Low, J.K. *et al.* Imaging mimickers of cholangiocarcinoma: a pictorial review. *Abdom Radiol* **47**, 981–997 (2022). https://doi.org/10.1007/s00261-021-03399-9

Mimickers of CCA

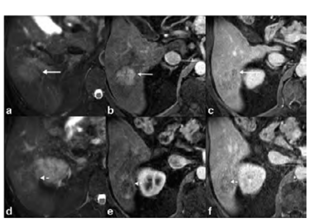
- Combined HCC-CCA
  - Rare liver malignancy
  - Contains mixture of HCC and CCA
    - arises from common hepatocyte/cholangiocyte progenitor cells
  - May mimic HCC or CCA
    - More common to mimic CCA



Sammon, J., Fischer, S., Menezes, R. *et al.* MRI features of combined hepatocellular- cholangiocarcinoma versus mass forming intrahepatic cholangiocarcinoma. *Cancer Imaging* **18**, 8 (2018). https://doi.org/10.1186/s40644-018-0142-z

Combined HCC-CCA

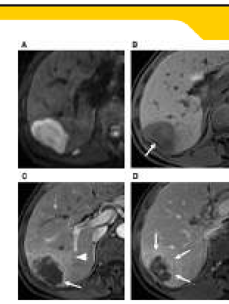
- Imaging features:
  - Tumors with avid rim enhancement during the arterial phase, subsequent washout or a combination of both washout and progressive enhancement in the same lesion



Sammon, J., Fischer, S., Menezes, R. *et al.* MRI features of combined hepatocellular- cholangiocarcinoma versus mass forming intrahepatic cholangiocarcinoma. *Cancer Imaging* **18**, 8 (2018). https://doi.org/10.1186/s40644-018-0142-z

Combined HCC-CCA

- Imaging features:
  - May fit the LI-RADS M targetoid features
    - RIM APHE
    - Peripheral Washout
  - Treatment = surgical resection
    - Recurrence rate 60-65%
    - Worse prognosis than HCC and CCA
      - Lymphatic and vascular spread more common



Shen, YT., Yue, WW. & Xu, HX. Non-invasive imaging in the diagnosis of combined hepatocellular carcinoma and cholangiocarcinoma. *Abdom Radiol* **48**, 2019–2037 (2023). https://doi.org/10.1007/s00261-023-03879-0

Sclerosed Hemangioma

- Rare lesion caused by degeneration and fibrous replacement of a hepatic cavernous hemangioma
  - May have Rim APHE, targetoid appearance
- Imaging showing hemangioma on prior imaging helpful
- Biopsy commonly needed for diagnosis
  - Lesion of exclusion

Doyle DJ, Khalili K, Guindi M, Atri M. Imaging features of sclerosed hemangioma. AJR Am J Roentgenol. 2007 Jul;189(1):67-72. doi: 10.2214/AJR.06.1076. PMID: 17579154.

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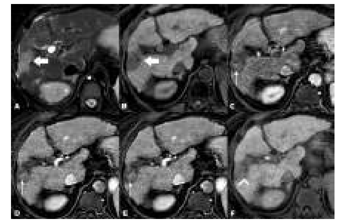
Confluent Hepatic Fibrosis

- Results from chronic liver injury in cirrhosis
- Commonly peripheral / wedge shaped
- May have mild T2 hyperintensity
- Arterial phase hypoenhancement
  - Delayed enhancement
    - Fibrosis
  - HPB mild enhancement in interstitial spaces



Chiow, S.M., Khoo, H.W., Low, J.K. *et al.* Imaging mimickers of cholangiocarcinoma: a pictorial review. *Abdom Radiol* **47**, 981–997 (2022). https://doi.org/10.1007/s00261-021-03399-9

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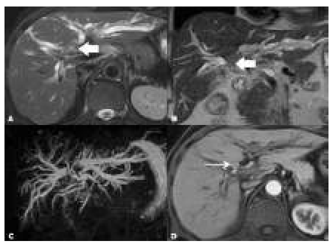
Mimickers of Periductal Infiltrating CCA

- IgG4-related disease
- PSC
- Benign fibrosis
- Tuberculosis



Chiow, S.M., Khoo, H.W., Low, J.K. *et al.* Imaging mimickers of cholangiocarcinoma: a pictorial review. *Abdom Radiol* **47**, 981–997 (2022). https://doi.org/10.1007/s00261-021-03399-9

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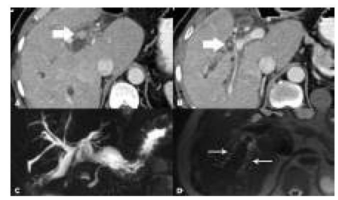
Mimickers of Intraductal CCA

- IPNB
- Calculi in recurrent pyogenic cholangitis
- Intraductal metastases



Chiow, S.M., Khoo, H.W., Low, J.K. *et al.* Imaging mimickers of cholangiocarcinoma: a pictorial review. *Abdom Radiol* **47**, 981–997 (2022). https://doi.org/10.1007/s00261-021-03399-9

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Standardized Reporting of iCCA

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Notes:
  - Perihilar CCA is an extrahepatic CCA if primary confluence is involved
  - This template takes in account items important to surgeons

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Background liver
  - Important as it may affect treatment options and outcomes
  - Future Liver Remnant = % of functional liver after resection
    - Patients with normal liver need 25% to survive
    - Cirrhosis or steatosis requires more FLR due to liver impairment

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Size of dominant mass = maximum diameter on axial OR coronal images
- 8th version of the American Joint Committee on Cancer incorporates T staging for iCCA
  - < or = 5 cm = T1a
  - > 5cm T1b
    - microscopic vascular invasion
    - higher tumor grade
    - worse overall survival

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Morphologic growth pattern
  - Mass forming
  - Periductal Infiltrating
  - Intraductal
    - Prognosis
    - Histological subtype
      - Large vs. Small duct

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Enhancement pattern
  - Use LI-RADS M terminology
    - Rim APHE
    - Targetoid DWI, APHE, HBP
    - Peripheral washout
    - Delayed central enhancement
  - Rim APHE or diffuse hypoenhancement = increased rates of post-surgical recurrence and death

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Variant vascular anatomy
  - Transarterial therapy
  - Surgical planning
    - Most common:
      - Replaced right hepatic from SMA
      - Replaced left hepatic from left gastric artery

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Vascular contact
  - Intrahepatic micro and macrovascular involvement is T2 disease
    - Worse prognosis
  - iCCA encases the vessels and narrows them
  - Direct invasion rare
    - Usually in chronic liver disease
    - Worse prognosis with poor post resection outcomes

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Vascular contact
  - No Contact = clear planes around the vessel
  - Abutment = < 180 degrees around the vessel
  - Encasement = > 180 degrees around the vessel, occlusion, or tumor thrombus

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Standardized Reporting of iCCA

- Other
  - Hepatic Metastases including satellite nodules
  - Direct invasion
  - Regional lymph node mets
  - Distant lymph node mets
  - Distant organ mets
    - Presence worse prognosis

Kierans, A.S., Cunha, G.M., King, M.J. *et al.* Standardized reporting of intrahepatic cholangiocarcinoma. *Abdom Radiol* (2024). https://doi.org/10.1007/s00261-024-04582-4

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Summary

- CCA includes both intrahepatic and extrahepatic bile duct cancers
- The SAR DFP on CCA lexicon is intended to complement the LI-RADS lexicon by expounding on imaging terms and features specific for CCA which were not defined in the terms related to LI-RADS M.
- Understanding and reporting morphologic type can help with surgical planning and prognosis
- There are several mimics of intra and extrahepatic CCA which likely require biopsies
- Structured reporting including using Lexicon terminology will help standardize the reporting and provide clear and concise information for both clinicians and surgeons who take care of these complex cases

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Thank you for your attention

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SELF EVALUATION

Cholangiocarcinoma Imaging Update

1. T/F - The SAR DFP cholangiocarcinoma lexicon was created to replace the terms associated with LI-RADS M in the LI-RADS lexicon?

2. Which lesion or disease process is a known precursor to intraductal cholangiocarcinoma?

a. Mucinous cystic neoplasm of the liver
b. Primary sclerosing cholangitis
c. Intraductal papillary neoplasm of the bile duct
d. Recurrent pyogenic cholangitis

3. Which of the of the following morphologic growth patterns of cholangiocarcinoma has the most favorable prognosis?

a. Intraductal
b. Periductal infiltrating
c. Mass Forming
d. Both B and C
e. Both A and B

4. T/F - Perihilar cholangiocarcinoma is an intrahepatic mass.

5. T/F - Perihilar cholangiocarcinoma most commonly is of the periductal infiltrating morphologic growth pattern.

Answer Key: 1. F, 2. C, 3. A, 4. F, 5. T

Wende N. Gibbs, MD

Wende N. Gibbs, MD is a neuroradiologist and the director of spine imaging and intervention at Barrow Neurological Institute. She is certified in diagnostic radiology and neuroradiology by the American Board of Radiology. Dr. Gibbs is an expert in diagnostic and interventional spine radiology, with distinct interests in spine oncology and pain management. She is the president-elect of the American Society of Spine Radiology and the Western Neuroradiological Society and serves as the chair of education for the American Society of Neuroradiology.

Dr. Gibbs earned her medical degree from the University of California, Irvine. While there, she also completed a one-year National Institutes of Health (NIH)/General Clinical Research Center (GCRC) research fellowship evaluating novel magnetic resonance imaging (MRI) contrast agents for the detection of metastatic lymph nodes in patients with head and neck cancer. She completed her residency in diagnostic radiology at Baylor University Medical Center in Dallas and a two-year neuroradiology fellowship at Barrow Neurological Institute.

Dr. Gibbs has authored multiple book chapters, peer-reviewed journal articles, and award-winning abstracts. She serves on the editorial boards of three journals and is the podcast editor and host of *Radiographic*, the educational journal of the Radiological Society of North America. Dr. Gibbs also works on several multidisciplinary spinal surgery committees, including the North American Spine Society, and is one of the original hosts of the weekly Virtual Global Spine Conference. Dr. Gibbs is passionate about patient safety, communication, ethics, education, and exploring artificial intelligence.

You may contact Dr. Gibbs with any questions or comments by email at wendengibbs@gmail.com.

A Compartment based approach to Spinal Pathology
Wende N. Gibbs, MD

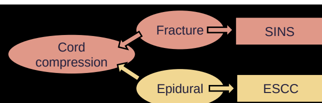
Which report is more useful?

Findings: Page 1, page 2.....

IMPRESSION:
1. Suspected metastasis with pathologic fracture of L1 with retropulsion produces moderate compression of the conus. Approximately 50% height loss.
2. Additional lesions at L3 and L4.

IMPRESSION:
1. Unstable spine: (SINS score 13). Recommend prompt spine surgery consultation.
2. Lytic metastasis L1: pathologic fracture with retropulsion, greater than 50% height loss, involvement of bilateral posterior elements, new kyphosis.
3. High grade conus compression (ESCC Grade 2).

Oncologic Instability



- Common, devastating consequences, identify early
- Differs from instability in trauma
  - Failure patterns (ligaments, discs typically spared)
  - Poor bone quality and compromised healing (surgical considerations)
  - Can predict impending failure based on pattern of involvement

Oncologic Instability

- My goal: Rapid triage of unstable/potentially unstable spine to surgical consultation
- The SINS score describes current instability and can predict impending instability
  - 5 radiologic components, 1 clinical
  - The higher the score, the more urgent

Significance of SINS (2010)

- Previously no consensus on definition, assessment, reporting
- Now widely used by surgeons, oncologists, all members of treatment team
- Validated, excellent inter-reader reliability across specialties (*Forney 2010, Campos 2011, Fisher 2014*)
- Incorporated into multiple treatment guidelines
- Contributes to standardized approach to reporting, consultation and treatment

Table 8. Summary Table Including All Elements of the SINS

Element of SINS	Score
Location	
Junctional (occiput–C2, C7–T2, T11–L1, L5–S1)	3
Mobile spine (C3–C6, L2–L4)	2
Semi rigid (T3–T10)	1
Rigid (S2–S5)	0
Pain relief with recumbency and/or pain with movement/loading of the spine	
Yes	3
No (occasional pain but not mechanical)	1
Pain free lesion	0
Bone lesion	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
Radiographic spinal alignment	
Subluxation/translation present	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
Vertebral body collapse	
>50% collapse	3
<50% collapse	2
No collapse with >50% body involved	1
None of the above	0
Posterolateral involvement of the spinal elements (facet, pedicle or CV joint fracture or replacement with tumor)	
Bilateral	3
Unilateral	1
None of the above	0

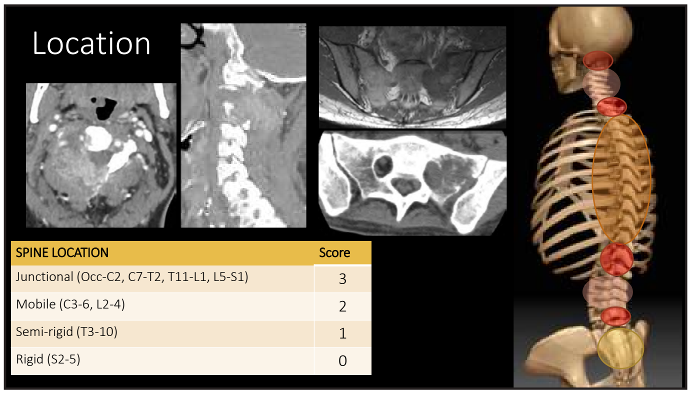
Fisher CG, Spine 2010.

SINS

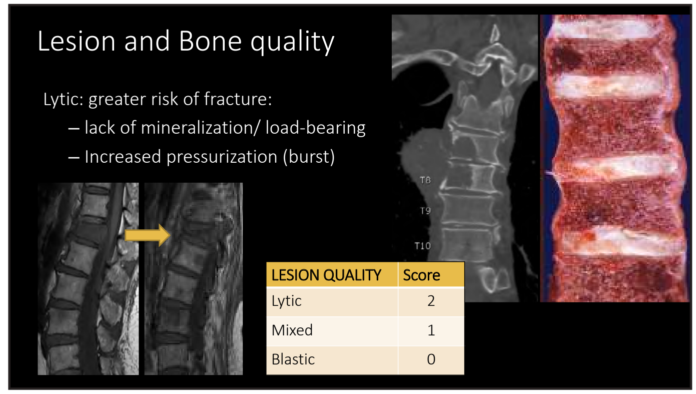
Questions	Answers (Point assignment)				
	4	3	2	1	0
Location		Junctional	Mobile	Semi-rigid	Rigid
Quality			Lytic	Mixed	Blastic
Alignment	Subluxation		Deformity		Preserved
Collapse		> 50%	< 50%	< 50% but > 50% body involved	None
Posterior Elements		Bilateral		Unilateral	None
Pain (Mechanical)		Yes		Occasional, not mechanical	No

Score	13-18 = Unstable	7-12 = Indeterminate	0-6 = Stable
Recommendation	Urgent surgical consult	Surgical consult	

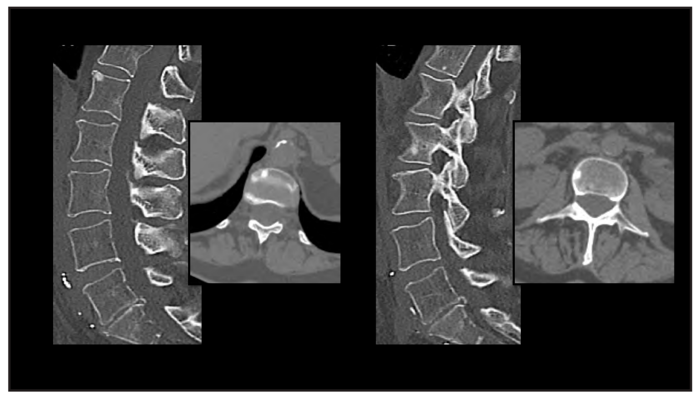
Modified from Fisher CG, Spine 2010.

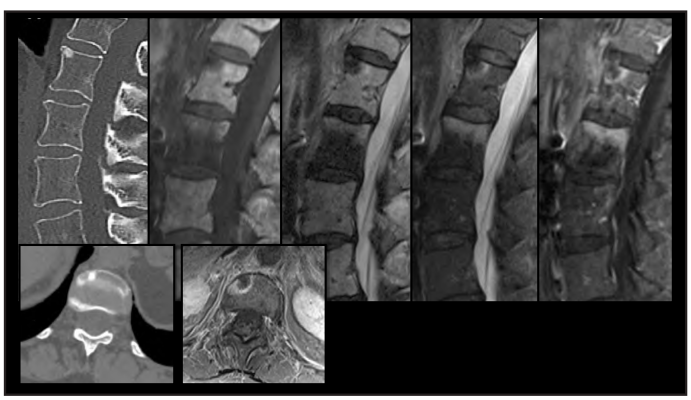


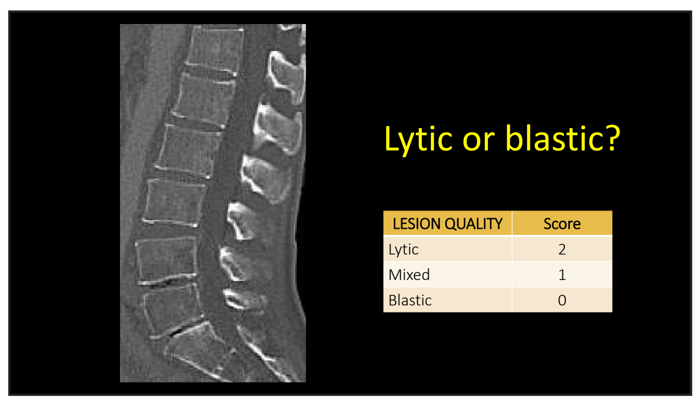
SPINE LOCATION	Score
Junctional (Occ-C2, C7-T2, T11-L1, L5-S1)	3
Mobile (C3-6, L2-4)	2
Semi-rigid (T3-10)	1
Rigid (S2-5)	0



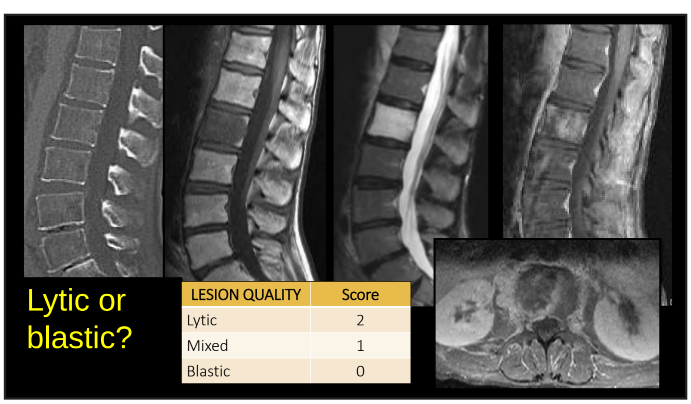
LESION QUALITY	Score
Lytic	2
Mixed	1
Blastic	0



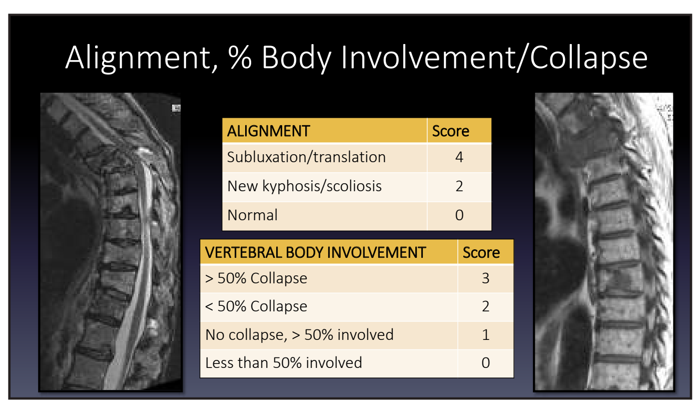




LESION QUALITY	Score
Lytic	2
Mixed	1
Blastic	0



LESION QUALITY	Score
Lytic	2
Mixed	1
Blastic	0

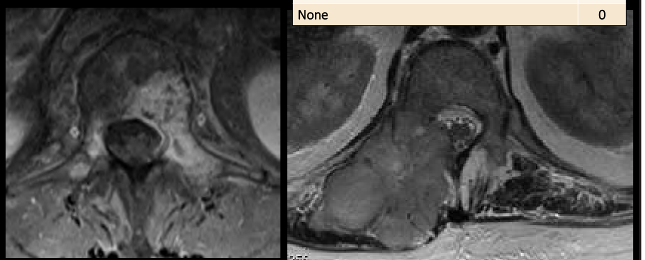


ALIGNMENT	Score
Subluxation/translation	4
New kyphosis/scoliosis	2
Normal	0

VERTEBRAL BODY INVOLVEMENT	Score
> 50% Collapse	3
< 50% Collapse	2
No collapse, > 50% involved	1
Less than 50% involved	0

Posterior elements

POSTERIOR ELEMENTS (Pedicle, Facet, CV joint)	Score
Bilateral	3
Unilateral	1
None	0

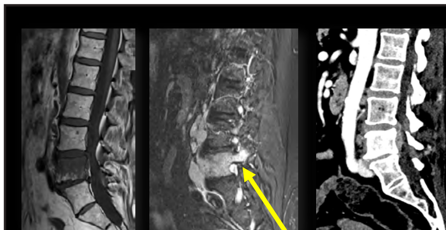


Costovertebral joint involvement greatest contributor to thoracic spine

Pain

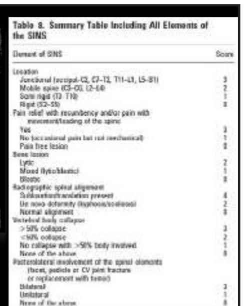
- Mechanical pain
- Pain associated with periosteal stretch or nerve root/cord compression is NOT indicative of instability (but may coexist)
- Pain unique component in definition of oncological instability

PAIN (mechanical) Relief with recumbence, pain w/ movement /loading	Score
Yes	3
Occasional, not mechanical	1
Pain free	0



Location = L5 Junctional [3]
Lesion quality= Mixed? [1]
Alignment = Normal [0]
Collapse = No, but >50% involved [1]
Posterior elements = Unilateral [1]
Pain = Severe mechanical [3]

SINS 9



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Bone lesion	
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Vertebral body collapse	
> 50% collapse	3
< 50% collapse	2
No collapse with > 50% body involved	1
None of the above	0
Posterolateral involvement of the spinal elements (facet, pedicle or CV joint fracture or replacement with tumor)	
Bilateral	3
Unilateral	1
None of the above	0

7-12 = Indeterminate

13-18 = Unstable

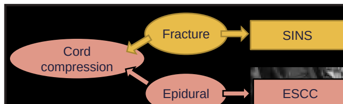
Evidence based management (e.g. NOMS)

- Considers four aspects of disease status:
  - Neurologic (cord compression) — ESCC grade
  - Oncologic (histology-radiosensitivity)
  - Mechanical stability — SINS score
  - Systemic status (life expectancy, comorbidities)
- Integration determines the use of radiation, surgery / cement augmentation, systemic therapy

Spine Oncology Management Algorithm (NOMS)

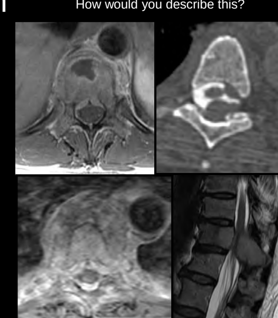
Neurologic (Cord compression)	Oncologic (Is the tumor radiosensitive (cEBRT)?)	Mechanical (Is the spine stable?)	Systemic (Can the patient tolerate surgery?)	Treatment Decision
Low-grade	Yes	Yes		External beam radiation (cEBR)
		No		Surgical stabilization -> cEBR
	No	Yes		Stereotactic radiosurgery (SRS)
		No		Stabilization ->SRS
High-grade	Yes	Yes		cEBR
		No		Stabilization -> cEBR
	No	Yes	Yes	Separation surgery -> SRS
			No	cEBR
		No	Yes	Stabilization & Sep surgery ->SRS
			No	Stabilization (cement) -> cEBR

Modified from Laufer et al. The Oncologist 2013

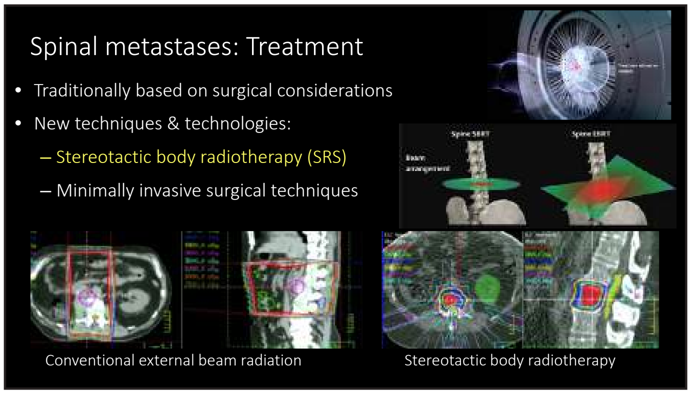


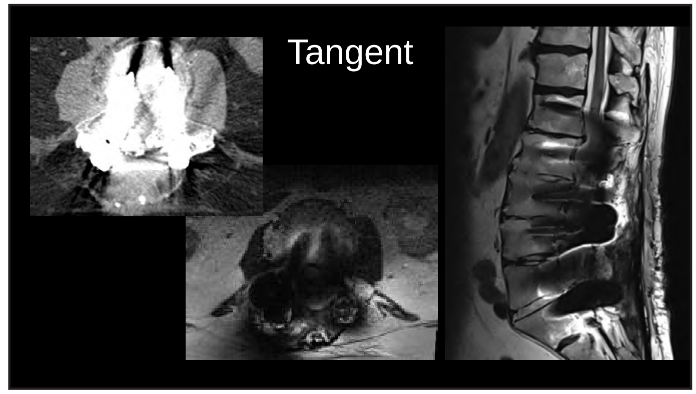
Epidural cord compression

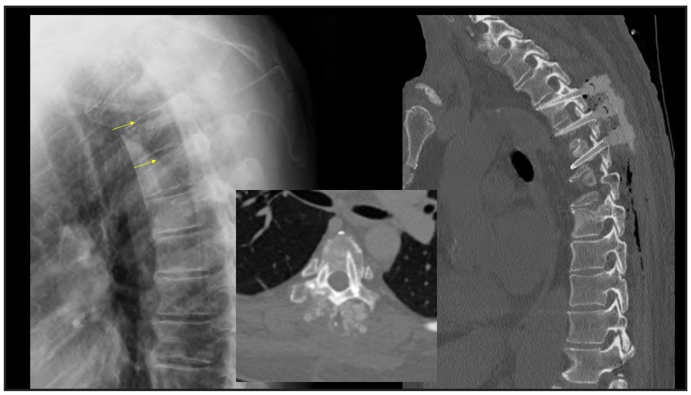
How would you describe this?

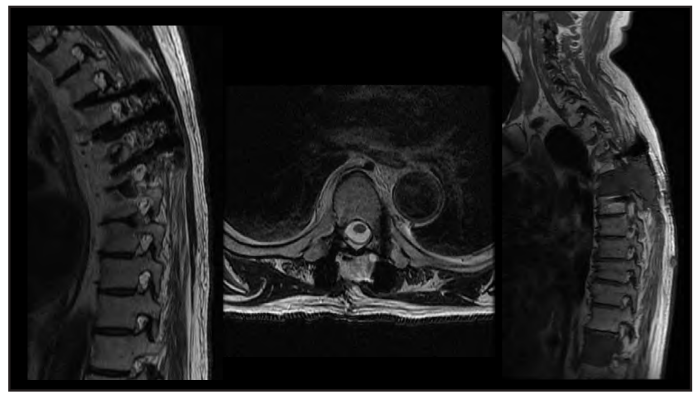


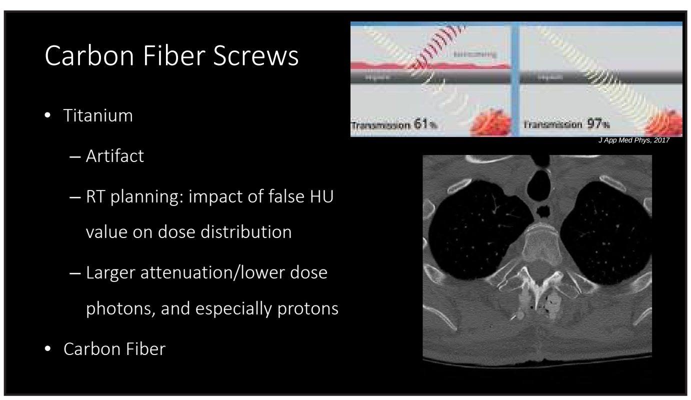
- If the spine is stable, treatment is based on degree of cord compression
- Epidural spinal cord compression scale (ESCC 2010)
  - 6 point scale for surgical / radiation planning
  - Uniform reporting for standardized treatment (and research, trials)

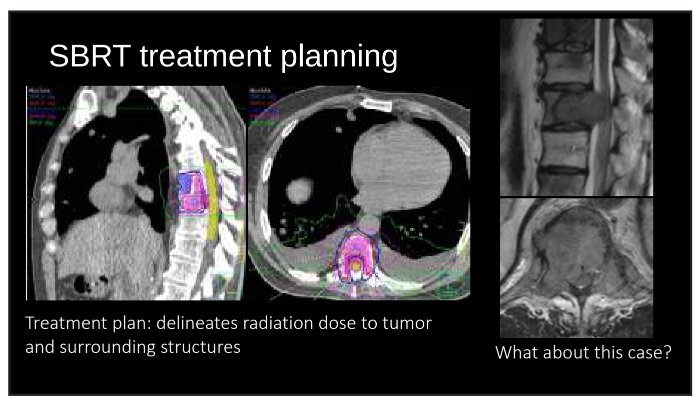

Spinal metastases: Treatment
• Traditionally based on surgical considerations
• New techniques & technologies:
– Stereotactic body radiotherapy (SRS)
– Minimally invasive surgical techniques
Spine SBRT
Spine EBRT
Conventional external beam radiation
Stereotactic body radiotherapy

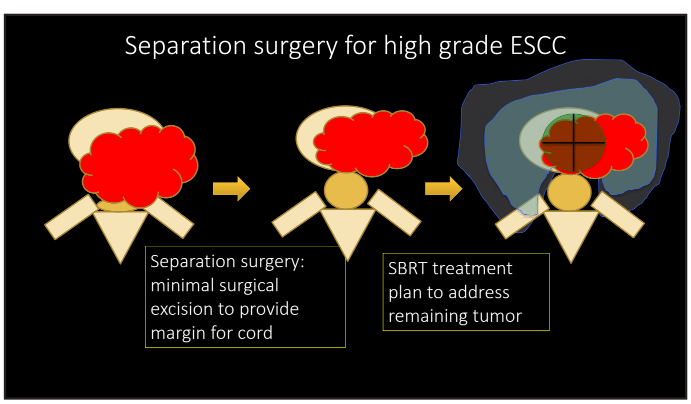

Tangent

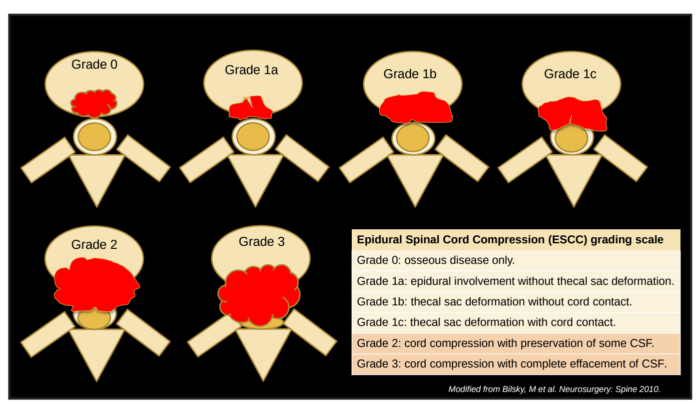


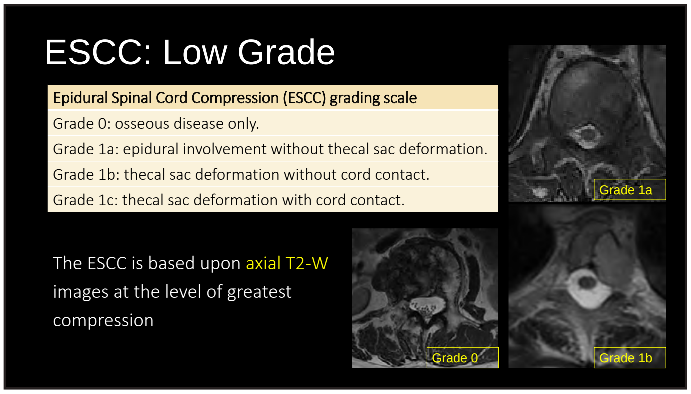


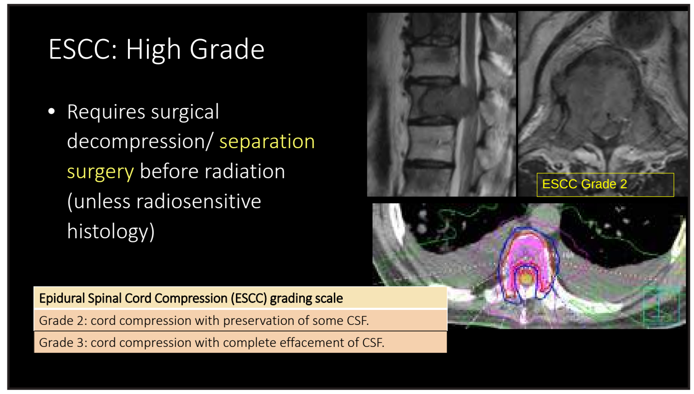

Carbon Fiber Screws
• Titanium
– Artifact
– RT planning: impact of false HU value on dose distribution
– Larger attenuation/lower dose photons, and especially protons
• Carbon Fiber
Transmission 61%
Transmission 97%
J App Med Phys, 2017

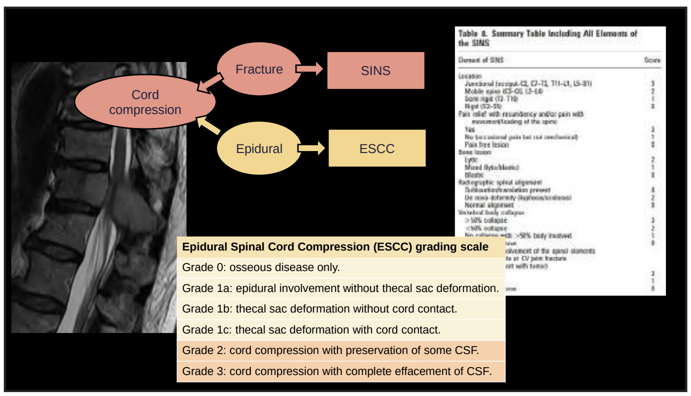

SBRT treatment planning
Treatment plan: delineates radiation dose to tumor and surrounding structures
What about this case?

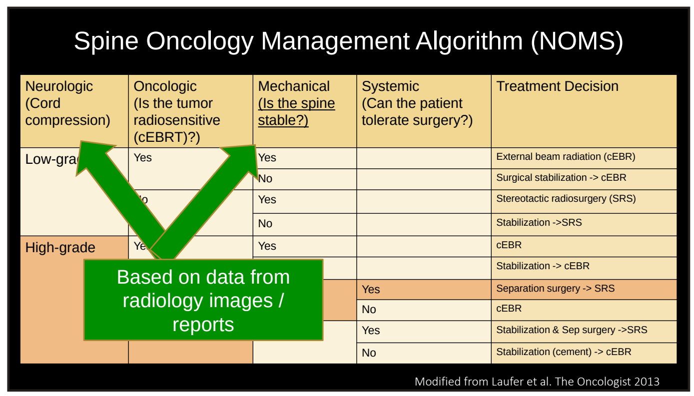

Separation surgery for high grade ESCC
Separation surgery: minimal surgical excision to provide margin for cord
SBRT treatment plan to address remaining tumor

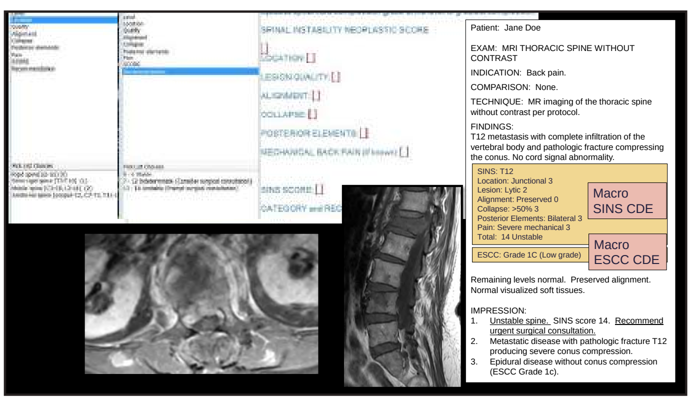

Grade 0
Grade 1a
Grade 1b
Grade 1c
Grade 2
Grade 3
Epidural Spinal Cord Compression (ESCC) grading scale
Grade 0: osseous disease only.
Grade 1a: epidural involvement without thecal sac deformation.
Grade 1b: thecal sac deformation without cord contact.
Grade 1c: thecal sac deformation with cord contact.
Grade 2: cord compression with preservation of some CSF.
Grade 3: cord compression with complete effacement of CSF.
Modified from Bilsky, M et al. Neurosurgery: Spine 2010.

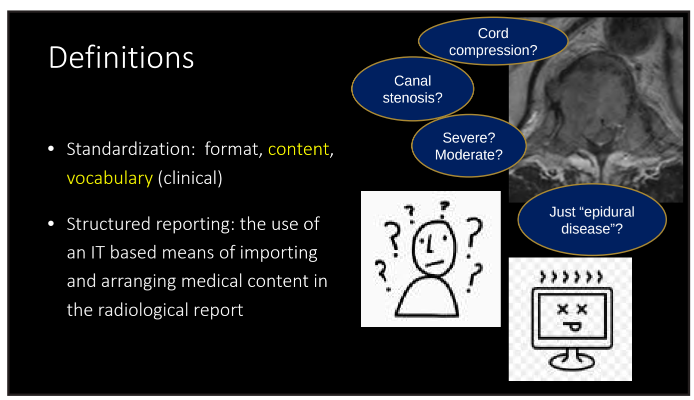

ESCC: Low Grade
Epidural Spinal Cord Compression (ESCC) grading scale
Grade 0: osseous disease only.
Grade 1a: epidural involvement without thecal sac deformation.
Grade 1b: thecal sac deformation without cord contact.
Grade 1c: thecal sac deformation with cord contact.
The ESCC is based upon axial T2-W images at the level of greatest compression
Grade 1a
Grade 0
Grade 1b

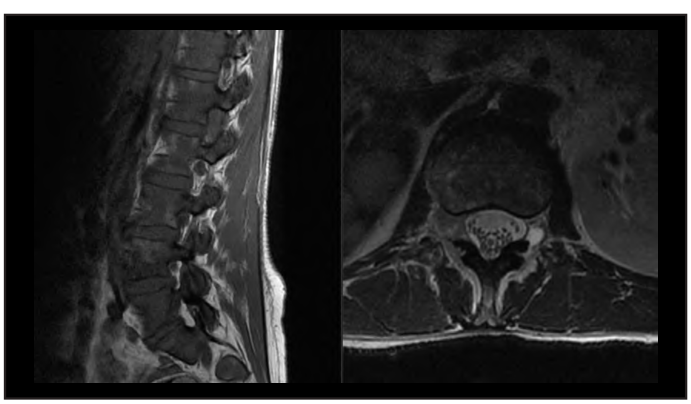

ESCC: High Grade
• Requires surgical decompression/ separation surgery before radiation (unless radiosensitive histology)
ESCC Grade 2
Epidural Spinal Cord Compression (ESCC) grading scale
Grade 2: cord compression with preservation of some CSF.
Grade 3: cord compression with complete effacement of CSF.

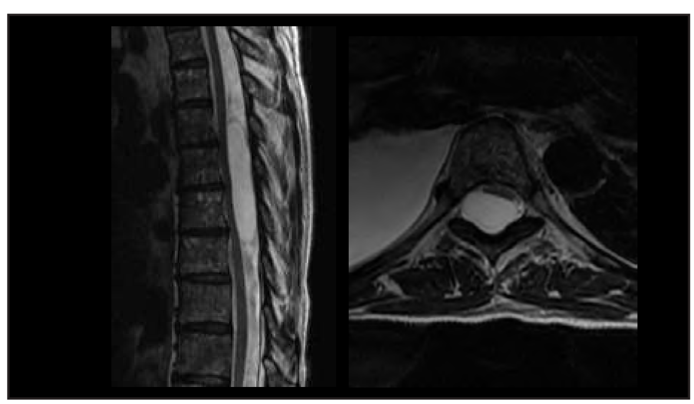

Cord compression
Fracture
SINS
Epidural
ESCC
Epidural Spinal Cord Compression (ESCC) grading scale
Grade 0: osseous disease only.
Grade 1a: epidural involvement without thecal sac deformation.
Grade 1b: thecal sac deformation without cord contact.
Grade 1c: thecal sac deformation with cord contact.
Grade 2: cord compression with preservation of some CSF.
Grade 3: cord compression with complete effacement of CSF.


Spine Oncology Management Algorithm (NOMS)
Neurologic (Cord compression)
Oncologic (Is the tumor radiosensitive (cEBRT)?)
Mechanical (Is the spine stable?)
Systemic (Can the patient tolerate surgery?)
Treatment Decision
Low-gra
Yes
Yes
External beam radiation (cEBR)
No
Surgical stabilization -> cEBR
o
Yes
Stereotactic radiosurgery (SRS)
No
Stabilization ->SRS
High-grade
Ye
Yes
cEBR
Stabilization -> cEBR
Yes
Separation surgery -> SRS
No
cEBR
Yes
Stabilization & Sep surgery ->SRS
No
Stabilization (cement) -> cEBR
Based on data from radiology images / reports
Modified from Laufer et al. The Oncologist 2013


SPINAL INSTABILITY NEOPLASTIC SCORE
LOCATION
LESION QUALITY
ALIGNMENT
COLLAPSE
POSTERIOR ELEMENTS
MECHANICAL BACK PAIN (if known)
SINS SCORE
CATEGORY and REC
Patient: Jane Doe
EXAM: MRI THORACIC SPINE WITHOUT CONTRAST
INDICATION: Back pain.
COMPARISON: None.
TECHNIQUE: MR imaging of the thoracic spine without contrast per protocol.
FINDINGS:
T12 metastasis with complete infiltration of the vertebral body and pathologic fracture compressing the conus. No cord signal abnormality.
SINS: T12
Location: Junctional 3
Lesion: Lytic 2
Alignment: Preserved 0
Collapse: >50% 3
Posterior Elements: Bilateral 3
Pain: Severe mechanical 3
Total: 14 Unstable
Macro SINS CDE
ESCC: Grade 1C (Low grade)
Macro ESCC CDE
Remaining levels normal. Preserved alignment. Normal visualized soft tissues.
IMPRESSION:
1. Unstable spine. SINS score 14. Recommend urgent surgical consultation.
2. Metastatic disease with pathologic fracture T12 producing severe conus compression.
3. Epidural disease without conus compression (ESCC Grade 1c).

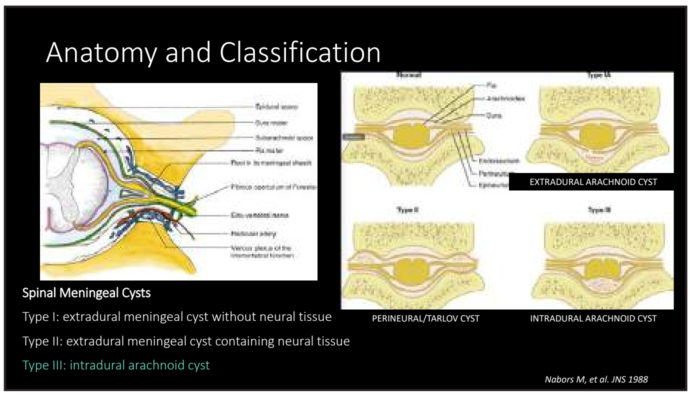

Definitions
• Standardization: format, content, vocabulary (clinical)
• Structured reporting: the use of an IT based means of importing and arranging medical content in the radiological report
Cord compression?
Canal stenosis?
Severe? Moderate?
Just "epidural disease"?

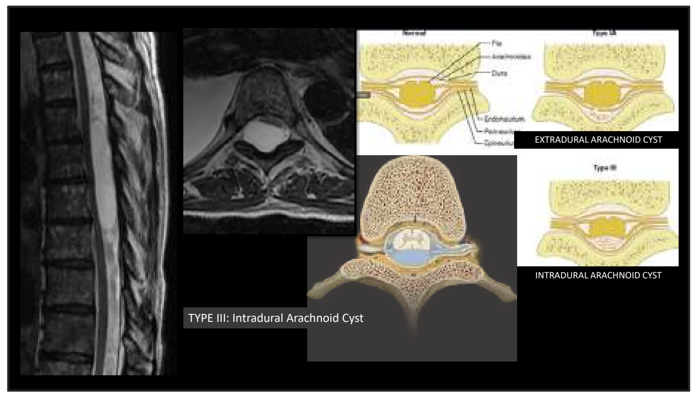


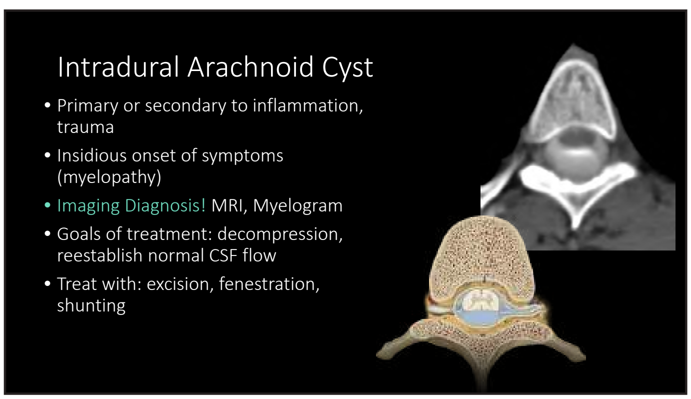


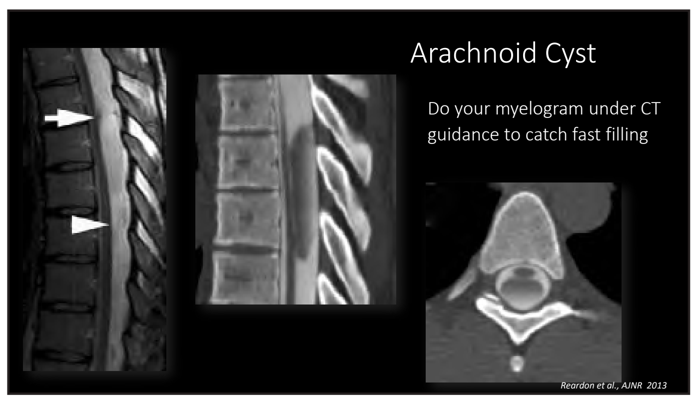

What are the tips for differentiating these entities?

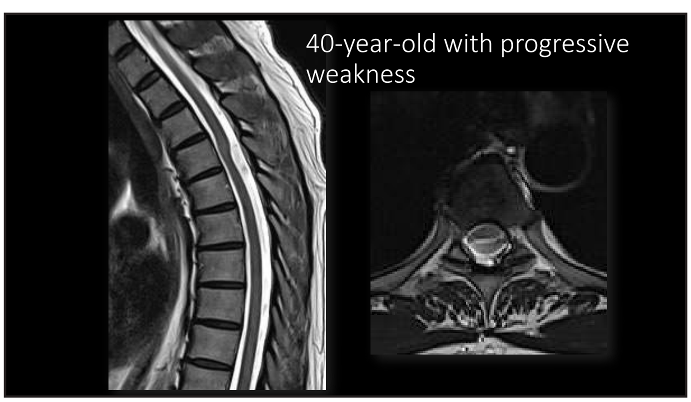

CSF space pathology
#1: Do a myelogram
#2: Evaluate cord:
✓Course
✓Caliber
✓Contour

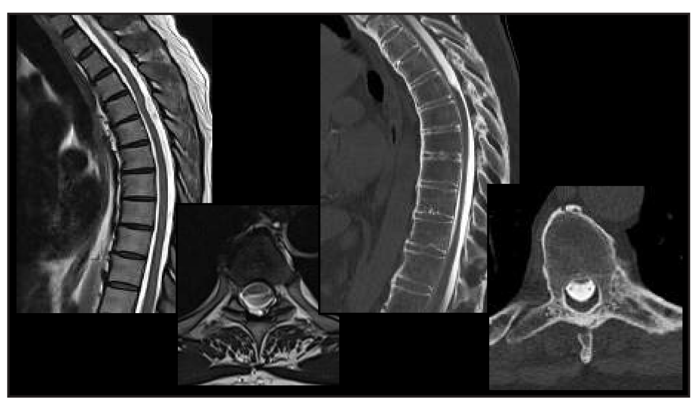

Anatomy and Classification
EXTRADURAL ARACHNOID CYST
PERINEURAL/TARLOV CYST
INTRADURAL ARACHNOID CYST
Spinal Meningeal Cysts
Type I: extradural meningeal cyst without neural tissue
Type II: extradural meningeal cyst containing neural tissue
Type III: intradural arachnoid cyst
Nabors M, et al. JNS 1988


EXTRADURAL ARACHNOID CYST
INTRADURAL ARACHNOID CYST
TYPE III: Intradural Arachnoid Cyst

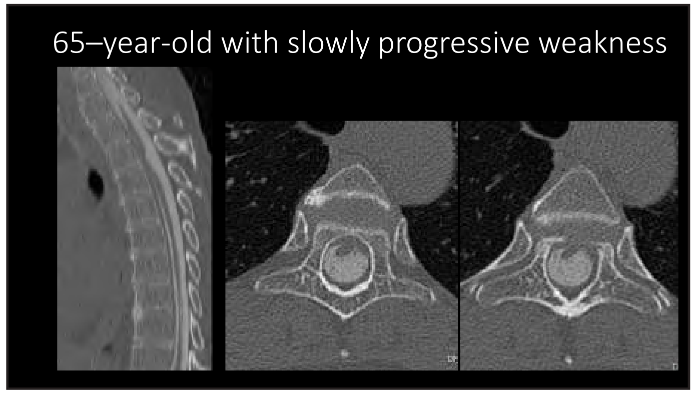

Intradural Arachnoid Cyst
• Primary or secondary to inflammation, trauma
• Insidious onset of symptoms (myelopathy)
• Imaging Diagnosis! MRI, Myelogram
• Goals of treatment: decompression, reestablish normal CSF flow
• Treat with: excision, fenestration, shunting

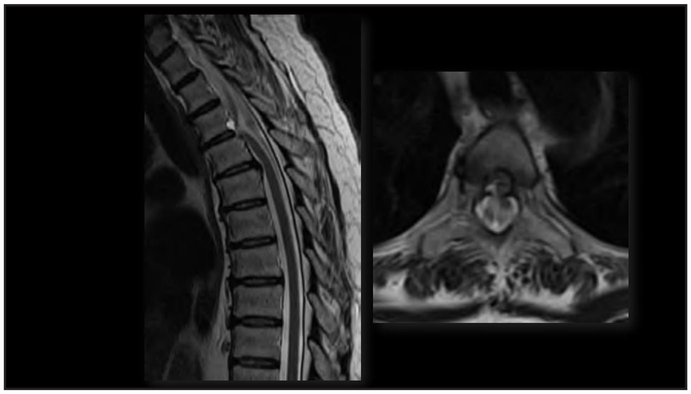

Arachnoid Cyst
Do your myelogram under CT guidance to catch fast filling
Reardon et al., AJNR 2013

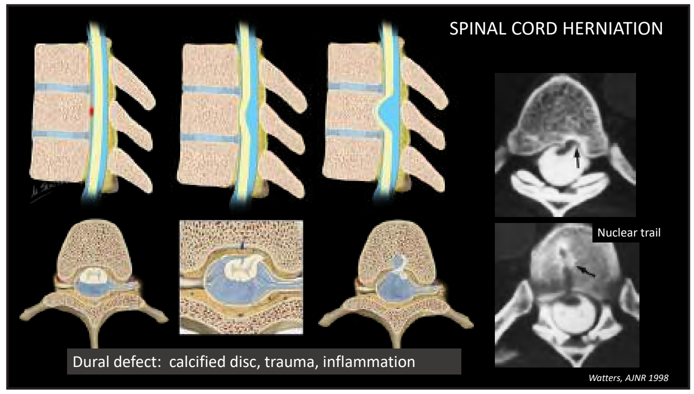

40-year-old with progressive weakness

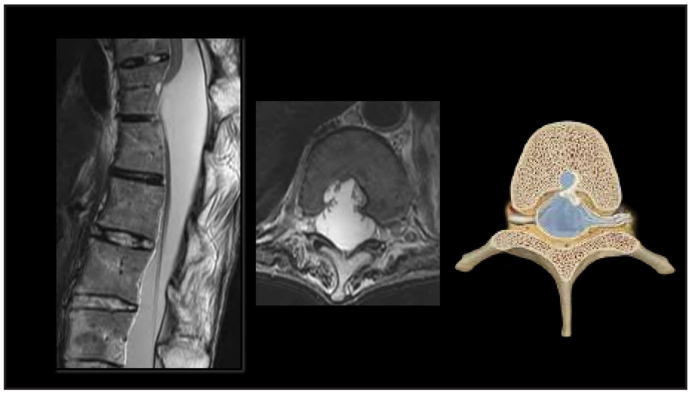


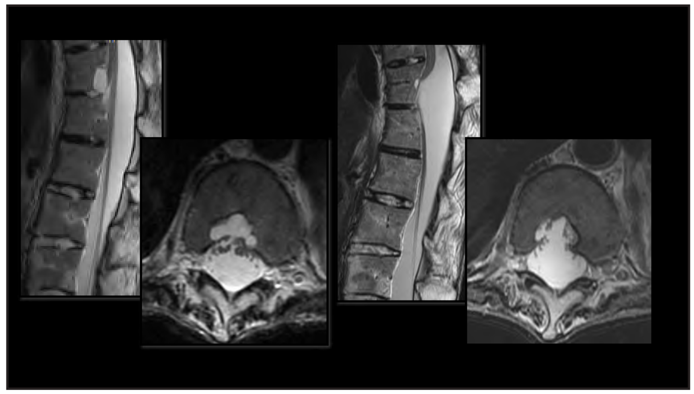

ARACHNOID WEB
JNS
Arachnoid web of the spine: a systematic literature review
A
B
C
D
E
F


65–year-old with slowly progressive weakness

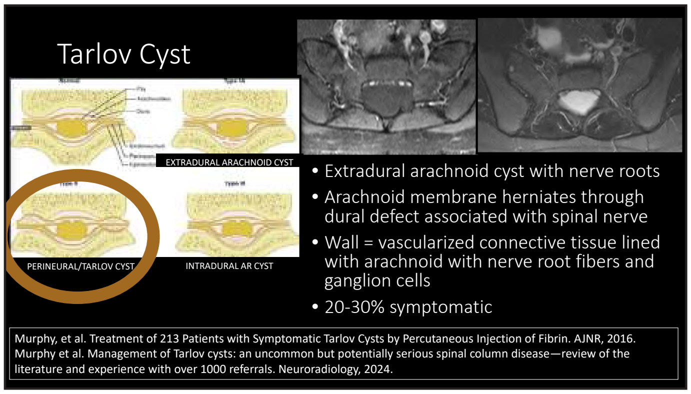


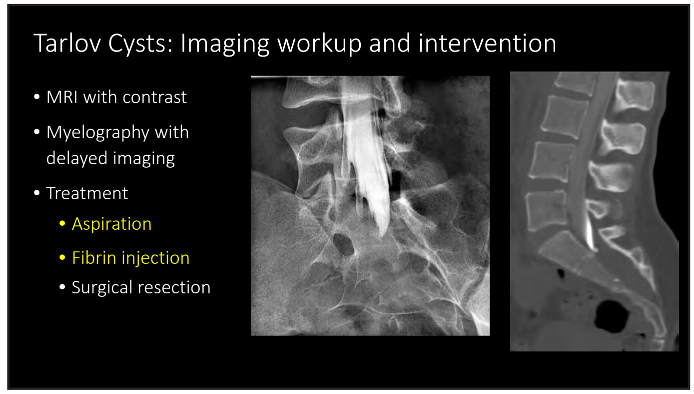

SPINAL CORD HERNIATION
Nuclear trail
Dural defect: calcified disc, trauma, inflammation
Watters, AJNR 1998

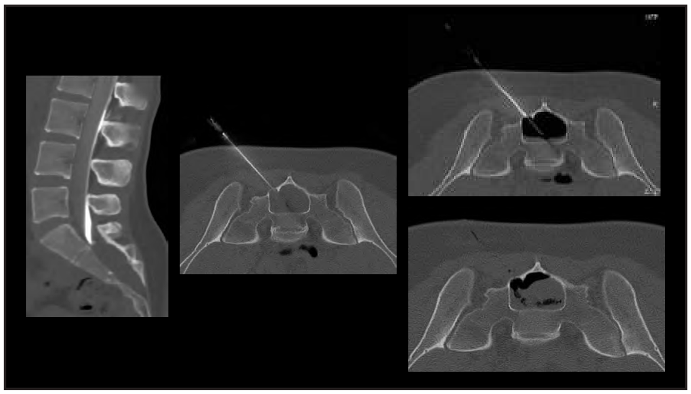


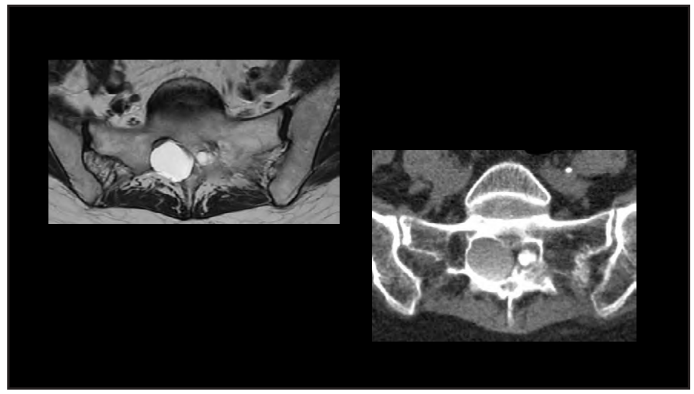


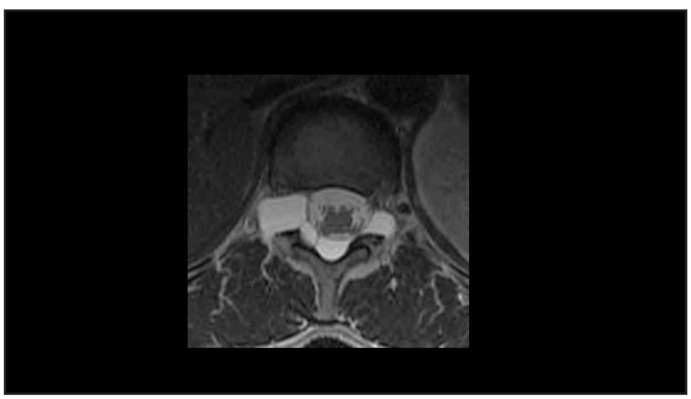

19-year-old with 2
years of progressive
lower back and
pelvic pain

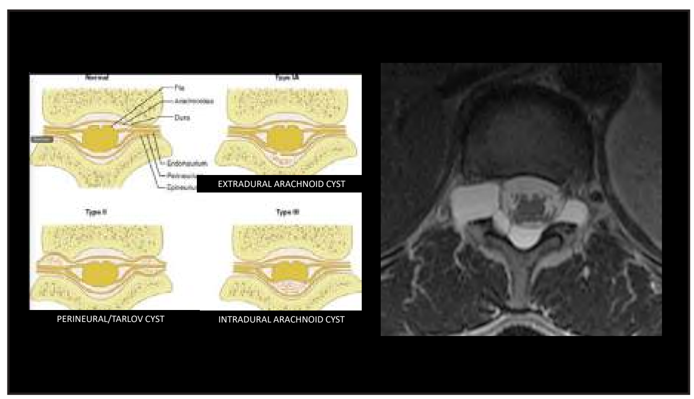

Tarlov Cyst
EXTRADURAL ARACHNOID CYST
PERINEURAL/TARLOV CYST
INTRADURAL AR CYST
• Extradural arachnoid cyst with nerve roots
• Arachnoid membrane herniates through dural defect associated with spinal nerve
• Wall = vascularized connective tissue lined with arachnoid with nerve root fibers and ganglion cells
• 20-30% symptomatic
Murphy, et al. Treatment of 213 Patients with Symptomatic Tarlov Cysts by Percutaneous Injection of Fibrin. AJNR, 2016.
Murphy et al. Management of Tarlov cysts: an uncommon but potentially serious spinal column disease—review of the literature and experience with over 1000 referrals. Neuroradiology, 2024.

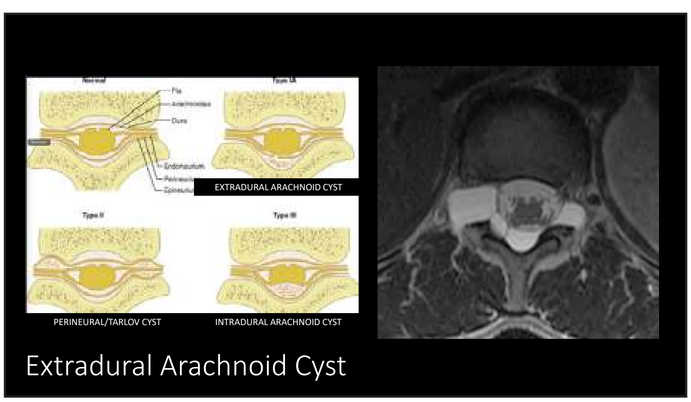

Tarlov Cysts: Imaging workup and intervention
• MRI with contrast
• Myelography with delayed imaging
• Treatment
• Aspiration
• Fibrin injection
• Surgical resection

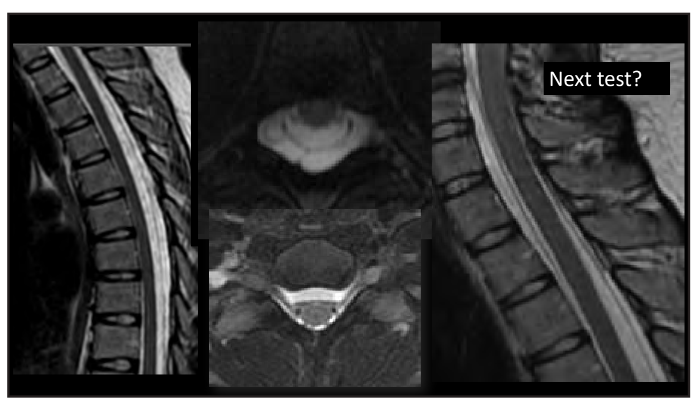


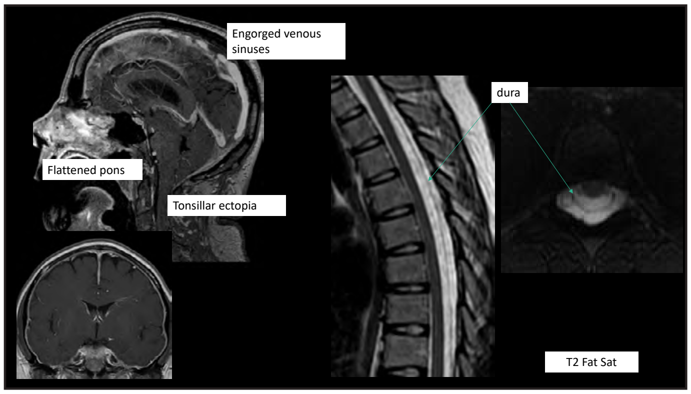


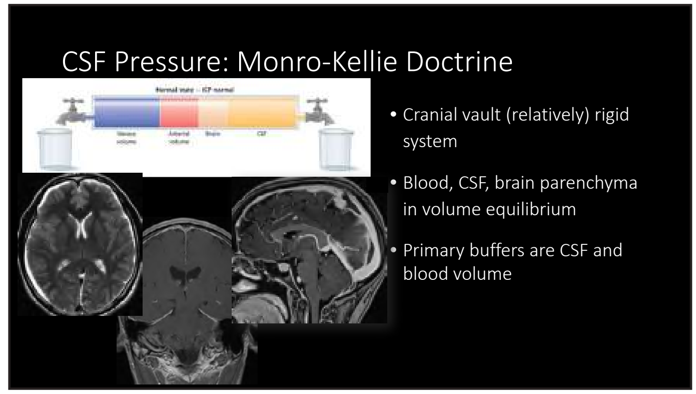



EXTRADURAL ARACHNOID CYST
PERINEURAL/TARLOV CYST
INTRADURAL ARACHNOID CYST


EXTRADURAL ARACHNOID CYST
PERINEURAL/TARLOV CYST
INTRADURAL ARACHNOID CYST
Extradural Arachnoid Cyst


Next test?





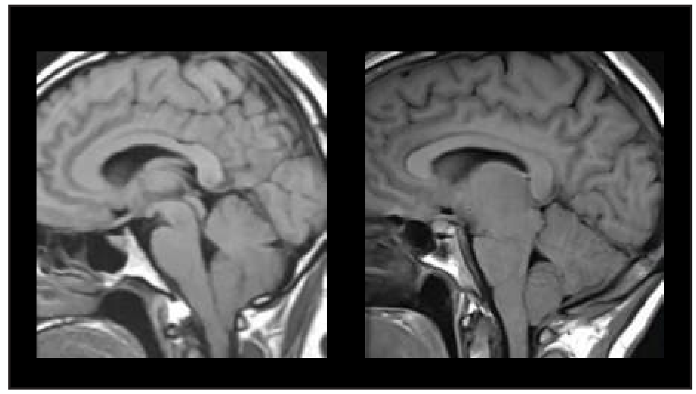
Major (2 points)	Minor (1 point)
Pachymeningeal enhancement	Subdural collections
Venous sinus engorgement	Prepontine cistern effacement - 5mm or less
Suprasellar cistern effacement - 4mm or less	Mamillopontine distance 6.5mm or less

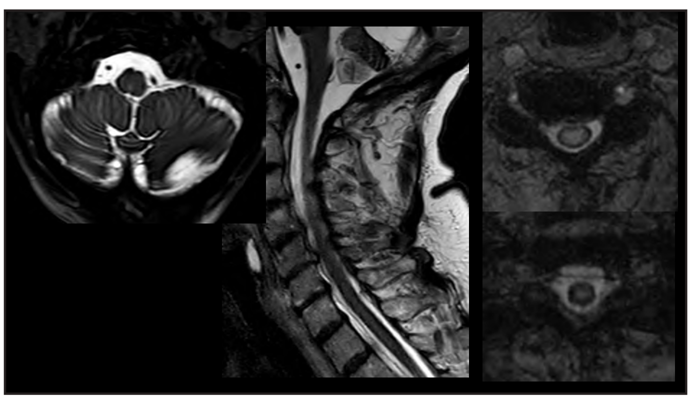
Bern/Dobrocky score

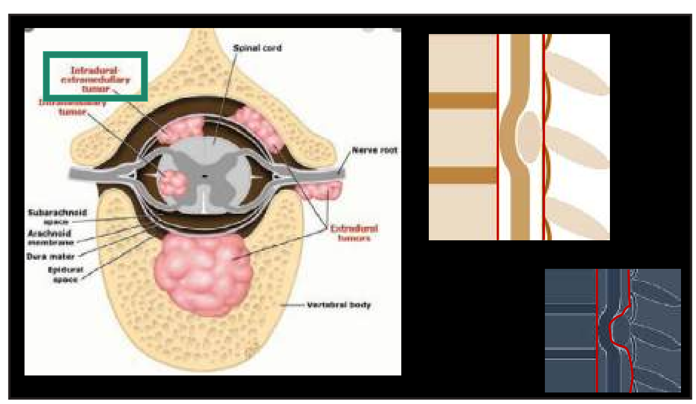
Points	Probability
5 or more	High
3-4	Intermediate
0-2	Low

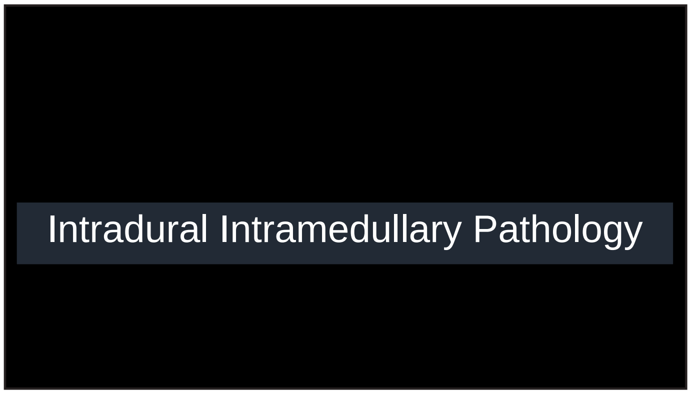
Likelihood of positive spinal imaging result – identify patients who may benefit from dynamic myelography

Dobrocky et al. JAMA Neurology 2019

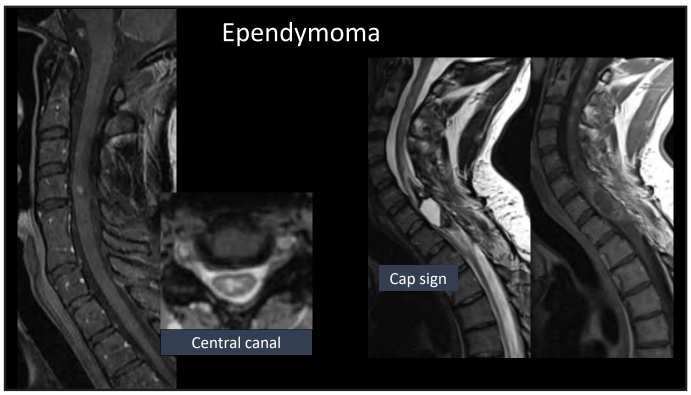


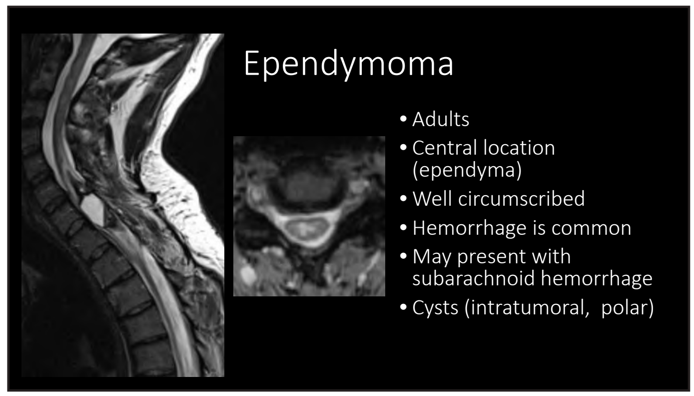


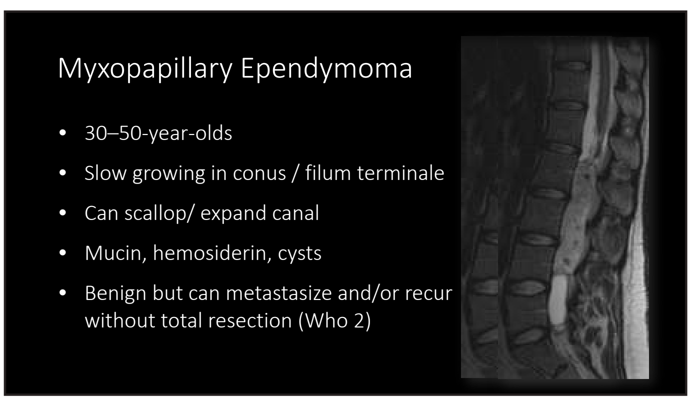



Intradural Intramedullary Pathology

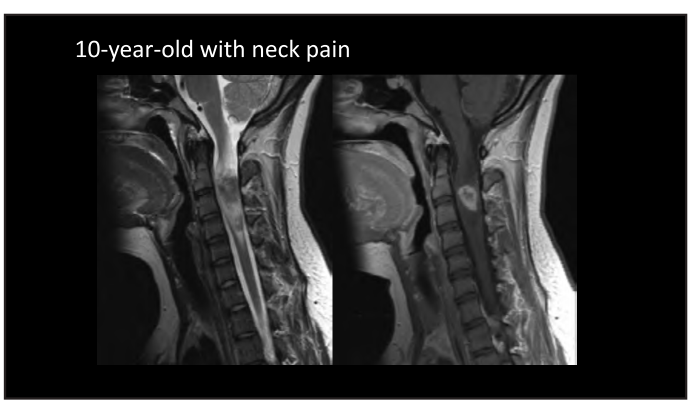

Two 60-year-olds with arm weakness

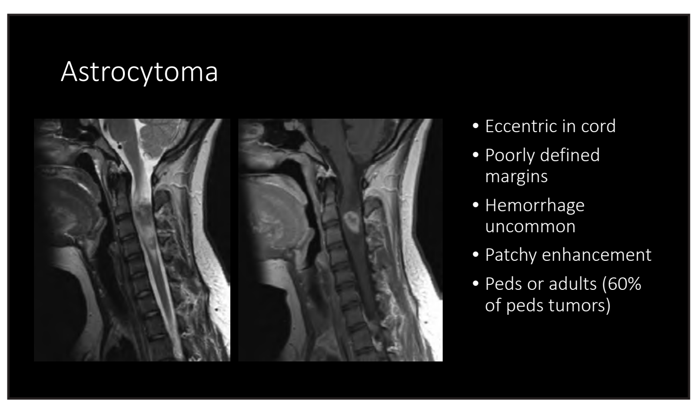

Ependymoma
Central canal
Cap sign

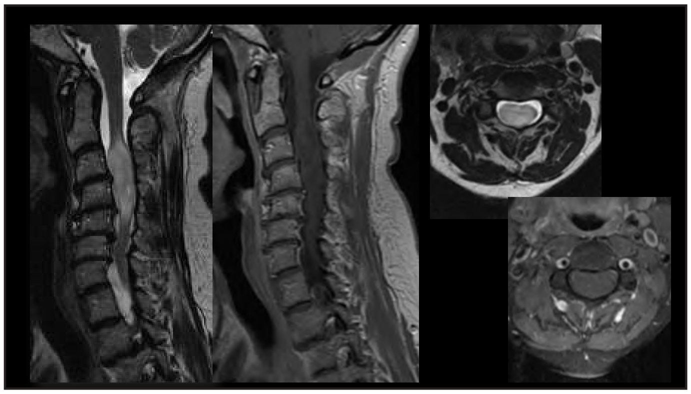

Ependymoma
• Adults
• Central location (ependyma)
• Well circumscribed
• Hemorrhage is common
• May present with subarachnoid hemorrhage
• Cysts (intratumoral, polar)


Myxopapillary Ependymoma
• 30–50-year-olds
• Slow growing in conus / filum terminale
• Can scallop/ expand canal
• Mucin, hemosiderin, cysts
• Benign but can metastasize and/or recur without total resection (Who 2)

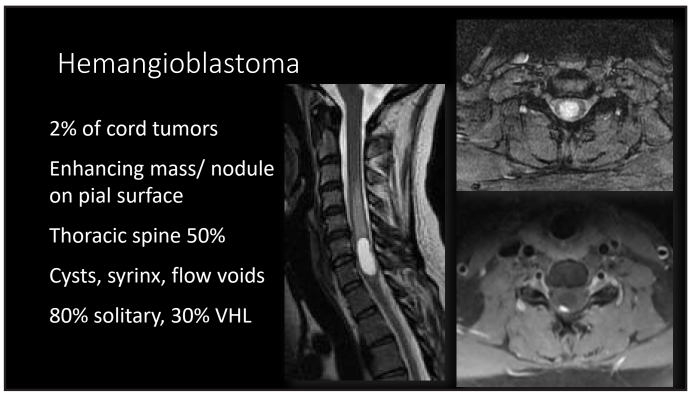

Paraganglioma


10-year-old with neck pain

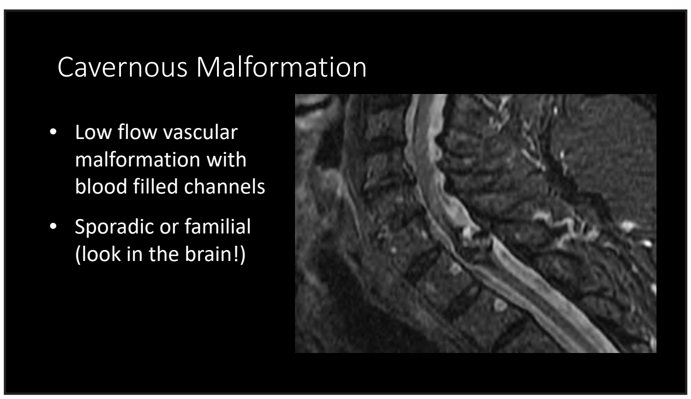

Astrocytoma
• Eccentric in cord
• Poorly defined margins
• Hemorrhage uncommon
• Patchy enhancement
• Peds or adults (60% of peds tumors)

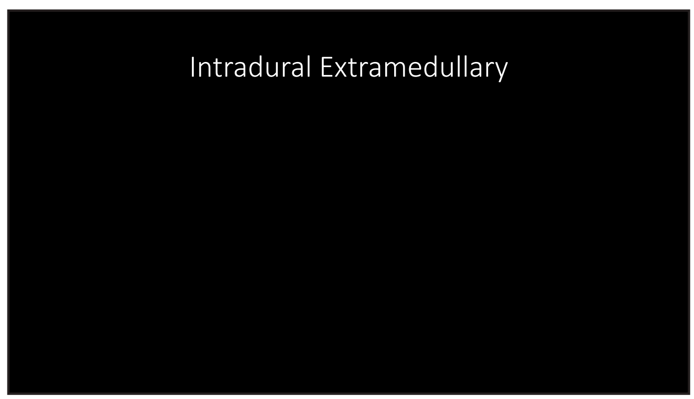


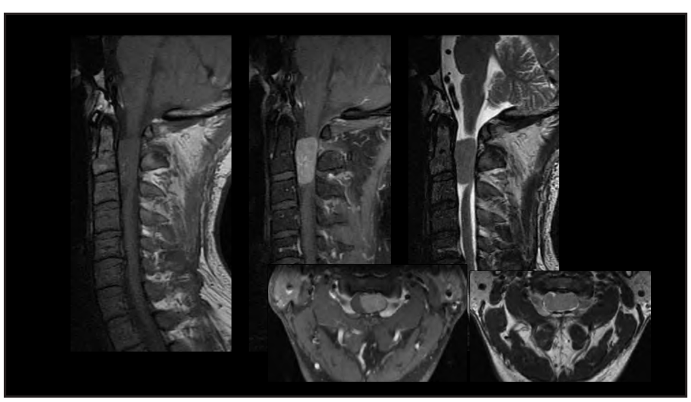

35-year-old with leg weakness

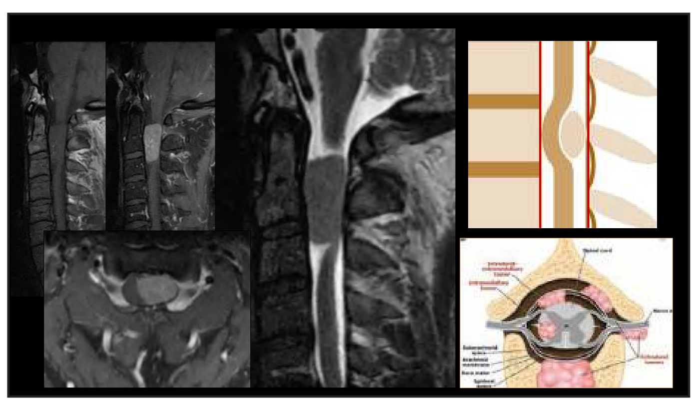

Hemangioblastoma
2% of cord tumors
Enhancing mass/ nodule on pial surface
Thoracic spine 50%
Cysts, syrinx, flow voids
80% solitary, 30% VHL


55-year-old with leg weakness

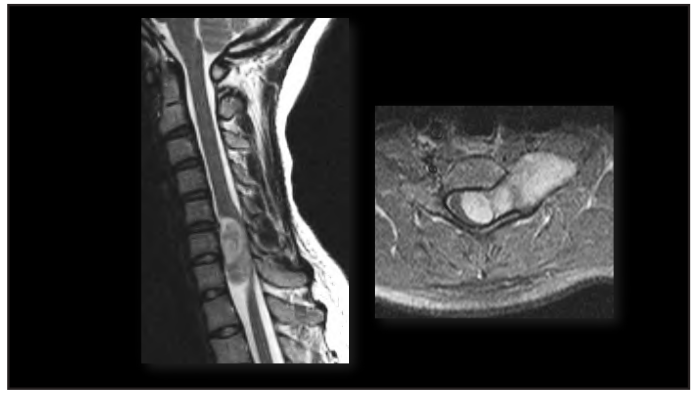

Cavernous Malformation
• Low flow vascular malformation with blood filled channels
• Sporadic or familial (look in the brain!)

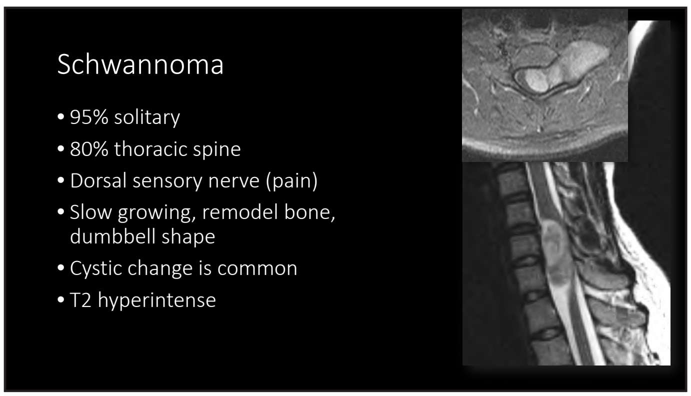

Intradural Extramedullary





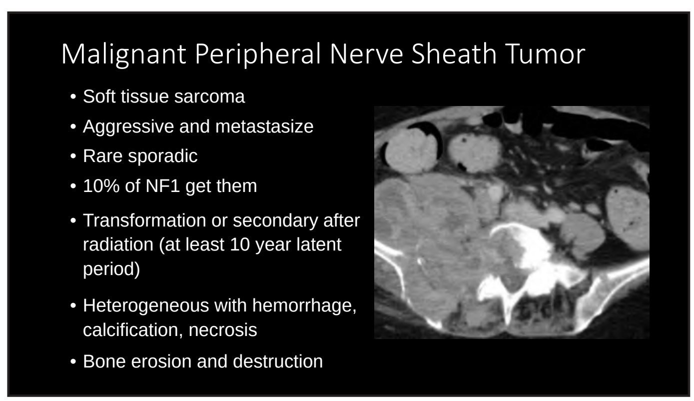

Meningioma
• In the spine, meningioma is much more common women (80%)
• 80% are in the thoracic spine
• Enhancing
• Mildly T2 hyperintense

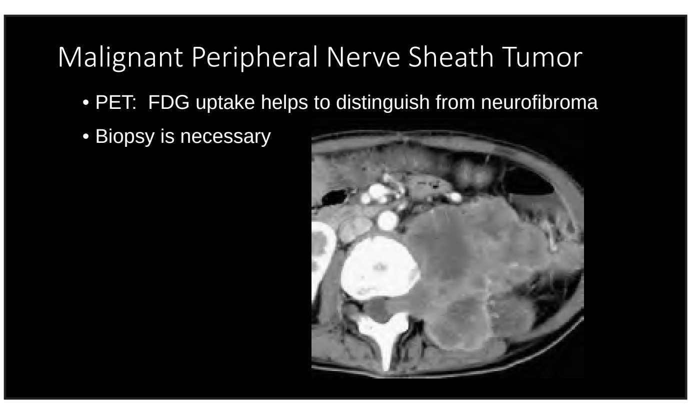


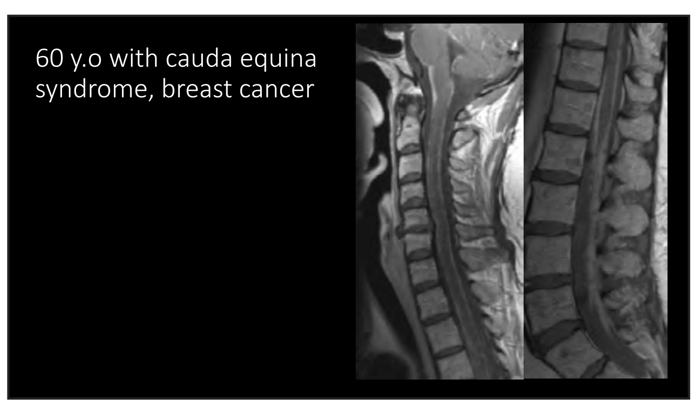

Schwannoma
• 95% solitary
• 80% thoracic spine
• Dorsal sensory nerve (pain)
• Slow growing, remodel bone, dumbbell shape
• Cystic change is common
• T2 hyperintense

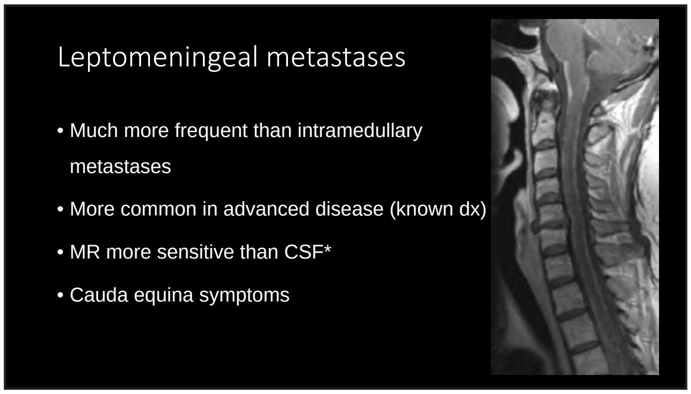

Schwannomatosis
• Spectrum of schwannoma predisposition syndromes (overlap with NF1 and 2)
• Younger
• Very painful


Neurofibroma
• Encase nerves
• Single sporadic or multiple NF1
• Plexiform: multiple fascicles of major nerve trunk or plexus
• Scoliosis
• Risk of malignant transformation

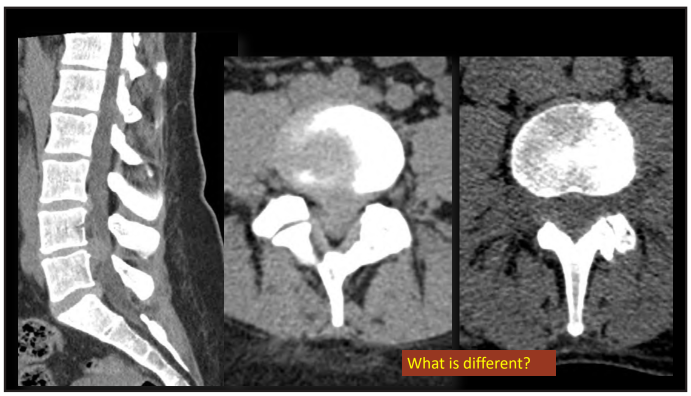

Malignant Peripheral Nerve Sheath Tumor
• Soft tissue sarcoma
• Aggressive and metastasize
• Rare sporadic
• 10% of NF1 get them
• Transformation or secondary after radiation (at least 10 year latent period)
• Heterogeneous with hemorrhage, calcification, necrosis
• Bone erosion and destruction

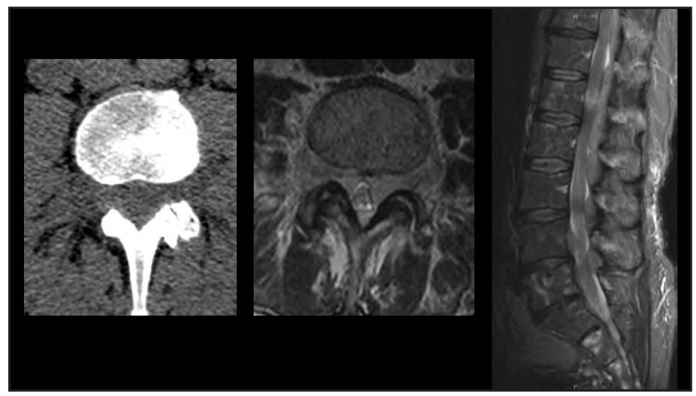

Malignant Peripheral Nerve Sheath Tumor
• PET: FDG uptake helps to distinguish from neurofibroma
• Biopsy is necessary


60 y.o with cauda equina syndrome, breast cancer

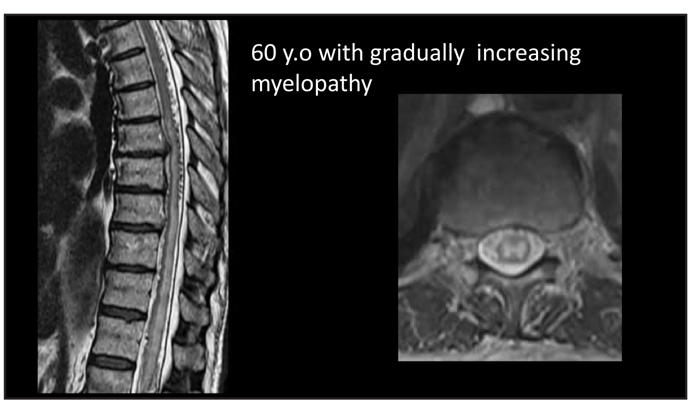

Leptomeningeal metastases
• Much more frequent than intramedullary metastases
• More common in advanced disease (known dx)
• MR more sensitive than CSF*
• Cauda equina symptoms

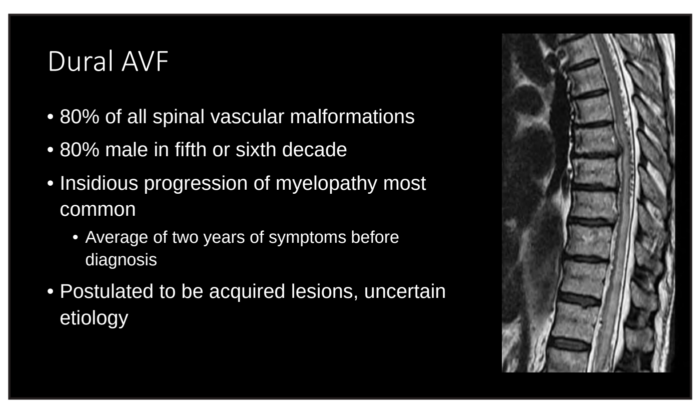

25-year-old with back pain

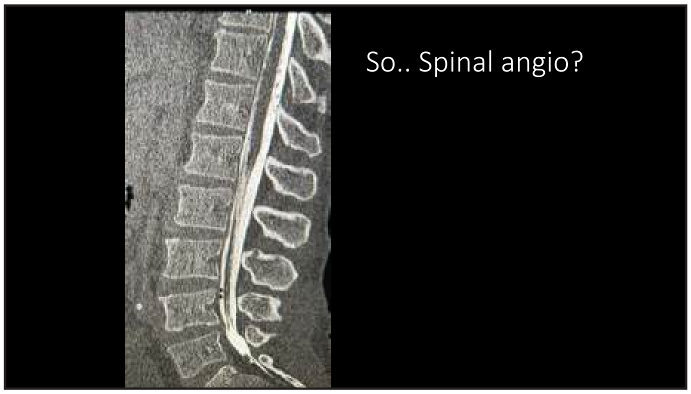

What is different?

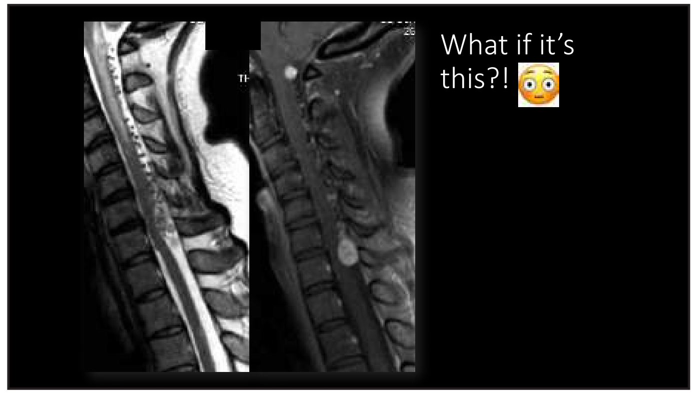


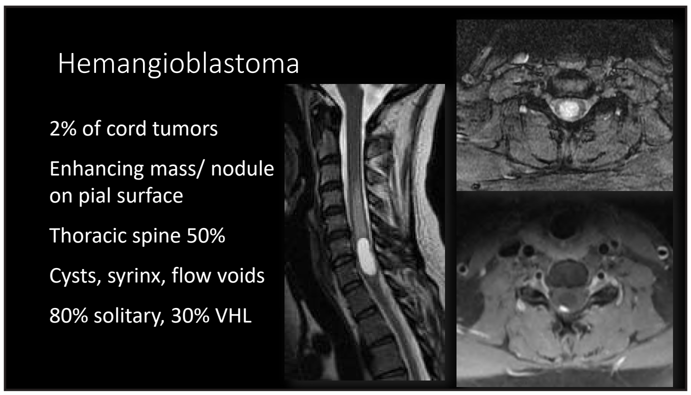

Burkitt Lymphoma


60 y.o with gradually increasing myelopathy


Dural AVF
• 80% of all spinal vascular malformations
• 80% male in fifth or sixth decade
• Insidious progression of myelopathy most common
• Average of two years of symptoms before diagnosis
• Postulated to be acquired lesions, uncertain etiology


So.. Spinal angio?


What if it's this?!


Hemangioblastoma
2% of cord tumors
Enhancing mass/ nodule on pial surface
Thoracic spine 50%
Cysts, syrinx, flow voids
80% solitary, 30% VHL


Barrow
Neurological Institute
WendeNGibbs@gmail.com

SELF EVALUATION

A Compartment based approach to Spinal Pathology

True/False

1. Arachnoid web and arachnoid cyst have the same surgical treatment, so it is unnecessary to differentiate between them.

2. Lesions within the CSF space, such as arachnoid cyst, arachnoid web, and spinal cord herniation, need both MRI and myelography for comprehensive diagnosis.

3. Osseous metastases are more common than primary spinal tumors.

4. The primary method for the treatment of osseous metastatic disease is surgery.

5. Metastasis within the thoracic vertebral bodies are inherently more unstable than those within the mid cervical spine.

Answer Key: 1. F, 2. T, 3. T, 4. F, 5. F

Summer L. Kaplan, MD

Summer L. Kaplan, MD is a pediatric radiologist in the Department of Radiology at The Children's Hospital of Philadelphia (CHOP) and an Associate Professor of Clinical Radiology at the University of Pennsylvania School of Medicine. Dr. Kaplan is certified in diagnostic radiology and Pediatric Radiology by the American Board of Radiology. She holds positions on the Clinical Information Technology Advisory Committee, the Education Committee and the Quality and Safety Committee at CHOP. Dr. Kaplan is a nationally recognized and frequent speaker on topics in pediatric radiology.

You may contact Dr. Kaplan with any questions or comments by email at KaplanS2@chop.edu.

Pediatric Non-Accidental Trauma
Summer L. Kaplan, MD

Objectives

After this presentation, the participant will be able to:

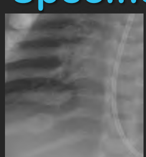
1. Discuss musculoskeletal findings of pediatric nonaccidental trauma
2. Explain high risk features of abdominal injuries
3. List neuroimaging features of nonaccidental trauma

Non-Accidental Trauma

Classical MSK features in children ≤ 2-years old

At-risk:
- Infants (< 1-year old)
- Chronic illness
- Sibling abused
- Parental/family stress

Specific Fractures of Abuse


Posterior rib


Scapula


Sternum


Spinous Process


Metaphysis

Fractures of Different Ages

Fractures of Different Body Parts

Common Fractures of Abuse


Posterior rib


Metaphysis


Diaphysis

Skeletal Survey

APPENDICULAR SKELETON
Right and left humerus (AP)
Right and left ulna & radius (AP)
Right and left hand (PA)
Right and left femur (AP)
Right and left tibia & fibula (AP)
Right and left foot (AP)

AXIAL SKELETON
Thorax (AP, lateral, right and left obliques), to include sternum, ribs [51,52], and thoracic and upper lumbar spine
Abdomen/pelvis, to include the thoracolumbar spine and sacrum (AP)
Lumbosacral spine (lateral)
Skull (frontal and lateral), to include cervical spine (if not completely visualized on lateral skull)*

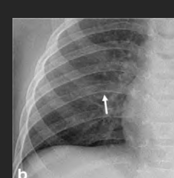
ACR-SPR Practice Parameters, 2021

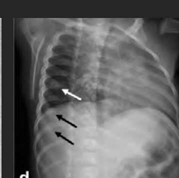
https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Skeletal-Survey.pdf, accessed January 2025

Skeletal Survey Uncertainty

Follow-up skeletal survey in 2 weeks
- Adds info in 12-34%

Caution:
- 20% metaphyseal fractures may heal in interval





Marine MB, Forbes-Amrhein MM. Pediatr Radiol. 2021

Bone Scintigraphy

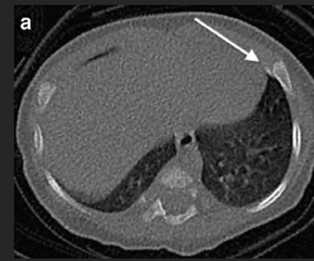
Tc-99m Methyl-Diphosphonate (MDP)
- When unsafe to wait 2 weeks for follow-up radiographs
- Adds info in 12%

Caution:
- False negatives occur in up to 72 hours after acute fracture
- Low sensitivity for metaphyses, skull
- Not used for dating fractures

Bainbridge JK et al. Clinical Radiol. 2017.

CT for Rib Fractures

- Sensitivity for fracture site ~ +3x
- No gains in specificity
- Caution:
  - Sensitivity 45-62% compared with autopsy
  - Slightly higher false positive rate on CT (3 – 5%)
- Radiation ~ 2x four-view chest XR for infant
  - 100 kV, 15 mA



Sanchez TR et al. Pediatr Radiol. 2015.
Shelmerdine SC et al. Lancet. 2019.

Ultrasound for Specific Area

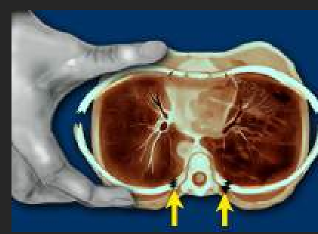
- Useful for targeted area in question
- Good visualization of injury
- Not yet robust data on sensitivity/specificity

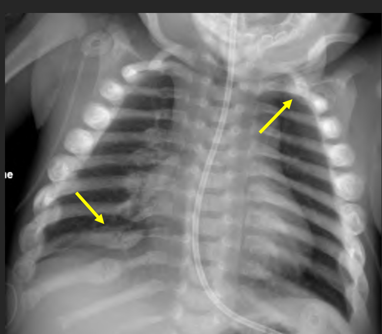
Marine MB, Forbes-Amrhein MM. Pediatr Radiol. 2021

Rib fractures

Anterior-posterior compression mechanism

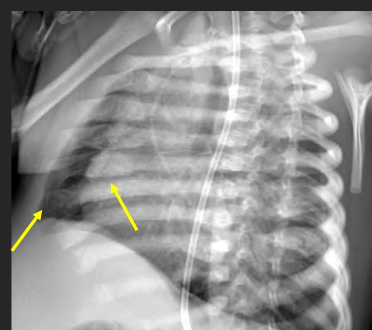
Multiple rib fractures
- 70% likelihood abuse
- 95% likelihood aligned posterior fractures


radiologyassistant.nl, accessed 01/2025



Rib Fractures

Specific
- Posterior
- Ribs 1 & 2



Rib Fractures

Specific
- Posterior
- Ribs 1 & 2

Common
- Lateral
- Anterior (bucket handle)

Rib Fracture Association

Upper abdominal organ injury with anterior rib fractures

Pleural fluid with rib fractures

Rib fractures from CPR?

2005 AHA-CPR guidelines for infants changed to encircling technique

Accompanied by increase in anterior and lateral rib fractures

No increase posterior fractures

Reyes JA et al. Resuscit 2011.

Metaphyseal corner fractures


- Most common long bone fracture in infants who die of abuse
- Lateral view long bones increases detection of fractures by 50%.

Metaphyseal normal appearance

- Slightly irregular
  - 2 views
  - Follow-up

- Pes anserius insertion

Femur diaphyseal fractures

- Most common fracture in abused children
- Specificity for abuse low
- Non-ambulatory child with femur diaphysis fracture 1/3- 1/4 probability of abuse

Humerus diaphyseal fractures

Humeral diaphyseal fractures in children < 18-months old high probability of abuse

Spiral fractures of humerus may occur as infants are beginning to roll over

Somers JM et al. Pediatr Radiol, 2014

Fracture dating

- Cannot provide time certainty
- Can identify recent vs old

Feature	Early	Peak	Delayed
Resolution of soft tissues	2–5 days	4–10 days	10–21 days
Subperiosteal new bone formation	4–10 days	10–14 days	14–21 days
Loss of fracture line definition	10–14 days	14–21 days	
Soft callus	10–14 days	14–21 days	
Hard callus	14–21 days	21–42 days	42–90 days
Remodelling	3 months	1 year	2 years to physeal closure

Offish A et al. Pediatr Radiol, 2009.

- Metaphyseal corner fracture may not follow classic pattern

False Theories

Birth trauma
- Metaphyseal corner fractures, posterolateral rib fractures possible
- Correlate with birth history; single fracture age

Short distance fall
- Expect minimal injuries; single fracture age
- Fall from ≤ 4 ft show 8x fatalities of falls from 10 – 45 ft; varied fracture ages

Temporary brittle bone disease
- Not a diagnosable pathophysiology

Genetic/Metabolic Conditions


Genetic/metabolic:
- Osteogenesis Imperfecta
- Rickets/vitamin D deficiency
- Copper deficiency/Menkes
- Collagen disorder/Ehlers-Danlos

Osteogenesis Imperfecta
- Genetic markers COL1A1, COL1A2, SERPINF1
- Diffusely abnormal bones
  - Overtubulation, cortical thinning, Wormian bones

Genetic/Metabolic Conditions


Genetic/metabolic:
- Osteogenesis Imperfecta
- Rickets/vitamin D deficiency
- Copper deficiency/Menkes
- Collagen disorder/Ehlers-Danlos

Rickets
- Testing for nutritional or genetic deficiency
- Diffuse osteopenia
  - Frayed, flared metaphyses
  - Fractures of deficiency not at metaphyses

Abdominal Injuries

- NAT in 25% children ≤ 3-years old hospitalized for blunt abdominal trauma
  - 2-3% abuse cases
- Any intra-abdominal injury may be forensically significant
- Alert to delays seeking care

Non-Accidental Trauma

2-year old, abuse suspected

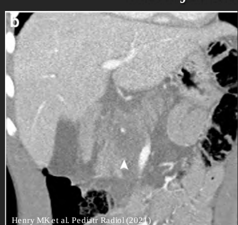
CT abdomen/pelvis for:

- Bruising
- Abdominal pain
- Abnormal liver or pancreas serology
- Altered mental status with normal head CT

- PECARN rules not applicable

Abdominal Injuries

No injuries specific for NAT



Pancreas, hollow viscus injuries more common in NAT

Injuries often more severe in NAT

Neuroimaging Non-Accidental Trauma

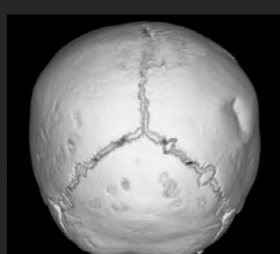
- Leading cause of fatal head injuries in children < 2-years old
- Mechanism shaking and/or impact
- Medical diagnosis, not legal term
- Present as
  - Developmental delay, seizure, macrocephaly
  - Trauma with unexplained mechanism, death
  - Incidental finding or during work-up of sibling

Outcomes
Death (20-25%)
Spastic hemiplegia or quadriplegia (15–64%)
Intractable epilepsy (11–32%)
Microcephaly with cortico-subcortical atrophy (61–100%)
Visual impairment (18–48%)
Language disorders (37–64%)
Agitation, aggression, tantrums, attention deficits, memory deficits, inhibition or initiation deficits (23–59%)

Choudhary AK et al, Pediatr Radiol 2018

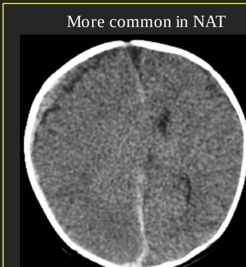
Imaging Evaluation

- First-line: Non-enhanced CT with 3-D bone reconstructions
  - Followed by: Non-enhanced MR brain and full spine
- May MR first-line if stable
- Skeletal survey does not need to XR head if CT done
- Head US not utilized
  - Point-of-care may be useful for triage



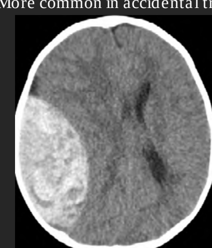
Intracranial Hemorrhage

More common in NAT



Subdural

More common in accidental trauma



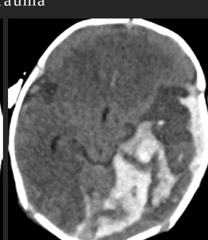
Epidural

Intracranial Hemorrhage

Equally common in NAT and accidental trauma

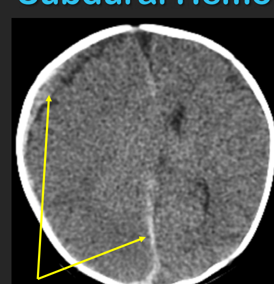
Subarachnoid

Intraventricular



Parenchymal

Subdural Hemorrhage



4-month old w/ head trauma

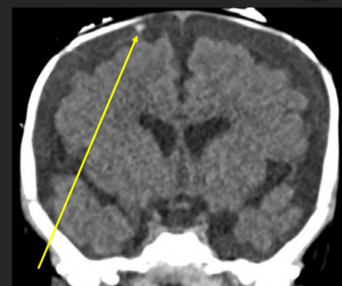
- Most frequent intracranial finding in NAT
- Most often parafalcine
  - Tearing of bridging veins at junction with sagittal sinus
- Dural tear and CSF leak appear mixed-attenuation
  - More common in NAT
  - 58% NAT-related subdural

Subdural Hemorrhage: Varied Age

5-month old w/ altered mental status

- Cannot give specific age
  - Acute
  - Subacute
  - Chronic

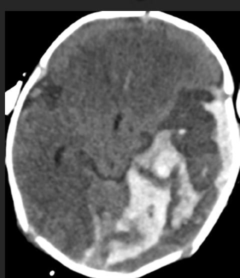
Thrombosed Bridging Veins



5-week old w/ trauma

- Sign of abuse
- "tadpole sign", "lollipop sign"

Parenchymal Hemorrhage



5-month old w/ fall

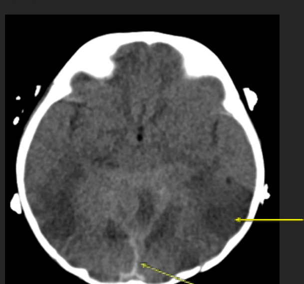
- Most significant cause of morbidity and mortality
- MR better for diffuse axonal injury

Retinal Hemorrhage

3-day old w/ coagulopathy, maternal syphillis

- Shearing injury
- Accompanies SDH and metaphyseal corner fractures
- Diagnosed by direct visualization

Infarcts



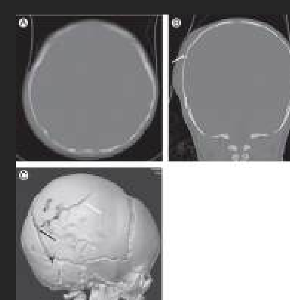
6-month old, lethargic

Infarcts
- Bilateral symmetric →global hypoxia

Needs skeletal survey x-rays

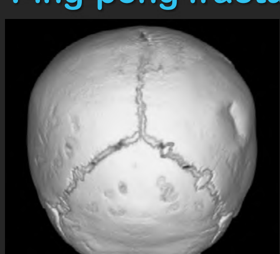
Skull Fractures

- Fractures occur in NAT and accidental trauma equally
- Complex fractures more common in NAT
- PECARN risk stratification for head CT appropriateness does not apply for abuse cases.



O'Brien WT et al. Semin US CT MR (2018)

Ping-pong fracture



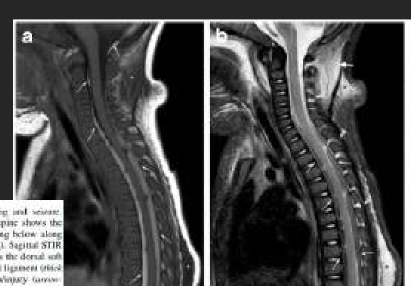
Relatively pliable bone

Often palpable, prompts CT

Not specific for abuse

Spine injury

- Most commonly ligamentous
- Spinal subdural hemorrhage tracking from posterior fossa



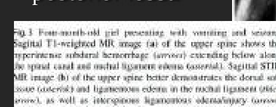


Fig.3 Four-month-old girl presenting with vomiting and seizure. Sagittal T1-weighted MR image (a) of the upper spine shows the hyperintense subdural hemorrhage (arrows) extending below along the spinal canal and nuchal ligament edema (asterisk). Sagittal STIR MR image (b) of the upper spine better demonstrates the dorsal soft tissue (asterisk) and ligamentous edema in the nuchal ligament (thick arrow), as well as interspinous ligamentous edema/injury (arrowheads). Note the STIR hypointense spinal SDH extending inferiorly

Derinkuyu BE, et al. Pediatr Radiol,. 2024

Summary

- Fractures specific for child abuse can be differentiated from fractures common in child abuse
  - Aligned posterior rib fractures and metaphyseal corner fractures are the most frequent specific fractures
  - Diaphyseal fractures are common but are not specific
- Subdural hemorrhage and complex fractures are more common in abuse cases but are not specific
- Pancreatic and bowel injury are more common in abuse but are not specific

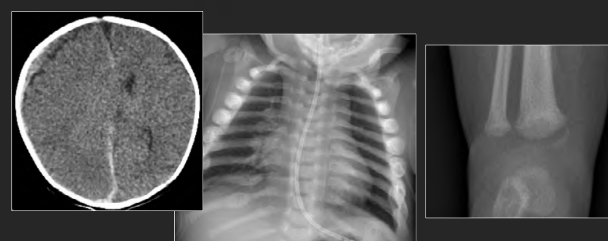
Summary

- Add certainty to diagnosis with
  - Additional XR views
  - Follow-up skeletal survey after 2 weeks
  - Tc99m-MDP scintigraphy
  - Ultrasound for specific area
  - Chest/Abdomen/Pelvis CT
  - Brain/Spine MR

Summary

- No abuse-specific fracture features from
  - Infant CPR
  - Birth trauma
  - Fall from ≤ 4 ft
  - Genetic/metabolic/nutritional abnormalities

Pediatric Non-Accidental Trauma



Dr. Summer L. Kaplan MD MS

SELF EVALUATION

Pediatric Non-Accidental Trauma

1. A skeletal survey should include at least how many images

a. 1, a large image covering the entire body
b. 15, frontal views of each body part
c. 21, frontal views of each body part and lateral views of the skull, spine, chest, abdomen, and pelvis
d. 35, frontal and lateral views of each body part and oblique views of the elbow, wrist, knee, and ankle

2. The intracranial injury most frequent in non-accidental trauma is:

a. Subararachnoid hemorrhage
b. Subdural hemorrhage
c. Intraventricular hemorrhage
d. ACA territory infarct

3. Posterior rib fractures may occur due to:

a. non-accidental trauma
b. CPR
c. birth trauma
d. all of the above

4. Which fracture type is specific for non-accidental trauma in a non-ambulatory child?

a. parietal skull fracture
b. spiral fracture of the humerus
c. phalangeal fractures
d. metaphyseal corner fracture

5. The intra-abdominal injuries more frequent in non-accidental trauma cases are:

a. pancreas and hollow viscus
b. spleen and left kidney
c. aorta and small bowel
d. liver and pancreas

Answer Key: 1. C, 2. B, 3. A, 4. D, 5. A

FACULTY

Anil K. Attili, MD

Anil K. Attili, MD is a board certified radiologist and Clinical Professor in the Department of Radiology, Division of Cardiothoracic Imaging at the University of Michigan. He has a joint appointment at the Veterans Administration Hospital Ann Arbor where he serves as the director of Cardiovascular Radiology. Dr. Attili's areas of expertise and clinical interests include Cardiac CT for Coronary Artery disease and Structural Heart disease, Cardiac MR evaluation of Ischemic Heart Disease, Cardiomyopathies and Congenital Heart Disease, HRCT evaluation of Interstitial Lung Disease, Lung Cancer Screening. He is a nationally recongized speaker on these topics.

You may contact Dr. Attili with your questions and comments at aattili@med.umich.edu.

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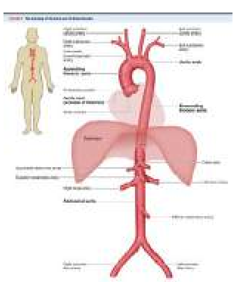
Imaging of the Thoracic Aorta

Imaging of the Thoracic Aorta

- Understand the role of CT and MRI in the imaging of Thoracic aortic disease
- Describe the imaging appearances of acute and non acute Thoracic aortic pathologies on CT and MRI
- To review the current guidelines and appropriate use criteria for CT and MRI in Thoracic aortic disease


2022 ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease

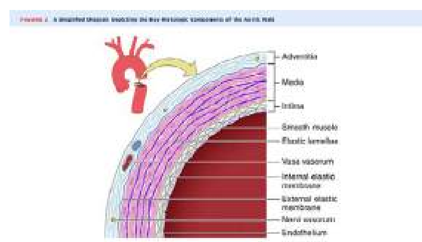
Normal Aortic Anatomy



The aorta is the largest artery in the body and can be divided into 5 main anatomic segments :

- The root or sinus segment, which extends from the aortic valve annulus to the sinotubular junction
- The ascending thoracic aorta, which extends from the sinotubular junction to the innominate artery
- The aortic arch, which extends from the innominate to the left subclavian artery
- The descending thoracic aorta, which extends from the left subclavian artery to the diaphragm
- The abdominal aorta, which extends from the diaphragm to the level of the aortic bifurcation

Histological Components of the Aortic Wall



The aortic wall is composed of 3 layers :

A thin inner intima, a thicker central media, and a thin outer adventitia.

The intima consists of a layer of endothelial cells within a matrix of connective tissue.

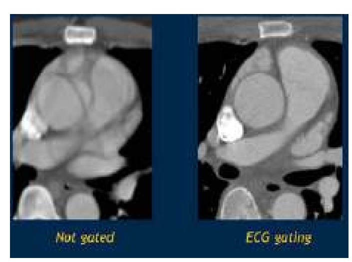
The media consists of smooth muscle cells, elastic fibers, collagen proteins, and polysaccharides sandwiched in >50 layers known as elastic lamellae. The media provides strength and distensibility to the aorta, features that are critical to circulatory function.

The adventitia is composed of connective tissue, fibroblasts, nerves, and the vasa vasorum, which perfuse the outer aortic wall and a substantial portion of the media.

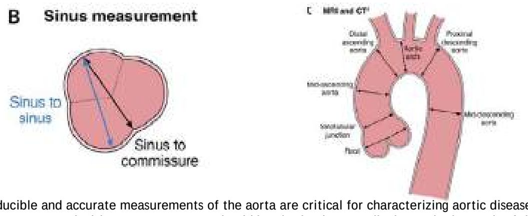
CT Aorta Technique

- IV contrast enhanced
- ECG gated-Prospective or retrospective
- Multidetector CT with thin section recons (0.5-1mm)
- Non contrast scan-optional

ECG Gating Essential for the root and ascending aorta



Aortic measurements

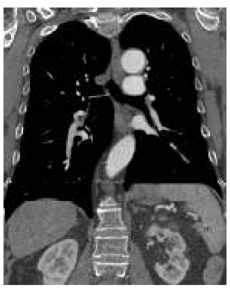


Reproducible and accurate measurements of the aorta are critical for characterizing aortic disease and guiding treatment decisions. Measurements should be obtained perpendicular to the long axis of the aorta at specified segmental locations with measurements also taken at the location of any abnormality. Maximum aortic diameter at each level of dilation, perpendicular to the axis of blood flow. In cases of asymmetric or oval contour, the longest diameter and its perpendicular diameter should be reported

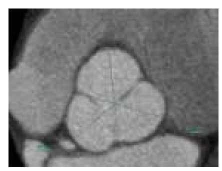
CT Aorta

ECG gated axial data set

CT Aorta . Multiplanar reformats

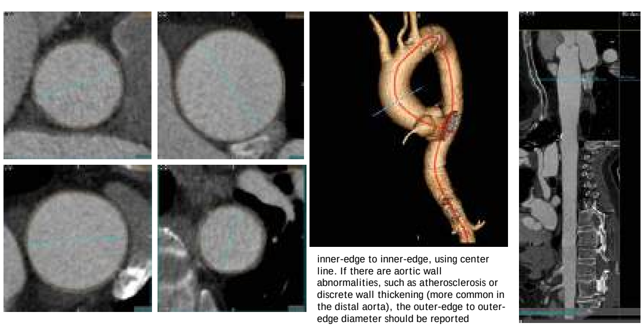


CT Aorta measurements



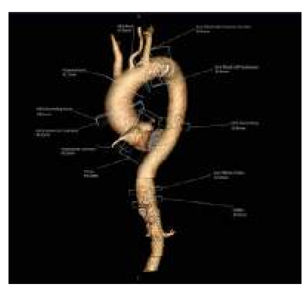
The root diameter can be measured from sinus-to-sinus (S-S) or sinus-to-commissure (S-C).

CT Aorta measurements



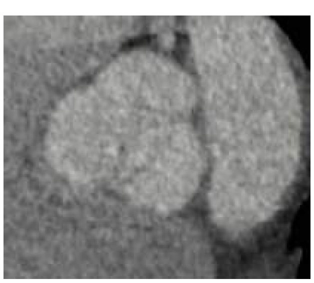
inner-edge to inner-edge, using center line. If there are aortic wall abnormalities, such as atherosclerosis or discrete wall thickening (more common in the distal aorta), the outer-edge to outer-edge diameter should be reported

CT Aorta measurements



MPR Radius (mm)	S of V Right	[illegible]
MPR Radius (mm)	S of V Left	[illegible]
MPR Radius (mm)	S of V Non	44.3
Diameter (mm)	Sinus	[illegible]
Diameter (mm)	Sinotubular Junction	[illegible]
Diameter (mm)	Mid-Ascending Aorta	48.5
Diameter (mm)	Proximal Arch	45.1
Diameter (mm)	Mid-Arch	[illegible]
Diameter (mm)	2 cm Distal Left Common Carotid	[illegible]
Diameter (mm)	2 cm Distal Left Subclavian	[illegible]
Diameter (mm)	Mid-Descending	25.8
Diameter (mm)	2 cm Above Celiac	[illegible]
Diameter (mm)	Celiac	[illegible]
Diameter (mm)	Aorta Maximum Diameter	48.2

CT Aortic valve cine

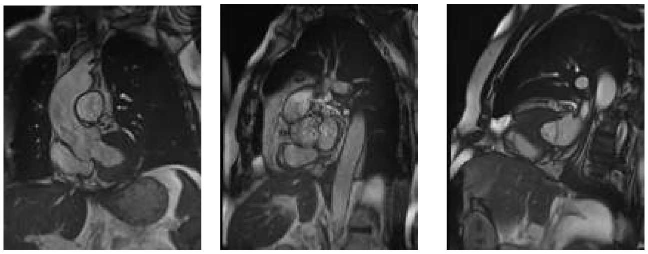


ECG gated retrospective data set enables reconstruction of cine loops

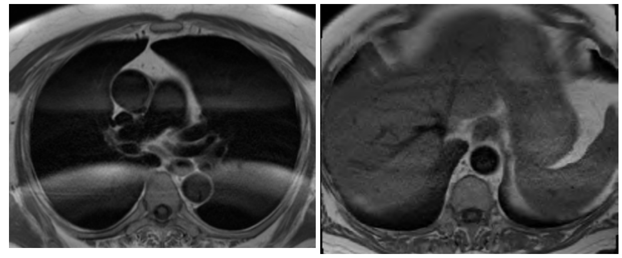
MR Aorta Technique

- 3D gadolinium enhanced MRA
- Gradient echo Cine imaging
- Spin echo Black blood imaging
- ECG and respiratory synchronized 3D non contrast MRA

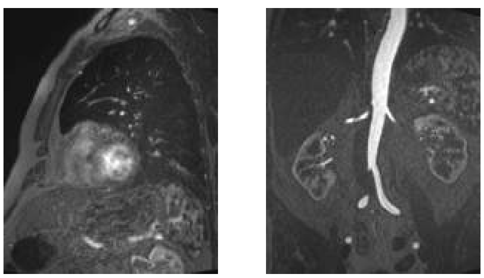
MR Aorta- Cine imaging



MR Aorta- Spin echo black blood imaging

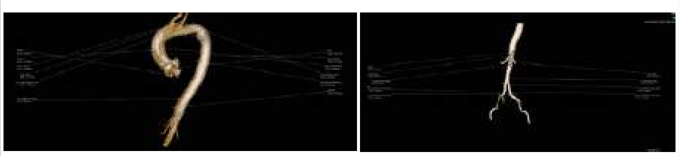


MR Aorta- 3D Gadolinium enhanced MRA



MR Aorta measurements

MR Aorta



Diagnostic Performance of Aortic Imaging Modalities

TABLE 5 Diagnostic Performance of Aortic Imaging Modalities

Parameter	CT	MRI	TTE	TEE	US
Availability	+++	++	+++	++	+++
Portability	+	+	+++	+++	+++
Speed of acquisition	+++	+	++	++	++
Spatial resolution	+++	++	++	+++	++
Temporal resolution	–	++	+++	+++	+++
Three-dimensional data set	+++	++	+	+	+
Arch branch vessel evaluation	+++	+++	++	+	NA
Evaluation of valve and ventricular function	+	++	+++	+++	NA

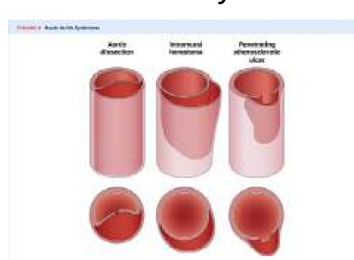
Isselbacher et al JACC VO L . 8 0 , N O.2 4, 2 0 2 2
2022 ACC/AHA Aortic Disease Guideline

Acute Aortic syndrome (AAS)

AAS are life-threatening conditions in which there is a breach in the integrity of the aortic wall

- Aortic dissection
- Penetrating atherosclerotic ulcer
- Acute Intramural hematoma (IMH)

Acute Aortic Syndromes



Isselbacher et al JACC VO L . 8 0 , N O.2 4, 2 0 2 2
2022 ACC/AHA Aortic Disease Guideline

In aortic dissection, a tear in the aortic intima allows blood to penetrate the aortic media, pushing the dissection flap into the middle of the aorta, separating the true from the false lumen.

In intramural hematoma, blood leaks into the aortic media at low pressure, forming a thrombus that pushes the outer wall of the aorta outward, leaving a relatively normal appearing aortic lumen.

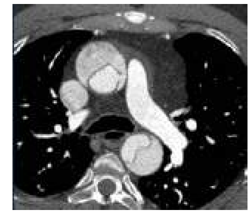
A penetrating atherosclerotic ulcer allows blood to enter the aortic media, but atherosclerotic scarring of the aorta typically confines the blood collection, often resulting in a localized dissection or pseudoaneurysm

Imaging of Acute Aortic Syndromes

CT is the imaging modality of choice in the acute, subacute, and chronic phases of AAS because of its wide availability and fast acquisition of volumetric datasets, which become instrumental in diagnosis, intervention planning, and follow-up monitoring

Aortic Dissection

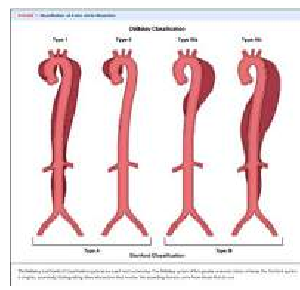
- Aortic dissection is the most common of the AAS
- Aortic dissection occurs when there is an intimal tear that allows the blood to pass through the tear and into the aortic media, splitting the intima longitudinally, creating a dissection flap that divides the true lumen from a newly formed false lumen



Aortic Dissection

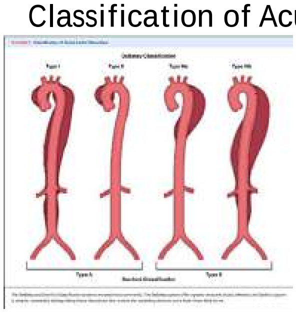
- The dissection flap can propagate in an antegrade or retrograde fashion and lead to a number of life-threatening complications, including acute aortic regurgitation (AR), myocardial ischemia, cardiac tamponade, acute stroke, or malperfusion syndromes
- The blood surging in the false lumen may rupture back through the intima into the true lumen, creating a reentry tear
- If the blood in the false lumen instead tears through the outer media and adventitia, aortic rupture will result

Classification of Acute Aortic Dissection



Stanford
DeBakey

Classification of Acute Aortic Dissection



The DeBakey system categorizes dissections into types I, II, and III, based on the origin of the intimal tear and the extent of the dissection:

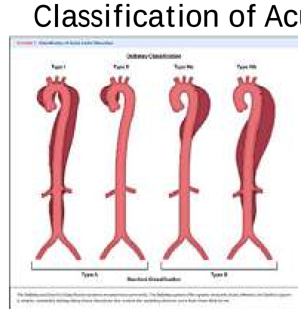
Type I: Dissection tear originates in the ascending aorta and propagates distally to include the aortic arch and typically, the descending aorta

Type II: Dissection tear is confined only to the ascending aorta

Type III: Dissection tear originates in the descending thoracic aorta and propagates most often distally

- Type IIIa: Dissection tear is confined only to the descending thoracic aorta
- Type IIIb: Dissection tear originates in the descending thoracic aorta and extends below the diaphragm

Classification of Acute Aortic Dissection



The Stanford classification system divides dissections into 2 categories according to whether the ascending aorta is involved or not, regardless of the site of origin:

Type A: All dissections involving the ascending aorta, irrespective of the site of the intimal tear

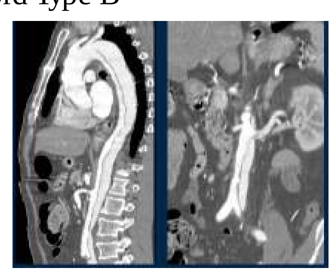
Type B: All dissections that do not involve the ascending aorta (including dissections that involve the aortic arch but spare the ascending aorta)

Aortic Dissection- Typical appearance Stanford Type A

Surgical Emergency

May result in death from
- Rupture
- Pericardial tamponade and hemopericardium
- Coronary occlusion
- Severe Aortic insufficiency

Aortic Dissection- Typical appearance Stanford Type B

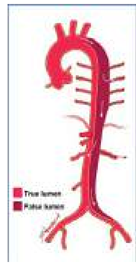


Most critical findings affecting initial intervention and prognosis are obtained at CT, including involvement of the ascending aorta (lesion type), location and size of the initiating intimal tear, rupture, end-organ malperfusion, size and patency of the false lumen, as well as presence of clot, complexity and extent of the dissection, maximum caliber of the aorta, and progression or postintervention complications

Aortic Dissection and Other Acute Aortic Syndromes: Diagnostic Imaging Findings from Acute to Chronic Longitudinal Progression
Horacio Murillo, Lior Molvin, Anne S. Chin, and Dominik Fleischmann
RadioGraphics 2021 41:2, 425-446

RSNA

Acute Aortic Syndrome- Imaging analysis and Reporting



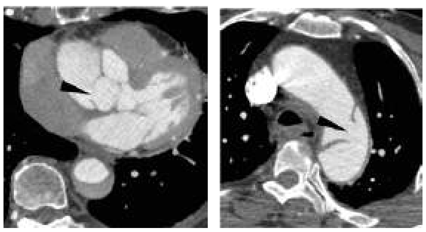
DISSECTION	Task
Dissection or other AAS	Dissection or other AAS: Yes/No? Ascending aorta involved: Yes/No?
Intimal tear	Primary intimal tear location and size if possible
Size of aorta & false lumen	Orthogonal or best axial measurement at largest caliber
Segment(s) of aorta involved	Root-STJ-Asc-Arch-Des-Abdominal-Iliac
Extent and termination	Extent and termination within the aorta and involved side branches
Complications	Yes/No? Type and location?
Thrombus in false lumen	Yes/No? Where?
Inspect False/True lumen	Simple, complex, motion, rigid, other?
Other factors to consider	Trauma, age, sex, symptoms, blood pressure, vasculitis, sympathomimetic drugs, other?
Notify the provider	If new or unexpected (rarely painless) If significant change or progression

Most critical findings affecting initial management and prognosis are obtained at CTand can be systematically identified using the DISSECTION mnemonic algorithm at any stage, as well as during assessment of postprocedure success and complications.

Murillo H. Published Online: March 01, 2021
https://doi.org/10.1148/rg.2021200138

RadioGraphics

Primary Intimal Tear location and size



Knowing the PIT location is important for surgical and endovascular interventions.

The origin of most initiating intimal tears clusters in the proximal ascending aorta near the ST junction and just distal to the left subclavian artery

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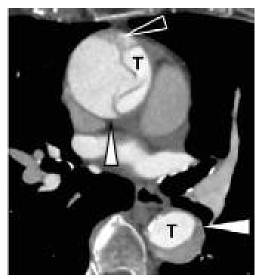
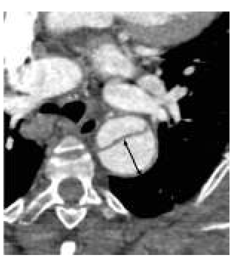
Size of the affected aorta and false lumen in Aortic dissection



- Size of the affected aorta where it is largest in caliber and size of the false lumen, are identified during systematic image analysis
- The prognostic value of these measurements is better defined in type B lesions, including the size of the type B false lumen
- Note the strands of dissected media forming the cobweb sign in the false lumen of the ascending aorta (black arrowhead) and the beak sign formed by the sharp angles of the false lumen in the ascending aorta (black-bordered white arrowhead) and descending aorta (solid white arrowhead)

Size of the affected aorta and false lumen in Aortic dissection



- Axial CT angiogram from systematic analysis of the entire aorta shows the proximal descending aorta to be the largest involved aortic segment and the site of the largest false lumen diameter (aortic orthogonal caliber = 3.70 × 3.64 cm; false lumen diameter = 2.35 cm [double-headed arrow]

What happens to the false lumen?

- Thromboses
- Increases in size over time
- Decreases in size over time
- Ruptures

The false lumen status influences late outcomes in AAD. Residual patent false lumen is independently associated with poor long-term survival in AAD. However, only type B AAD patients with partial false lumen thrombosis had an increased late mortality risk

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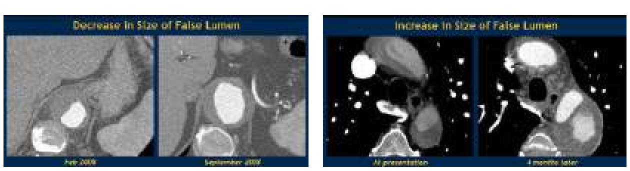
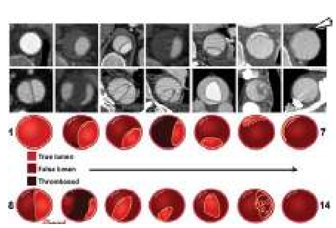
False lumen status in AAD



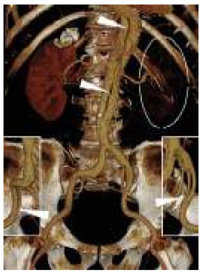
AAD- Inspection of true and false lumen morphology and complexity



Spectrum of AAD lumina and dissection flaps. Axial images and corresponding diagrams *1-7* and *8-14* show variable morphologies seen in AAD with variable size and caliber of the false and true lumina. The prognostic impact may relate to increasing complexity of dissection along the continuum (long black arrow), the presence of thrombus in the false lumen, and the extent of dissected intima circumference. The false lumen is commonly less brightly perfused at first-pass arterial phase imaging, and the true lumen is commonly smaller and compressed by the false lumen's higher pressures, from mild (image and diagram *2*) to complete collapse or occlusion (image and diagram *7*; arrowhead). A variable degree of intima circumference dissection is seen, from that in image and diagram *2* to its entire circumference in image and diagram *12*. The dissected intima-media complex may be partially avulsed and intussuscepted (image and diagram *13*) or completely avulsed and embolized (image and diagram *14*).

Murillo H. Published Online: March 01, 2021
https://://doi.org/10.1148/rg.2021200138

Extent and termination of the dissection or AAS within the aorta and involved side branches



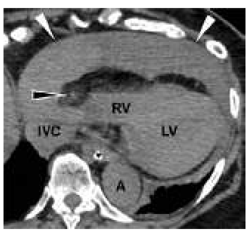
AAD involvement of abdominal aorta and iliofemoral arteries. Complete analysis of the abdominal aorta and iliofemoral vessels on axial raw data images can be augmented with 3D volume-rendered visualization.

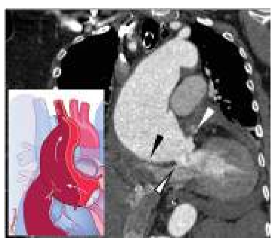
Volume-rendered image shows the relation of the true and false lumina, the dissection plane (top two arrowheads), complications such as marked hypoperfusion of the left kidney (white oval), and termination of the dissection at the iliofemoral arteries (arrowhead in insets), affecting vascular access.

Acute Aortic Dissection- Complications

- Aortic rupture
- Hemopericardium and tamponade
- Coronary artery occlusion or dissection
- Cervical branch occlusion or stenosis,
- Visceral organ infarcts such as kidney, bowel, or iliofemoral occlusion or thrombosis

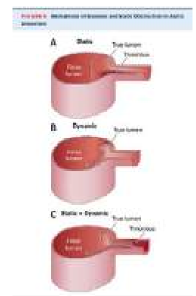
AAD Complications- Hemopericardium





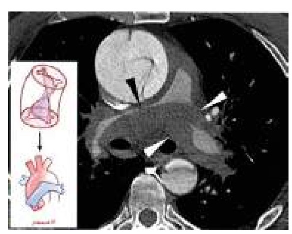
AAD- Malperfusion

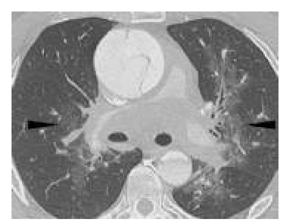
- Malperfusion syndrome occurs when there is end-organ ischemia related to inadequate perfusion of the aortic branch vessels



AAD Complications-Coronary artery and arch vessel occlusion

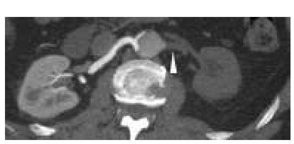
AAD with adventitial hemorrhage extending to the pulmonary artery adventitia





AAD- Renal malperfusion

Dynamic



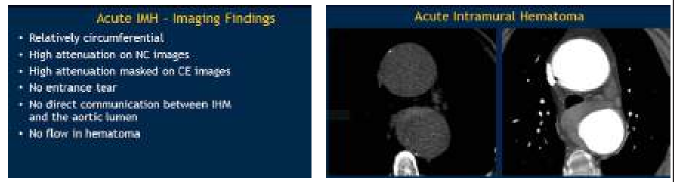
Static

AAD- Mesenteric and iliofemoral malperfusion

Intramural Hematoma (IMH)

- IMH describes the presence of blood within the medial layer of the aortic wall in the absence of an overt intimal tear or patent false lumen.
- The blood may arise from either rupture of the vasa vasorum causing bleeding within the media or small intimal tears that are not visualized on standard imaging exams
- IMH is diagnosed CT, MRI, and echocardiography by the presence of a circular or crescent-shaped thickening of the aortic wall of >5 mm in the absence of detectable blood flow

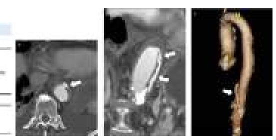
Acute Intramural Hematoma



Intramural Hematoma

- Of patients presenting with suspected AAS, studies suggest that 5% to 25% have IMH, a proportion that approaches 30% to 40% in the Asian literature
- The natural history of IMH is variable. Fewer than 10% of IMH cases resolve spontaneously, whereas 16% to 47% progress to aortic dissection if the intimal layer ruptures and creates an entry tear
- IMH occurs more commonly in the descending thoracic aorta (60%) than in the ascending aorta (30%) or aortic arch (10%)
- Classification is the same as is used for acute aortic dissection

High Risk Imaging features of IMH



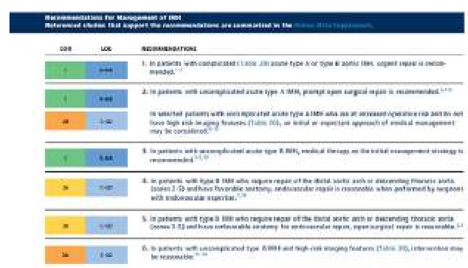
FID is more specifically defined by its communicating orifice measuring >3 mm, while tiny intimal disruption has a communicating orifice < 3 mm.FID occurs in 32% of type B IMH and significantly predicts cardiovascular- or aorta-related death and aorta-related events, especially when it develops in the acute, rather than chronic, phase. Tiny intimal disruptions are lower risk and considered a benign finding.

Type B aortic intramural hematoma and ulcer-like projection

Clinical Features of Complicated IMH

- Malperfusion
- Periaortic hematoma
- Pericardial effusion
- Persistent, refractory or recurrent pain
- Rupture

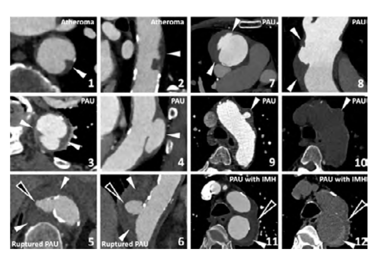
Management of IMH



Penetrating Atherosclerotic Ulcer (PAU)

- A PAU is an atherosclerotic lesion of the aorta with ulceration that penetrates the internal elastic lamina and allows hematoma formation within the media of the aortic wall.
- PAUs may progress to AAS with IMH formation, aortic dissection, or rupture
- PAU with IMH is associated with a high risk of short-term disease progression, particularly when localized to the ascending aorta (i.e., Stanford type A).
- Data on outcomes for PAU with descending thoracic and abdominal aorta (ie, Stanford type B) IMH are limited to small retrospective reviews but suggest significant early disease progression among patients treated with medical management

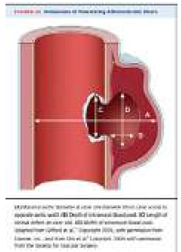
CT Spectrum of PAUs



High- Risk Imaging Features and measurements of PAU

TABLE 31 High-Risk Imaging Features of PAUs

Feature
■ Maximum PAU diameter ≥13-20 mm[1]
■ Maximum PAU depth ≥10 mm[1]
■ Significant growth of PAU diameter or depth
■ PAU associated with a saccular aneurysm[5]
■ PAU with an increasing pleural effusion[1]



Management of PAU- With IMH, Rupture or both

Recommendations for PAU With IMH, Rupture, or Both
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	RECOMMENDATIONS
I	B-NR	1. In patients with PAU of the aorta with rupture, urgent repair is recommended.[1-3]
I	B-NR	2. In patients with PAU of the ascending aorta with associated IMH, urgent repair is recommended.[1-3]
2a	C-LD	3. In patients with PAU of the aortic arch or descending thoracic aorta with associated IMH, urgent repair is reasonable.[1-3]
2b	C-LD	4. In patients with PAU of the abdominal aorta with associated IMH, urgent repair may be considered.[4]

Management of Isolated PAUs

Recommendations for Isolated PAU
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	RECOMMENDATIONS
I	B-NR	1. In patients with isolated PAU who are symptomatic and have persistent pain that is clinically correlated with the radiologic findings, repair is recommended.[1,2]
2b	C-LD	2. In patients with isolated PAU who are asymptomatic but have high-risk imaging features (Table 31), elective repair may be considered.[1,3,4]

- Isolated PAUs are those without associated IMH, aortic dissection, or saccular aneurysm

Repair of PAUs- Open Surgical vs Endovascular

Recommendations for PAU Open Surgical Repair Versus Endovascular Repair

COR	LOE	RECOMMENDATIONS
I	C-LD	1. In patients who require repair of a PAU in the ascending aorta or proximal aortic arch (zones 0-1), open surgical repair is recommended.
2a	C-LD	2. In patients who require repair of a PAU in the distal aortic arch (zones 2-3), descending thoracic aorta, or abdominal aorta, either open surgical repair[1-3] or endovascular repair is reasonable, based on anatomy and medical comorbidities.[4-6]

Acute Aortic syndrome (AAS)

AAS are life-threatening conditions in which there is a breach in the integrity of the aortic wall

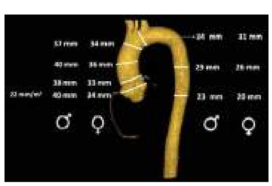
- Aortic dissection
- Penetrating atherosclerotic ulcer
- Acute Intramural hematoma (IMH)

Non acute Thoracic Aortic disease

- Aneurysms
- Vasculitis
- Congenital

Definitions of Dilation and Aneurysm of the Aortic Root and Ascending Thoracic Aorta

- The conventional definition of an arterial aneurysm is any artery that is dilated to at least 1.5 times its expected normal diameter
- This definition applies well to the abdominal and descending thoracic aorta
- However, it has long been recognized that this definition fails when it comes to defining aneurysms of the aortic root and ascending thoracic aorta



Normal aortic dimensions

Definitions of Dilation and Aneurysm of the Aortic Root and Ascending Thoracic Aorta

- For example, a man in his 40s would be expected to have an average aortic root diameter of 3.5 cm; applying the standard definition of 1.5 times reference diameter, his aortic root would have to reach 5.25 cm before it would be considered an aneurysm
- Increase in risk of dissection at 4.0 cm to 4.4 cm justifies defining an aorta of this size "dilated," and the abrupt increase in risk at a diameter of 4.5 cm justifies defining an aorta of this size as an aneurysm

Definitions of Dilation and Aneurysm of the Aorta

- **Aortic root and ascending Aorta:**
- Dilatation: 4-4.5 cm
- Aneurysm: ≥ 4.5 cm
- **Aortic Arch:**
- Dilatation :3.5-4cm
- Aneurysm:≥ 4cm
- **Descending Thoracic Aorta:**
- Dilatation: 3-3.5cm
- Aneurysm: ≥ 3.5cm
- **Abdominal Aorta:**
- Dilatation: 2.5-3cm
- Aneurysm: ≥ 3cm

Causes of TAA

TABLE 6 Causes of TAA

HTAD (see Table 7): syndromic:
- Marfan syndrome
- Loeys-Dietz syndrome
- Vascular Ehlers-Danlos syndrome
- Smooth muscle dysfunction syndrome
- Others: attributable to pathogenic variants in FLNA, BGN, LOX

HTAD (see Table 7): nonsyndromic:
- ACTA2, MYH11, PRKG1, MYLK, and others
- Familial thoracic aortic aneurysm without identified pathogenic variants in a known gene for HTAD

Congenital conditions:
- Bicuspid aortic valve
- Turner syndrome
- Coarctation of the aorta
- Complex congenital heart defects (tetralogy of Fallot, transposition of the great vessels, truncus arteriosus)

Hypertension

Atherosclerosis

Degenerative

Previous aortic dissection

Inflammatory aortitis
- Giant cell arteritis
- Takayasu arteritis
- Behçet disease
- Immunoglobulin G4-related disease, antineutrophil cytoplasmic antibody-related, sarcoidosis

Infectious aortitis
- Bacterial, fungal, syphilitic

Previous traumatic aortic injury

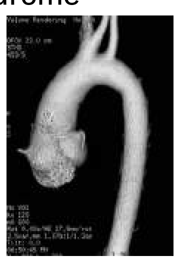
Sporadic Aortic Aneurysms

- Less than 30% of all TAAD cases are genetically triggered, whereas more than 70% are sporadic.
- Genetically triggered TAAD are caused by mutations in genes encoding proteins such as smooth muscle (SM) contractile proteins,[17] extracellular matrix (ECM) proteins, and proteins involved in transforming growth factor beta (TGF-ß) signaling.
- Sporadic TAAD are mainly associated with risk factors such as aging, male sex, smoking, and hypertension

Surgical recommendations for sporadic aneurysms of the aortic root and ascending aorta

≥5-5.5cm

Marfans syndrome



Annular ectasia- effacement of the sinotubular junction

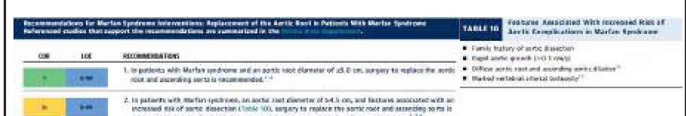
Dilatation/aneurysms of the aorta

Aortic dissection

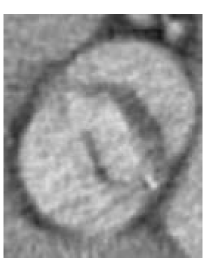
Aortic and mitral valve disease

FBN1 mutations. Autosomal Dominant

Recommendations for surgery in Marfans syndrome



Bicuspid Aortic Valve Disease



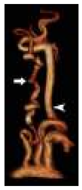
Prevalence of 1-2% . Most common congenital heart disease

Aortic stenosis
Aortic insufficiency
Aortopathy- Aortic dilatation

Recommendations for Bicuspid aortic disease

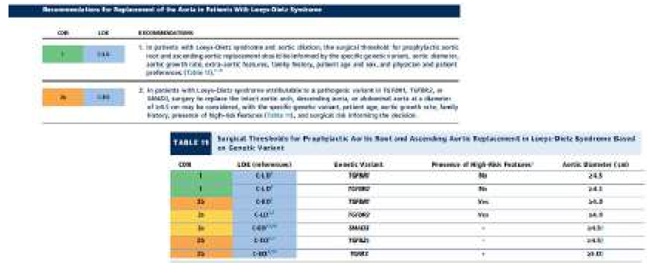
Loeys Dietz syndrome



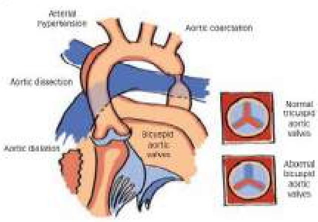


- Loeys-Dietz syndrome is characterized by aortic and branch vessel aneurysms and dissections, arterial tortuosity, and skeletal features similar to those seen in Marfan syndrome but with unique craniofacial and cutaneous features
- Pathogenic variants in 5 genes cause Loeys- Dietz syndrome, also termed transforming growth factor vasculopathies

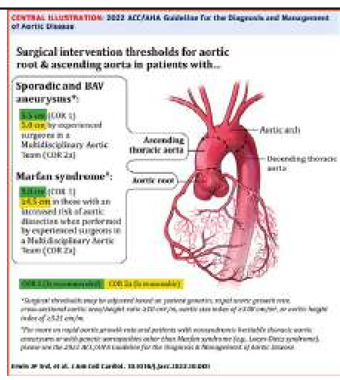
Recommendations for Replacement of the Aorta in Loeys-Dietz Syndrome



Turners syndrome

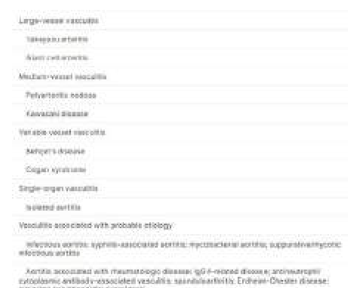


Recommendations for Aortic disease in Turners syndrome



Vasculitis

Systemic vasculitides are multisystem blood vessel disorders, which are defined by the size of the vessel predominantly affected, namely small, medium, or large vessels. The term "large vessel" relates to the aorta and its major branches; "medium vessel" refers to the main visceral arteries and veins and their initial branches.



Jennette JC, Falk RJ, Bacon PA, Basu N, Cid MC, Ferrario F, Flores-Suarez LF, Gross WL, Guillevin L, Hagen EC, et al. 2012 revised International Chapel Hill Consensus Conference nomenclature of vasculitides. *Arthritis Rheum.*2013;65:1-11. doi: 10.1002/art.37715

Large Vessel Vasculitis (LVV)- Giant cell Arteritis (GCA) and Takayasu Arteritis (TA)

Imaging manifestations on CT and MRI

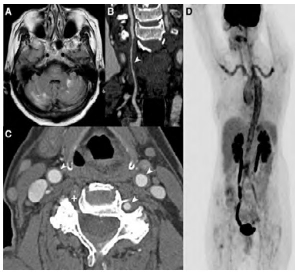
- Dilatation/Aneurysms
- Arterial stenosis
- Wall thickening
- Vessel wall enhancement

- Large vessel vasculitides (LVV) comprise a group of inflammatory disorders that involve the large arteries, such as the aorta and its primary branches.
- Giant cell arteritis is the most common form of LVV affecting people >50 years of age with a slight female predominance. Takayasu arteritis is more frequently seen in younger populations and is significantly more common in women

Imaging of Vasculitis

- Given the challenges of large-vessel tissue biopsy, imaging plays a crucial role in the diagnosis and management of LVV
- CTA has high spatial resolution and can assess large-vessel wall abnormalities . It is widely available and can assess the entire aorta and its main branches with a single acquisition
- Compared with CTA, MRA has higher tissue contrast resolution but lower spatial resolution. Non-ionizing. Well suited for follow up
- FDG PET CT to assess for inflammation and disease activity

Giant Cell Arteritis (GCA)



- In the US population, GCA is the most frequent primary vasculitis
- Classically affects the extracranial branches of the carotid artery
- The major risk of large-vessel involvement in GCA is the development of aorta aneurysm or dissection, which can affect up to 30% of patients. Predilection for the thoracic aorta and subclavian and axillary arteries

Stenosis of the right vertebral artery. Thickening of both carotid and left vertebral arteries. FDG uptake in the carotid, subclavian arteries, entire aorta.

Takayasu Arteritis (TA)

Occluded LSCA and retrograde flow in the vertebral in a 37 F with TA

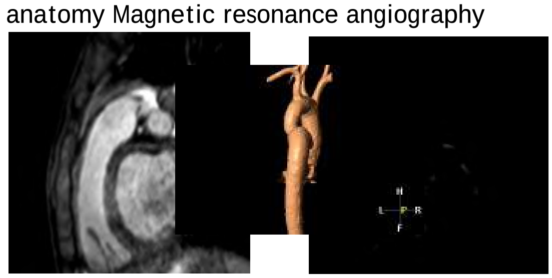
- LVV with female predominance, though it affects younger patients (< 40 years old)
- It is the most common cause of aortitis in young patients and can extend to the main aortic branches
- TA can also involve the pulmonary arteries
- Compared with GCA, TA more frequently involves the symmetric arch vessels, the abdominal aorta and its branches (renal and mesenteric arteries), and the coronary arteries.
- Isolated left subclavian artery involvement is also more common in TA
- Another critical difference between the two is a higher degree of luminal stenosis in TA

Congenital Aortic Disease

- Bicuspid Aortic Valve
- Coarctation of the Aorta (CoA)
- Vascular rings
- Aortic involvement in Conotruncal anomalies

- MR test of choice for follow up of ACHD
- Non-ionizing. Comprehensive evaluation of cardiovascular anatomy, morphology and function.

CoA: 3D evaluation of extracardiac vascular anatomy Magnetic resonance angiography

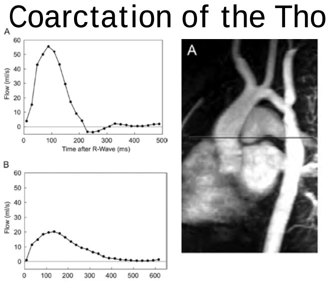


Non contrast MRA: 3D gated SSFP

Gadolinium enhanced MRA. Time resolved

83

Coarctation of the Thoracic Aorta (CoA)



In patients with CoA, the combination of narrowest aortic cross-sectional area and heart rate-corrected mean flow deceleration in the descending aorta obtained by MRI provides a sensitive and specific test for predicting a catheterization gradient ≥20 mm Hg.

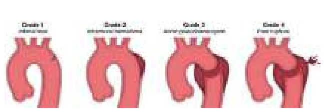
Nielsen JC, et al. Magnetic resonance imaging predictors of coarctation severity. Circulation. 2005 Feb 8;111(5):622-8.

- Residual arch narrowing and gradients. Peak-to-peak coarctation gradient of ≥20 mm Hg considered significant
- Post surgical complications such as pseudoaneurysm at the repair site
- Morphology of the aortic valve and function
- Dimensions of the entire thoracic aorta
- Ventricular size and function

Other Indications for Aortic Imaging

- Traumatic Aortic Injury
- Post operative Aorta
- Structural heart disease- Aortic Stenosis

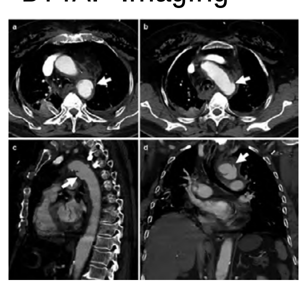
Blunt Traumatic Aortic Aortic Injury (BTTAI)



Classification system for BTTAIs. Society of Vascular Surgery

- BTTAI, although rare, is the second-most common cause of death in trauma patients; it results from high deceleration forces and is often associated with concomitant injuries
- The most common site of BTTAI is the aortic isthmus, because of its site as transition from the unfixed aortic arch to the fixed descending thoracic aorta and the relatively lesser tensile strength of this region.
- Other segments that may be involved include the proximal ascending aorta (8%–27%), aortic arch (8%–18%), and distal descending thoracic aorta (11%–21%)

BTTAI- Imaging



Aortic pseudoaneurysm in a 58 M involved in a MVA

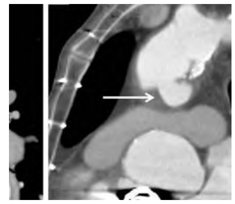
- CTA is the preferred imaging modality: Accuracy, speed and evaluation of other traumatic injuries
- A CTA scan can help identify the following signs of a TAI:

-Pseudoaneurysm formation
-Intimal flap
-Luminal filling defects
-Periaortic hematoma formation
-Abnormal aortic contour
-Extravasation of contras

Post operative imaging of the Thoracic Aorta

- Follow up of thoracic aortic disease (acute or non acute) treated by open or endovascular repair can be performed by CT or MRI
- CT higher spatial resolution, rapid, widely available vs MRI lower spatial resolution, less accessible though without ionizing radiation
- Precise follow up intervals dependent on pathology and treatment, however as a general rule CT/MR at discharge then 1 month, 6 months, 12 months and annual there after

Post operative aortic imaging

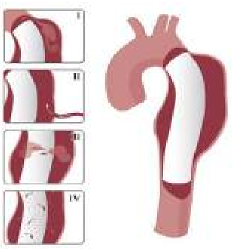


Pseudoaneurysm after ascending aortic graft repair

- Follow up after Acute aortic syndromes e.g. residual dissection
- Post op aneurysm repair complications e.g.

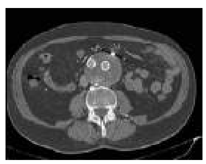
- pseudoaneurysms at repair site
- Infection, hematoma
- Disease in the unoperated aortic segments

Endoleaks- Persistent blood flow within the aneurysm sac following endovascular aneurysm repair (EVAR)



Drawings illustrate the various types of endoleak: type I, leak at the attachment site; type II, leak from a branch artery; type III, graft defect; and type IV, graft porosity.

3 phase CTA key technique



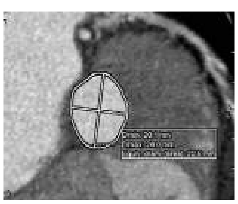
Imaging of the Aorta for Structural Heart disease interventions

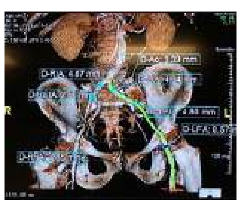
- Transcatheter Aortic Valve Implantation (TAVI)

-FDA approved for patients with severe AS across all risk categories

-Transfemoral arterial access commonest route of implantation

CT Pre TAVR

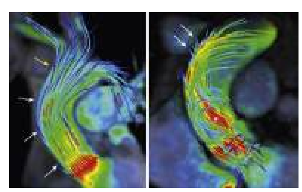




CT of the entire Aorta essential for pre-operative planning

- Annulus size
- Coronary height
- Sinus widths
- Iliofemoral access measurements

Emerging applications and new Frontiers



4D flow MRA in a patient with a normal 3-cusp aortic valve and another with a bicuspid aortic valve

4D Flow MRA

Flow derangements visualized and quantified

Novel measurements like wall shear stress can be measured

SELF EVALUATION

Imaging of the Thoracic Aorta

1. Which of the following imaging modalities is the test of choice for evaluation of a suspected Acute Aortic Syndrome?

a. ECG gated CT of the Thoracic Aorta
b. MRI of the Thoracic Aorta
c. Transthoracic Echocardiography
d. Transesophageal Echocardiography
e. Catheter Angiography

2. Which of the following findings pertaining to the false lumen in a type B dissection has a better long term prognosis?

a. A diameter > 22mm and patent
b. A patent partially thrombosed false lumen
c. A completely patent false lumen
d. Enlarging false lumen on serial studies
e. A completely thrombosed false lumen

3. Which of the following signs are NOT characteristic of a false lumen in an acute aortic dissection?

a. Size larger than the true lumen
b. Size smaller than the true lumen
c. Beak sign
d. Cobweb sign
e. Hypodense appearance on early phase imaging

4. Which of the following are NOT a high risk imaging feature of an Intramural Hematoma of the Thoracic Aorta

a. Hematoma thickness > 15mm
b. A dilated aorta > 45-50mm
c. Pericardial or Pleural effusions
d. Intimal disruption that is focal and has a communicating orifice > 3mm with the lumen at the site of the hematoma
e. Intimal disruption that is focal and has a communicating orifice < 3mm with the lumen at the site of the hematoma

5. Which of the following maximum measurements would be indicative of an aneurysm of the aortic root or ascending aorta as opposed to dilatation?

a. 3.5cm
b. 4cm
c. 4.5cm
d. 5cm
e. 5.5cm

6. Which of the following imaging modalities is the preferred test of choice to evaluate the extent and severity of inflammation in suspected aortic vasculitis?

a. Non contrast CT
b. ECG gated contrast enhanced CT
c. T2 weighted MRI
d. Late gadolinium enhancement MRI
e. FDG PET

7. At which of the following size thresholds is repair of an asymptomatic sporadic ascending aneurysm recommended if performed by experienced surgeons at a high volume center?

a. ≥ 4cm
b. ≥ 4.5cm
c. ≥ 5cm
d. ≥ 5.5cm
e. ≥ 6cm

8. Access for Transaortic valve implantation (TAVI) is most commonly obtained by which of the following routes?

a. Transfemoral
b. Subclavian
c. Carotid
d. IVC
e. Transapical

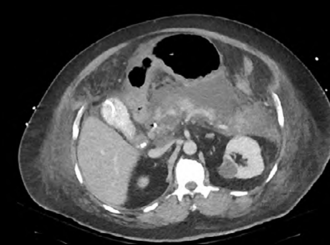
Answer Key: 1. A, 2. E, 3. B, 4. E, 5. C, 6. E, 7. C, 8. A

Pancreas MRI
Robert M. Marks, MD

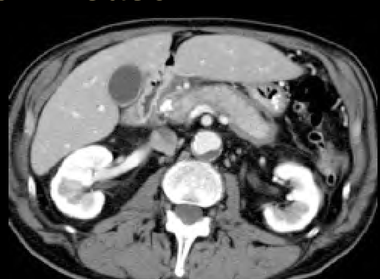
Disclosures

- Consultant: Guerbet LLC
- Co-Owner: Tailored Lactation
- Compensation for lectures CME Science

Unknown Case 1



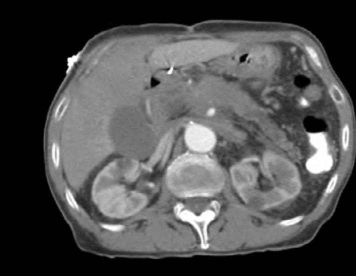
Unknown Case 2



Unknown Case 3

Unknown Case 4

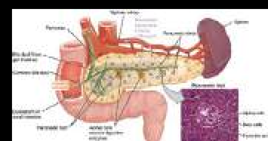
Unknown Case 5



Overview

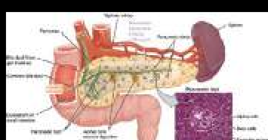
- Pancreas
  - Anatomy/Variants
  - Pancreatitis
  - Cystic Lesions
  - Solid Lesions

What does the pancreas do?

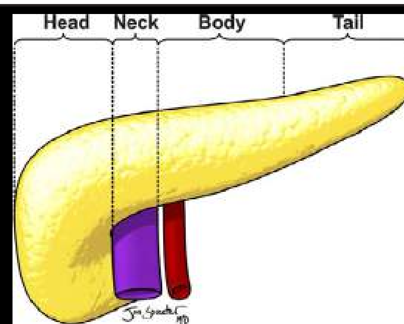


- Endocrine gland
  - Pancreatic islet cells secrete hormones in the blood stream
    - Glucagon, insulin, somatostatin, and pancreatic polypeptide

What does the pancreas do?



- Exocrine gland
  - Acinar cells secrete digestive enzymes
    - Lipase
    - Amylase
    - Proteases

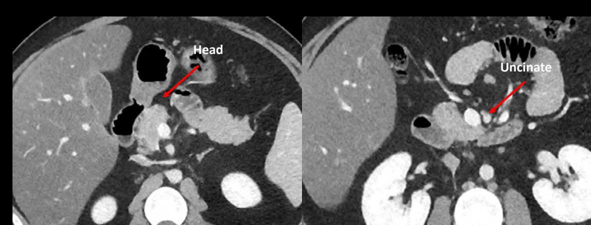


Mortelé K J et al. Radiographics 2006;26:715-731

RadioGraphics

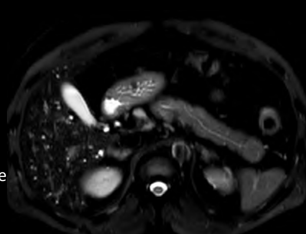
Normal Anatomy

Normal Anatomy



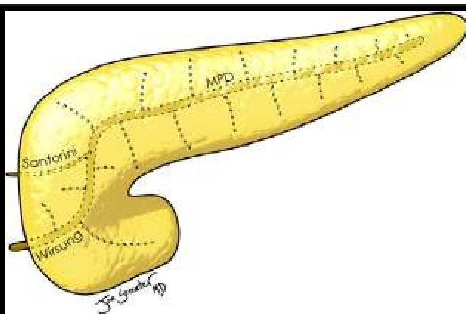
Normal Anatomy

- MRI
  - Bright on T2W imaging
    - Brighter than muscle
  - Pancreatic duct should be smooth
    - Should not see side branche



Pancreatic Anatomy

- Retroperitoneal in anterior pararenal compartment
- Varies in size
  - Does not have a capsule, so it can be infiltrated with fat
- Pancreatic Duct size: 3-4 mm
  - 3 ducts
  - Duct of Santorini (Dorsal Duct)- drains body and tail
  - Duct of Wirsung (Ventral Duct)- drains head and uncinate process
  - Main Pancreatic Duct (formed by fusion of duct of Santorini and Wirsung)
  - Variant ductal anatomy is common



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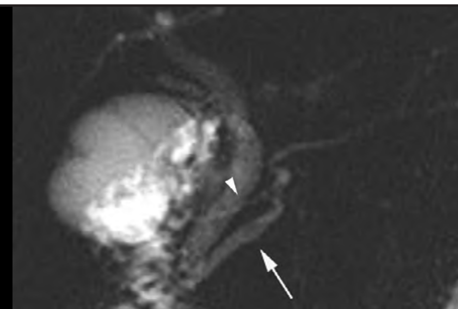

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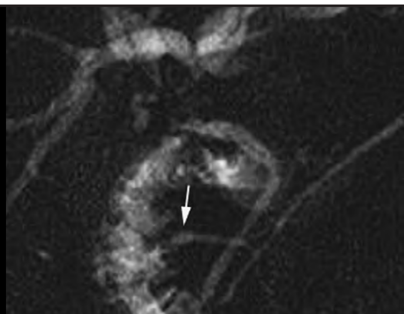

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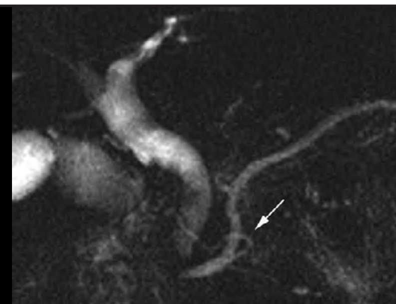

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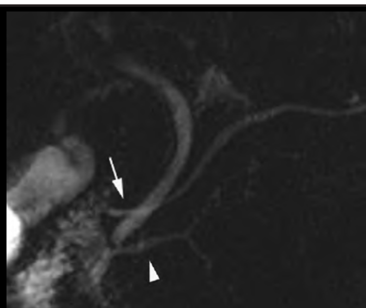


Mortelé K J et al. Radiographics 2006;26:715-731 RadioGraphics

Pancreatitis

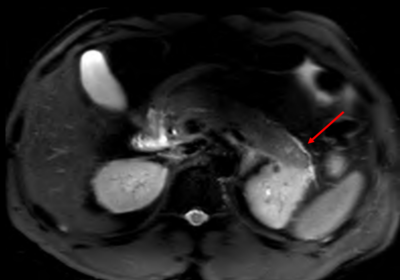
- Imaging is to determine severity, prognosis, and complications.
- Causes
  - Choledocholithiasis
  - Alcohol
  - Hyperlipidemia
  - Hypercalcemia
  - Trauma/ERCP
  - Meds
  - Scorpion Bite

Pancreatitis

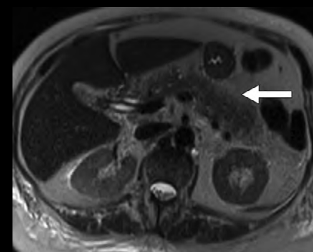
- Morbidity associated with pancreatic necrosis
- Interstitial Edematous Pancreatitis (IEP)
  - Self limiting
  - Low mortality <1%
- Necrotizing Pancreatitis
  - More severe
  - 20% of cases
  - Morbidity/Mortality between 10% - 23%

Interstitial Edematous Pancreatitis

Interstitial Edematous Pancreatitis



Interstitial Edematous Pancreatitis



O'Connor, et al. American Journal of Roentgenology. 2011;197: W221-W225. 10.2214/AJR.10.4338

AJR

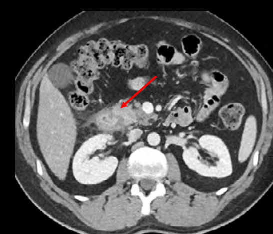
Interstitial Edematous Pancreatitis

Miller F H et al. AJR 2004;183:1637-1644

AJR

Interstitial Edematous Pancreatitis

- Groove Pancreatitis
  - Pancreatitis with inflammation in the groove between the:
    - Pancreatic Head
    - Duodenum
    - Common Bile Duct
    - Rare



Revised Atlanta Classification

Collection	Time after Onset of Pain (wk)	Pancreatitis Subcategory	Location	Imaging Features
APFC	≤4	IEP	Extrapancreatic	Homogeneous, fluid attenuation, conforms to retroperitoneal structures, no wall
ANC	≤4	Necrotizing pancreatitis	Intra- and/or extrapancreatic	Inhomogeneous*, nonliquefied components†, no wall
Pseudocyst	>4	IEP	Extrapancreatic‡	Homogeneous, fluid filled, circumscribed, encapsulated with wall
WON	>4	Necrotizing pancreatitis	Intra- and/or extrapancreatic	Inhomogeneous, nonliquefied components, encapsulated with wall

Revised Atlanta Classification for Acute Pancreatitis: A Pictorial Essay
Bryan R. Foster, Kyle K. Jensen, Gene Bakis, Akram M. Shaaban, and Fergus V. Coakley
RadioGraphics 2016 36:3, 675-687

Acute Peripancreatic Fluid Collection

- Occur in the first 4 weeks
- No capsule
- Normal enhancement of pancreas (IEP)

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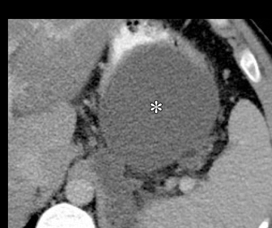

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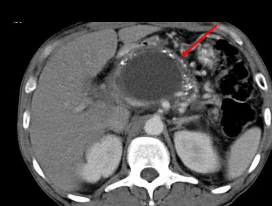
RadioGraphics

Pseudocyst

- Occur after 4 weeks in IEP
- Extrapancreatic
- Have a wall
- Homogeneous fluid



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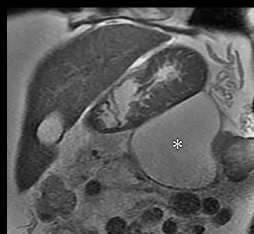

Revised Atlanta Classification for Acute Pancreatitis: A Pictorial Essay
Bryan R. Foster, Kyle K. Jensen, Gene Bakis, Akram M. Shaaban, and Fergus V. Coakley2016 36:3, 675-687

RadioGraphics

Revised Atlanta Classification

Collection	Time after Onset of Pain (wk)	Pancreatitis Subcategory	Location	Imaging Features
APFC	≤4	IEP	Extrapancreatic	Homogeneous, fluid attenuation, conforms to retroperitoneal structures, no wall
ANC	≤4	Necrotizing pancreatitis	Intra- and/or extrapancreatic	Inhomogeneous*, nonliquefied components†, no wall
Pseudocyst	>4	IEP	Extrapancreatic‡	Homogeneous, fluid filled, circumscribed, encapsulated with wall
WON	>4	Necrotizing pancreatitis	Intra- and/or extrapancreatic	Inhomogeneous, nonliquefied components, encapsulated with wall

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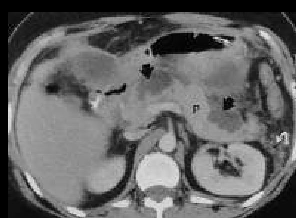
RadioGraphics 2016 36:3, 675-687

Acute Necrotic Collection

- Three patterns of necrosis
  - Parenchymal Necrosis



Balthazar E J Radiology 2002;223:603-613

Radiology

Acute Necrotic Collection

- Three patterns of necrosis
  - Peripancreatic Necrosis

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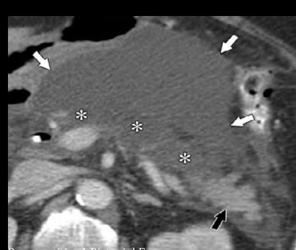
Acute Necrotic Collection

- Three patterns of necrosis
  - combined type (peripancreatic and parenchymal necrosis): most common



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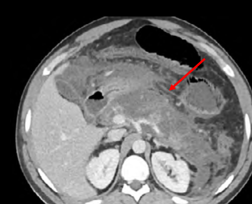
Walled Off Necrosis

- Occur after 4 weeks in Necrotizing Pancreatitis
- Can be intra or extrapancreatic
- Have a wall
- Heterogenous non-liquified material



Walled Off Necrosis

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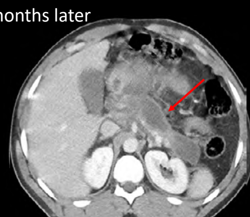
- 3 months later



Walled Off Necrosis

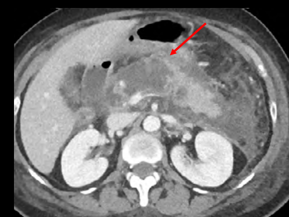
- Occur after 4 weeks in Necrotizing Pancreatitis
- Can be intra or extrapancreatic
- Have a wall
- Heterogenous non-liquified material

Evolution of Necrotizing Pancreatitis

- Initial CT 2 days after onset of symptoms
- Choledocholithiasis

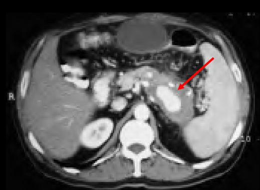
Evolution of Necrotizing Pancreatitis

- Follow-up CT 3 days later
- Worsening pain

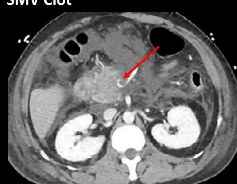


Look for complications

Splenic Artery Pseudoaneurysm



SMV Clot



Chronic Pancreatitis

- Recurrent bouts of pancreatitis
  - Parenchymal atrophy
  - Progressive fibrosis
- Causes
  - 70% Alcohol
  - 20% Biliary stone disease
  - Autoimmune Pancreatitis
- Appearance
  - Dilatation of pancreatic duct, beaded appearance
  - Atrophy
  - Calcifications

Reporting Standards for Chronic Pancreatitis by Using CT, MRI, and MR Cholangiopancreatography: The Consortium for the Study of Chronic Pancreatitis, Diabetes, and Pancreatic Cancer
Temel Tirkes, Zarine K. Shah, Naoki Takahashi, Joseph R. Grajo, Stephanie T. Chang, Sudhakar K. Venkatesh, Darwin L. Conwell, Evan L. Fogel, Walter Park, Mark Topazian, Dhiraj Yadav, Anil K. Dasyam, and For the Consortium for the Study of Chronic Pancreatitis, Diabetes, and Pancreatic Cancer
Radiology 2019 290:1, 207-215

Autoimmune Pancreatitis

- Distinct form of pancreatitis
- Spectrum of IgG-4 disease
  - Check labs
- Sausage-like pancreas
  - Rim of enhancement
- Presentation variable
  - Jaundice, weight loss, diabetes
  - Abdominal pain unusual
  - Treated with Steroids
  - Associated with other IgG-4 related pathologies
    - PSC, pseudotumors of kidneys and liver, retroperitoneal fibrosis

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Shanbhogue A K P et al. Radiographics 2009;29:1003-1026

RadioGraphics

Cystic Pancreatic Lesions

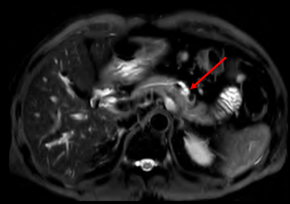
- Intraductal Papillary Mucinous Neoplasm (IPMN)
- Mucinous Cystic Neoplasm
- Serous Cystadenoma
- Von-Hippel Lindau

IPMN

- Mucin producing neoplasm that grows within the main pancreatic duct or one of its side branches
- Mean age 65, 60% occur in men
  - Thus, it is known as the GRANDFATHER lesion…
- Most are incidental findings and do not cause symptoms
  - Especially side branch IPMNS
  - Pain, pruritis, pancreatitis
- Can have elevated CEA and amylase
- Serial imaging to evaluate for malignant change
  - A vast majority, especially small side branch IPMNS are benign

Side Branch IPMN

- Have connection to main duct through a side branch



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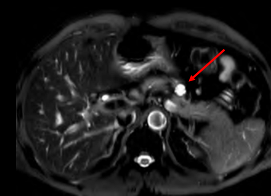


Side Branch IPMN

- Have connection to main duct through a side branch

Kawamoto S et al. Radiographics 2005;25:1451-1468

RadioGraphics

Side Branch IPMN

- Have connection to main duct through a side branch

Sahani D V et al. Radiographics 2005;25:1471-1484

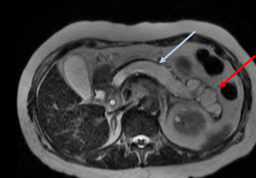
RadioGraphics

IPMN

- When to worry???
  - Rapid growth, >3cm in size
  - Solid Nodules within cyst
  - New onset jaundice
  - All IPMNs have malignant potential
    - Much higher malignant potential in main duct IPMN

Main Duct IPMN

- Diffuse dilatation of pancreatic duct
- May see mucin from major papilla on endoscopy
- Associated with a cystic mass
- Look for solid nodules
- 60% are malignant

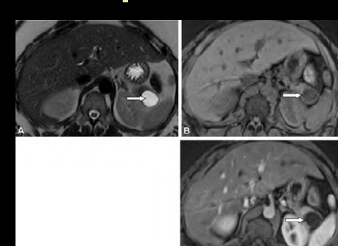


Mucinous Cystic Neoplasm

- Mucin producing neoplasm without ductal involvement*.
- All have malignant potential.
- Female to male 20:1
  - "Mother lesion"
- Non-specific symptoms
  - Abdominal pain
  - Fullness
  - Nausea
- Cyst fluid has elevated CEA, normal amylase

Mucinous Cystic Neoplasm

- Multilocular thick-walled cysts, typically round or ovoid
- <6 cysts....>2cm each
- Ovarian stroma
- Features of carcinoma
  - Enhancing wall, septa, and mural nodules
  - Calcifications in wall or septa 10%



Pancreatic Cystic Lesions and Malignancy: Assessment, Guidelines, and the Field Defect
Frank H. Miller, Camila Lopes Vendrami, Hannah S. Recht, Cecil G. Wood, Pardeep Mittal, Rajesh N. Keswani, Helena Gabriel, Amir A. Borhani, Paul Nikolaidis, and Nancy A. Hammond
RadioGraphics 2022 42:1, 87-105

RadioGraphics

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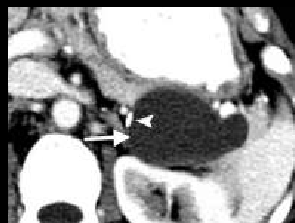

Sahani D V et al. Radiographics 2005;25:1471-1484 RadioGraphics

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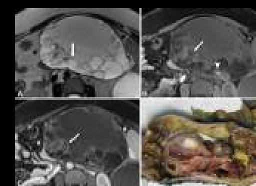

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RadioGraphics 2022 42:1, 87-105
RadioGraphics

Serous Cystadenoma

- Benign lesion of glycogen rich cells
- Mean age 65, 70% occur in women
  - Thus..."Grandmother lesion"
- Non-specific symptoms when large
- Cyst fluid: normal CEA, elevated pancreatic and salivary enzymes
- Innumerable cysts <1-2cm
  - Honeycomb appearance

Serous Cystadenoma

- Honeycomb or sponge appearance
  - Bright T2 foci on MRI
- Lobulated margins
- Central scar 30%, with or without Calcs
- Early and late enhancement of fibrous portion

Choi J et al. AJR 2009;193:136-142 AJR

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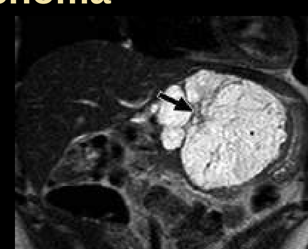
Serous Cystadenoma

- Honeycomb or sponge appearance
  - Bright T2 foci on MRI
- Lobulated margins
- Central scar 30%, with or without Calcs
- Early and late enhancement of fibrous portion
- Can look like a hypervascular mass when small



Choi J et al. AJR 2009;193:136-142 AJR

Serous Cystadenoma

- Oligocystic Variant
  - Unilocular or larger fewer cysts >1 cm
  - Lobulated margins
  - Lack of wall enhancement
  - Look like mucinous cystic neoplasms

Choi J et al. AJR 2009;193:136-142 AJR

Von Hippel Lindau

- Autosomal dominant
- Pancreas with multiple cysts with histology identical to microcystic cystadenocarcinoma
- Diffuse cystic replacement of pancreas can occur

Choi J et al. AJR 2009;193:136-142 AJR

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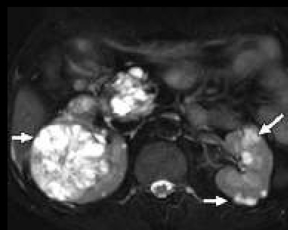


Choi J et al. AJR 2009;193:136-142

Solid Pancreatic Lesions

- Adenocarcinoma
- Solid Pseudopapillary Neoplasm (SPN)
- Endocrine Neoplasms - Islet Cell Tumors
- Metastatic Disease
- Pancreatic Lymphoma

Pancreatic Adenocarcinoma

- 85-90% of pancreatic neoplasms
- Second most common GI tract malignancy
- 4th most common cause of cancer death
- Risk factors include smoking, genetics (BRCA 2, Peutz-Jeghers, VHL)
- Abdominal pain, weight loss, jaundice

Pancreatic Adenocarcinoma

- 60-70% pancreatic head, 5-15% body, 5-15% tail, 5-15% diffuse
- 80% cause upstream atrophy from obstruction
- Poorly defined margins, most extend beyond gland
- CT- poorly defined hypo-enhancing mass

Pancreatic Adenocarcinoma

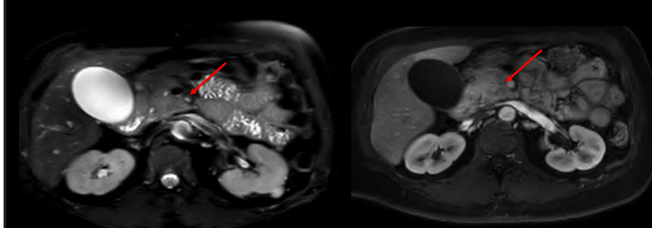
- Secondary signs
  - Pancreatic duct obstruction
  - Common bile duct obstruction
    - "Double Duct Sign"
  - Contour deformity or focal enlargement
  - Pancreatic atrophy

Pancreatic Adenocarcinoma: Unresectable

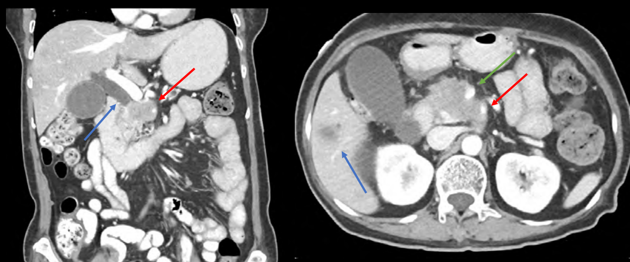
- SMV or portal thrombosis or long segment occlusion
- Vascular encasement >180 degrees of the SMA or celiac axis
- Systemic metastatic disease (i.e. liver, peritoneum)

Pancreatic Adenocarcinoma

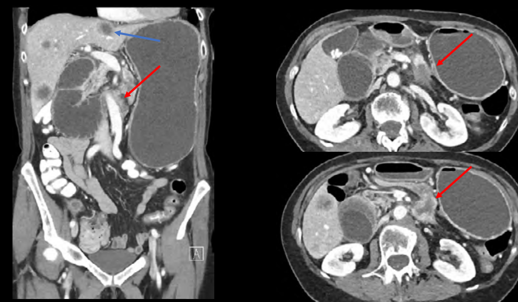
Pancreatic Adenocarcinoma



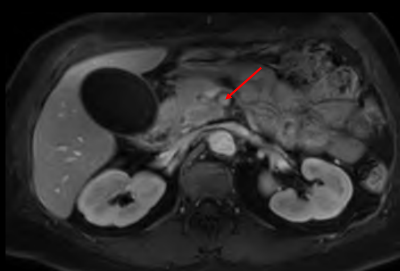
Pancreatic Adenocarcinoma



Pancreatic Adenocarcinoma



Pancreatic Adenocarcinoma



Pancreatic Adenocarcinoma (replaced right hepatic artery)

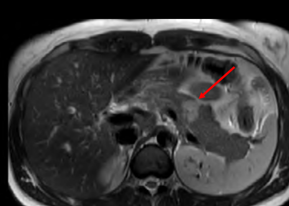
Pancreatic Adenocarcinoma

Solid-Pseudopapillary Neoplasm

- 1-6% of pancreatic neoplasms
- All have malignant potential
- Mean age 25-28, 90-95% female
    - Thus....Daughter lesion
- Non-specific symptoms
    - 33% incidental
- Can rupture to cause hemoperitoneum

Solid-Pseudopapillary Neoplasm

- Well circumscribed mass
    - Thick capsule
    - Calcs
- Central cavities with hemorrhage and necrosis



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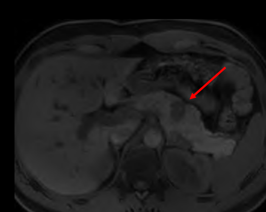

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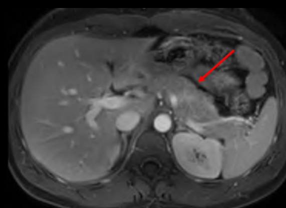

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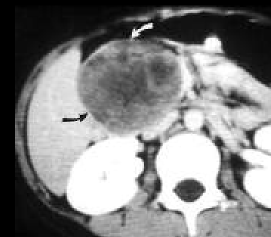

Kim Y H et al. Radiographics 2005;25:671-685 RadioGraphics

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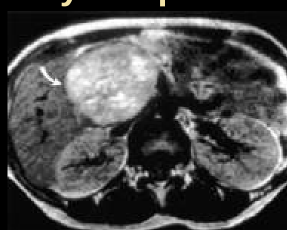

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Pancreatic Neuroendocrine Tumors

- Neoplasms of islet cells that secrete hormones
- 1-2% of pancreatic neoplasms
- Can occur at any age
- No gender predilection
- Associated with:
  - Von Hippel-Lindau 5-10%
  - Multiple Hereditary Neoplasia Type 1 40% (major cause of mortality)

Pancreatic Neuroendocrine Tumors

- Classifications
  - Endocrine microadenoma <5mm, nonfunctional
  - Well-differentiated Neoplasm
    - Non-functional/Non-syndromic 50%
    - Functional/Syndromic: insulinoma, gastrinoma, glucagonoma, VIPoma, etc. 40-50%
  - Poorly differentiated endocrine carcinoma 2-3%

Pancreatic Neuroendocrine Tumors

- Insulinoma most common functional neoplasm
  - Whipple triad: fasting hypoglycemia, symptoms of hypoglycemia, symptoms relieved by administration of glucose

Horton K M et al. Radiographics 2006;26:453-464 RadioGraphics

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Horton K M et al. Radiographics 2006;26:453-464

RadioGraphics

Pancreatic Neuroendocrine Tumors

- Gastrinoma most common neoplasm in MEN 1
  - 60-70% malignant, liver mets 30%
  - Zollinger Ellison Syndrome
  - MEN 1: AD, Pituitary, Pancreas, Parathyroid
  - Gastrinoma triangle: confluence of cystic and CBD superiorly, the second and third portion of the duodenum inferiorly, neck/ body of pancreas medially

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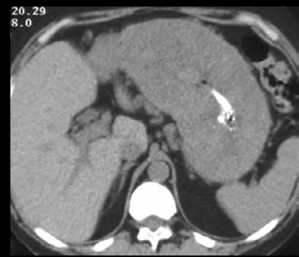


Horton K M et al. Radiographics 2006;26:453-464

RadioGraphics

Pancreatic Neuroendocrine Tumors

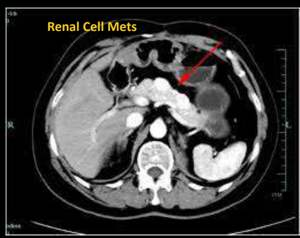
- Glucagonoma 14% of islet cells tumors and the most malignant
  - Liver mets 60% at presentation
- VIPoma secrete vasoactive intestinal polypeptide
  - WHDA syndrome, watery diarrhea, hypokalemia, achlorhydria
  - AKA Verner-Morrisson Syndrome
  - Bigger 4-5 cm, 70% in tail, mets in 60%

Horton K M et al. Radiographics 2006;26:453-464

RadioGraphics

Pancreatic Metastases

- 4-5% of pancreatic masses
- Most common
  - Renal
  - Melanoma
  - Bronchogenic
  - Breast
- Variable appearance
- RCC appears hyperenhancing, looks like islet cell



Chin, W., Cao, L., Liu, X. *et al.* Metastatic renal cell carcinoma to the pancreas and subcutaneous tissue 10 years after radical nephrectomy: a case report. *J Med Case Reports* **14**, 36 (2020). https://doi.org/10.1186/s13256-020-2355-6

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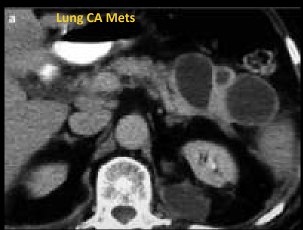

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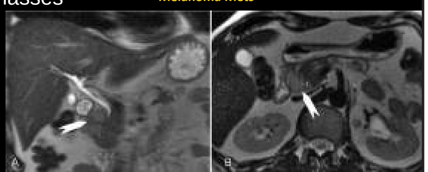
Melanoma Mets



Junker, et al. Magnetic resonance imaging of less common pancreatic malignancies and pancreatic tumors with malignant potential December 2014

•European Journal of Radiology Open 1(1)

Pancreatic Lymphoma

- Secondary significantly more common than primary
- 30% Non-Hodgkin Lymphoma
- Homogeneous, hypodense CT
- Low T1, low to intermediate T2
- Poor enhancement
- Rare pancreatic duct dilation

Leite N P et al. Radiographics 2007;27:1613-1634

RadioGraphics

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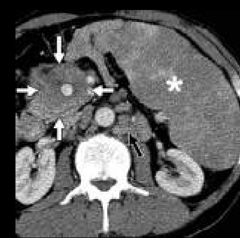


Leite N P et al. Radiographics 2007;27:1613-1634

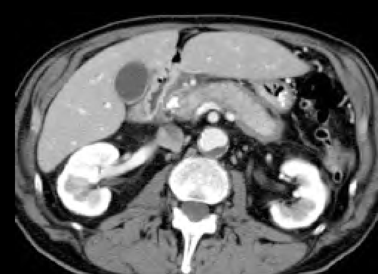
RadioGraphics

Let's review the unknown cases…

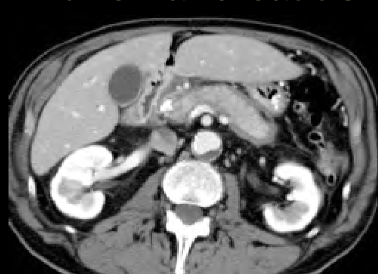
Unknown Case 1

Necrotizing Pancreatitis

Unknown Case 2

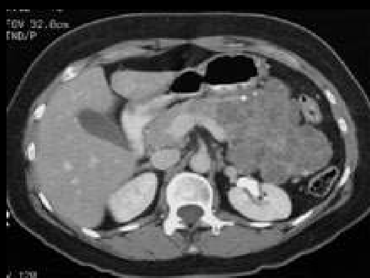


Autoimmune Pancreatitis



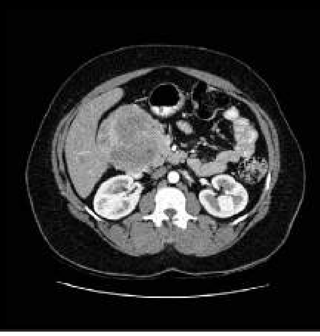
Unknown Case 3

Serous Cystadenoma



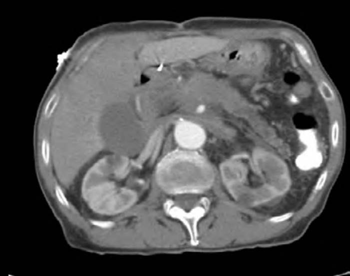
Unknown Case 4

Pancreatic Neuroendocrine Tumor



Unknown Case 5

Pancreatic Adenocarcinoma



SELF EVALUATION

Pancreas MRI

1. According to the Revised Atlanta Classification: Which of the following describes acute per-ipancreatic fluid collections (APFCs)?

a. Occur in patients with interstitial edematous pancreatitis typically within 4 weeks of diag-nosis
b. Occur in patients with necrotizing pancreatitis typically within 4 weeks of diagnosis
c. Occur in patients with interstitial edematous pancreatitis typically after 4 weeks of diagno-sis
d. Occur in patients with necrotizing pancreatitis typically after 4 weeks of diagnosis

2. T/F - Pancreatic necrosis occurs within 24 hours of the onset of symptoms in patients with necrotizing pancreatitis.

3. Which of the following is false about serous cystadenomas of the pancreas

a. They typically occur in women
b. They have a 10% chance of malignant transformation
c. They have a honeycomb appearance
d. They have lobulated margins

4. T/F - The “double duct sign” refers to the imaging findings on MRCP of a Gastrinoma in the Gastrinoma triangle.

5. What is false about solid pseudopapillary neoplasms of the pancreas?

a. The mean age is patients in their 20’s
b. They almost always occur in women
c. They do not have malignant potential
d. They commonly have internal hemorrhage and necrosis

Answer Key: 1. A, 2. F, 3. B, 4. F, 5. C

FACULTY

Lawrence Tanenbaum, MD, FACR

Lawrence N. Tanenbaum, MD, FACR is an active consultant in the imaging space. He is a long-term collaborator with the medical imaging industry and continues to chair advisory boards for imaging OEMs, pharma, and AI concerns. He has interests in developing applications of AI and machine learning, contrast agents, MR, CT and advanced rendering. Dr. Tanenbaum served as Vice President, Chief Technology Officer and Director of Advanced Imaging at Radnet Inc from 2015 -2024. Having come from Icahn School of Medicine at Mount Sinai where he attended in Neuroradiology and served as an Associate Professor of Radiology, Director of MRI, CT and Outpatient / Advanced Imaging Development from 2008-2015. Prior to that he spent over 20 years in the private practice of Radiology at the JFK Medical Center / New Jersey Neuroscience Institute as Director of MRI, CT and Neuroradiology.

Dr. Tanenbaum is passionate about advancing the clinical practice of medicine focusing on patient centric care, efficiency, radiation dose and physiologic imaging. He is an active educator with interests in advanced imaging and innovative value-adding applications in the spine and brain. He has authored over 100 scholarly and peer reviewed articles which have been cited over 2000 times, continues to chair educational and academic meetings and has delivered close to 2000 invited lectures around the world.

Dr. Tanenbaum is a senior member of the American Society of Neuroradiology, and long-term member of the Radiological Society of North America. He is a past President of the Eastern Society of Neuroradiology, and the national Clinical Magnetic Resonance Imaging Society as well as former Editor in Chief of their Journal Vision. Dr. Tanenbaum is a member of the editorial boards of several journals and educational organizations and is Associate Editor and Columnist for Artificial Intelligence of *Applied Radiology*.

You may contact Dr. Tanenbaum with your questions and comments at nuromri@gmail.com.

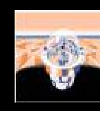
AI and Quantitative Neuroimaging
Lawrence Tanenbaum, MD, FACR

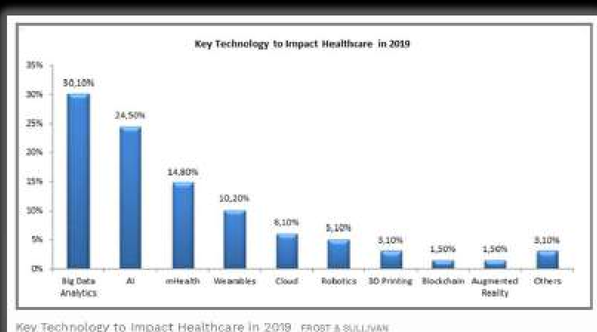
Impact of AI in Neuroimaging

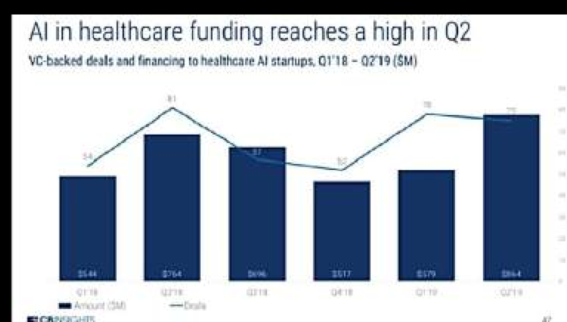
- Intro to AI in Imaging
- Impact on diagnosis and surveillance
  - MS
  - TBI
  - Dementia

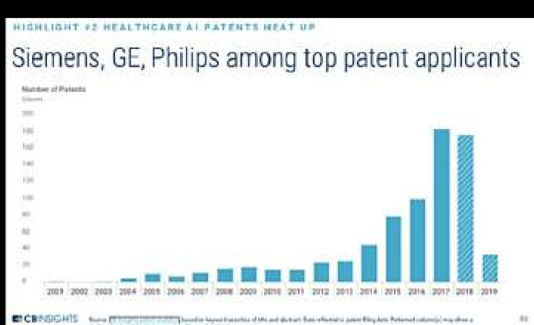
What is AI?

- Branch of computer science devoted to creating systems to perform tasks that ordinarily requires human intelligence
- Broad umbrella term encompassing a wide variety of subfields and techniques



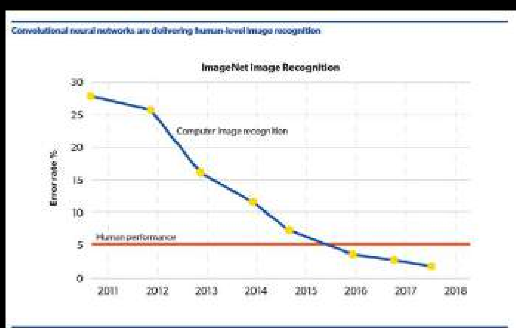


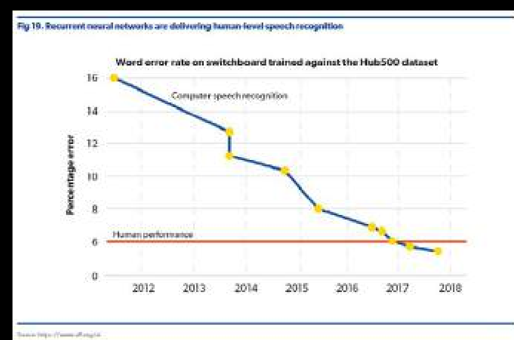




Machine beats champion at Go in 2017

Autonomous driving



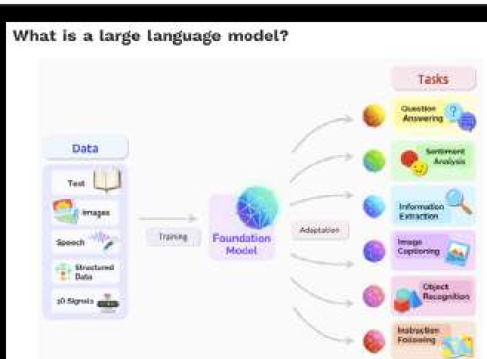


Artificial intelligence
Generative AI

- Foundation models 2017
  - Model trained to be used for downstream tasks.
    - Effective for tasks for which it has not previously been trained.
    - Can be fine-tuned for specific applications, such as detecting lesions or segmenting anatomical structures.

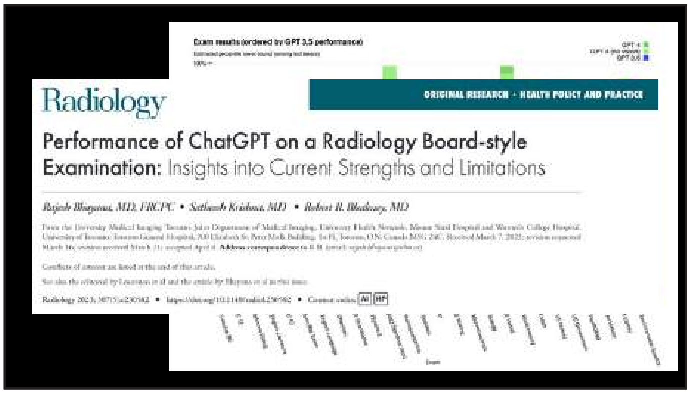
Large language models
2018

- **Foundation models** that utilize DL in natural language processing (NLP) and natural language generation (NLG).
- To learn the complexity and linkages of language, large language models are pre-trained on a vast amount (billions of weights or more) of unlabeled data
- These models have the ability to understand and produce human language and also apply to images and audio

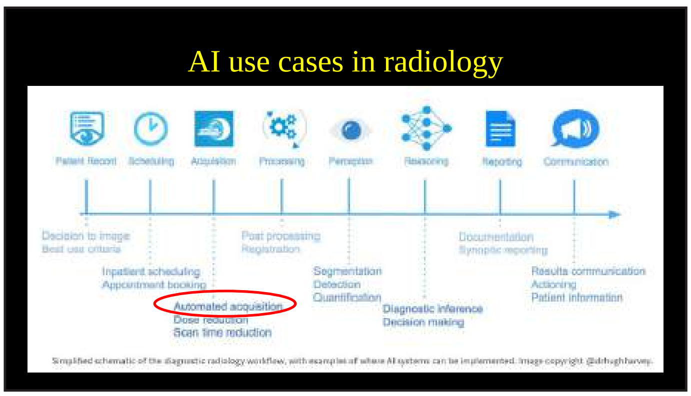


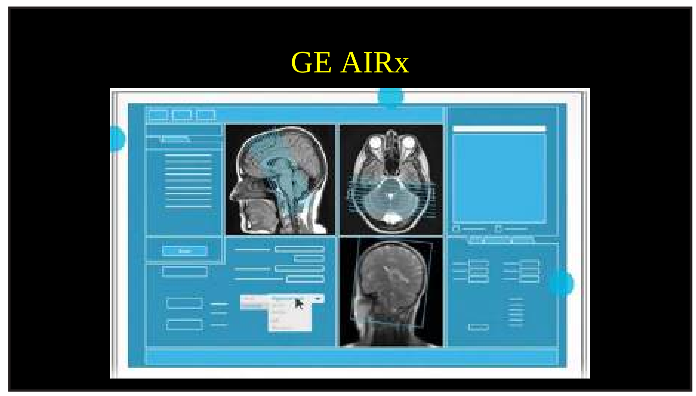
Large language models

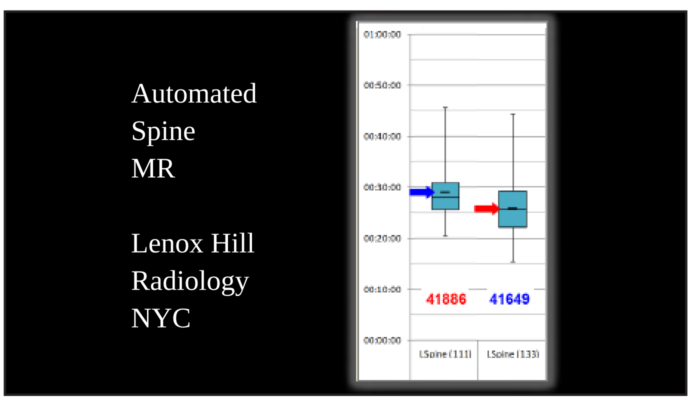
- OpenAI - GPT 4o
  - Bing Chat -with current info available via web search
- Google – Gemini
  - Med PaLM provides high quality answers to medical questions
- Meta – LLaMa
  - Open-source research tool that can be deployed on premises
- Apple – Apple Intelligence
  - On device LLM and Private Cloud Compute


Radiology
ORIGINAL RESEARCH • HEALTH POLICY AND PRACTICE
Performance of ChatGPT on a Radiology Board-style Examination: Insights into Current Strengths and Limitations
Exam results (ordered by GPT 3.5 performance)

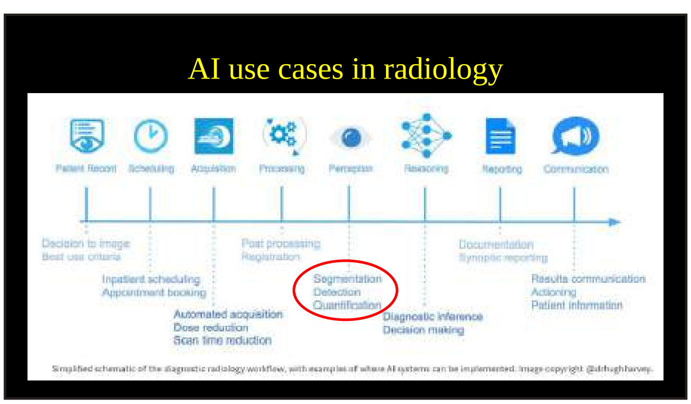

median
QLARITY IMAGING
qure.ai
CuraCloud
enlitic
QMENTA
i2sigma
ai analysis inc.
Blackford
JLK INSPECTION
quibim
zebra
WEKA.IO
terarecon
VAREX
FLYWHEEL
DNP
PHILIPS
VARIAN
imbio
aidence
CAIDE
TOMTEC
aidoc
INCEPTO
Quantib
AIRS
infervision
Rad AI
COGNEX
KHEIRON
vuno
koios
PURESTORAGE
iCAD
DeepRadiology
HEALTHMYNE
MEDICVISION
RADLogics
VIDA
DeepTek
BioMind
onyx
SOPHiA
BALZANO
densitas
Watson
mirada
Fraunhofer
icometrix
Lunit
NUANCE


AI use cases in radiology
Patient Record
Scheduling
Acquisition
Processing
Perception
Reasoning
Reporting
Communication
Decision to image
Best use criteria
Inpatient scheduling
Appointment booking
Automated acquisition
Dose reduction
Scan time reduction
Post processing
Registration
Segmentation
Detection
Quantification
Diagnostic inference
Decision making
Documentation
Synoptic reporting
Results communication
Actioning
Patient information
Simplified schematic of the diagnostic radiology workflow, with examples of where AI systems can be implemented. Image copyright @drhughharvey.


GE AIRx


Automated
Spine
MR
Lenox Hill
Radiology
NYC
01:00:00
00:50:00
00:40:00
00:30:00
00:20:00
00:10:00
00:00:00
41886
41649
LSpine (111)
LSpine (133)


In-line Quality Assurance and Improvement
Pass
Fail
Detection of motion +
SNR issues


AI use cases in radiology
Patient Record
Scheduling
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Processing
Perception
Reasoning
Reporting
Communication
Decision to image
Best use criteria
Inpatient scheduling
Appointment booking
Automated acquisition
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Scan time reduction
Post processing
Registration
Segmentation
Detection
Quantification
Diagnostic inference
Decision making
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Synoptic reporting
Results communication
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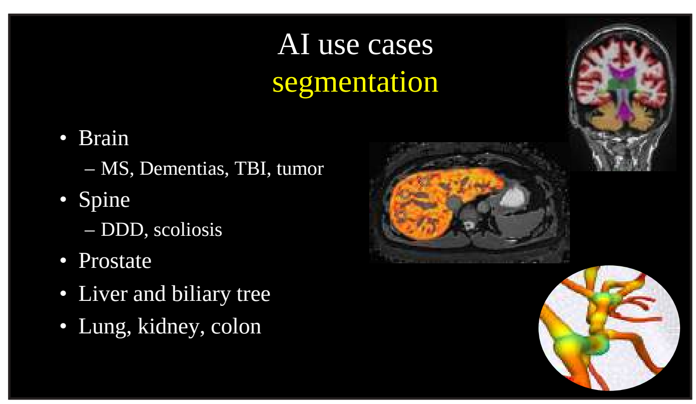
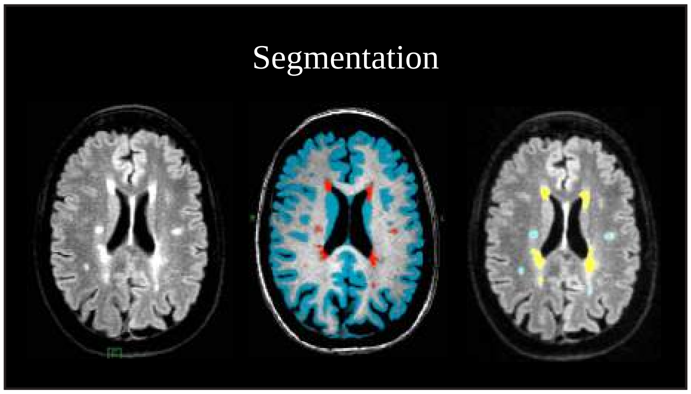
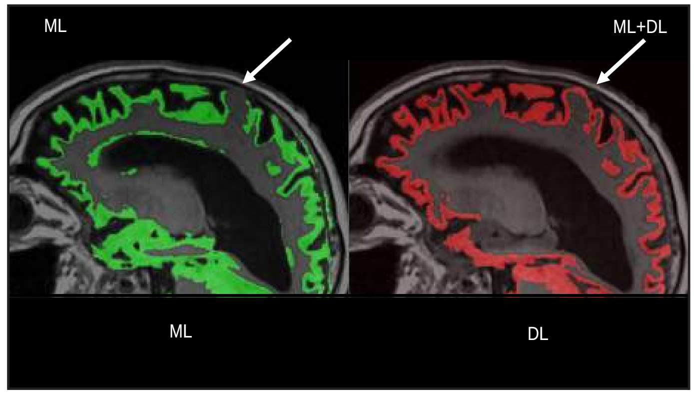
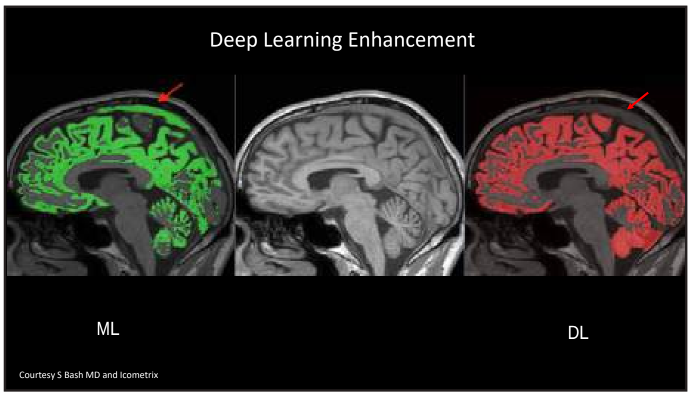
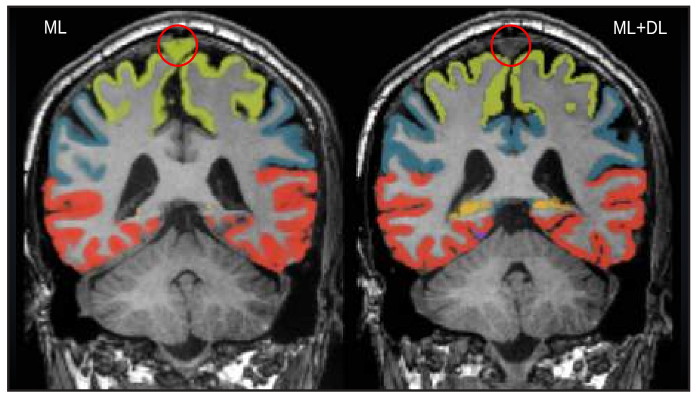
Patient information
Simplified schematic of the diagnostic radiology workflow, with examples of where AI systems can be implemented. Image copyright @drhughharvey.

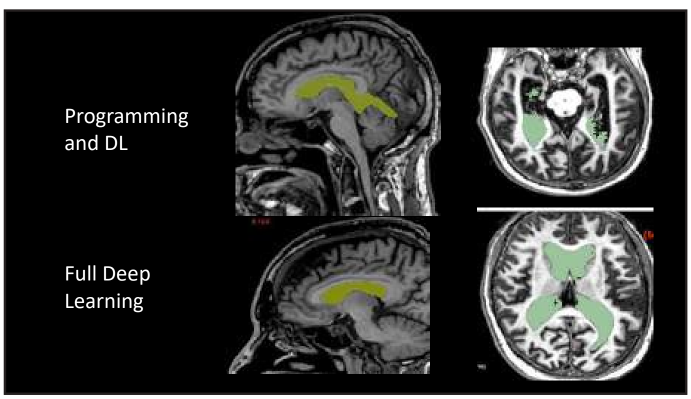

AI use cases
segmentation
• Brain
– MS, Dementias, TBI, tumor
• Spine
– DDD, scoliosis
• Prostate
• Liver and biliary tree
• Lung, kidney, colon

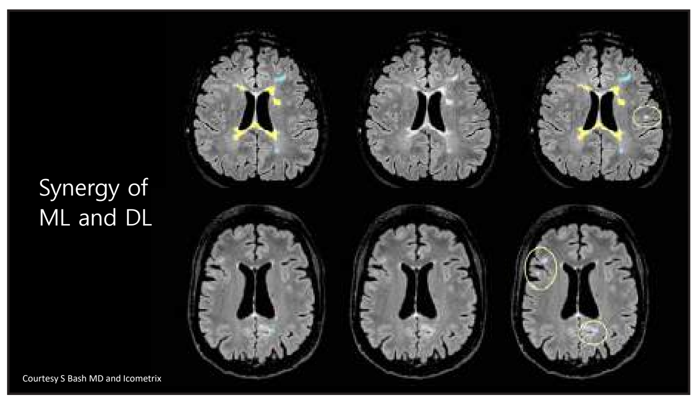

Segmentation

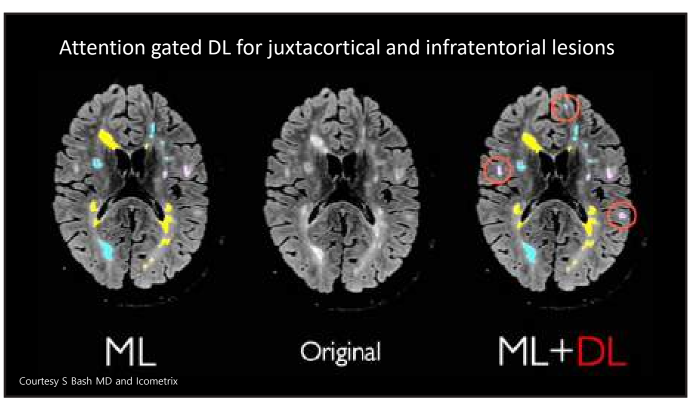

ML
ML+DL
ML
DL

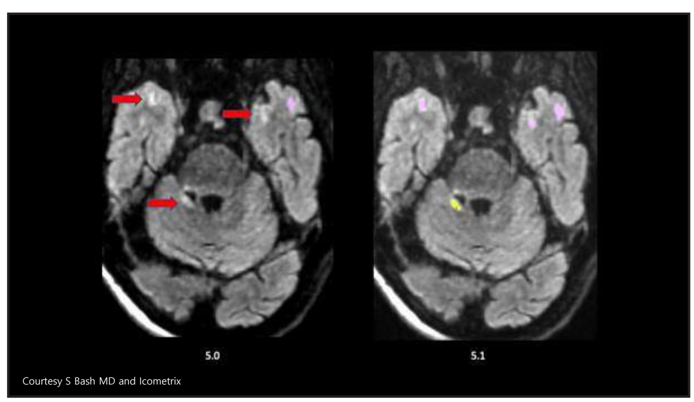

Deep Learning Enhancement
ML
DL
Courtesy S Bash MD and Icometrix

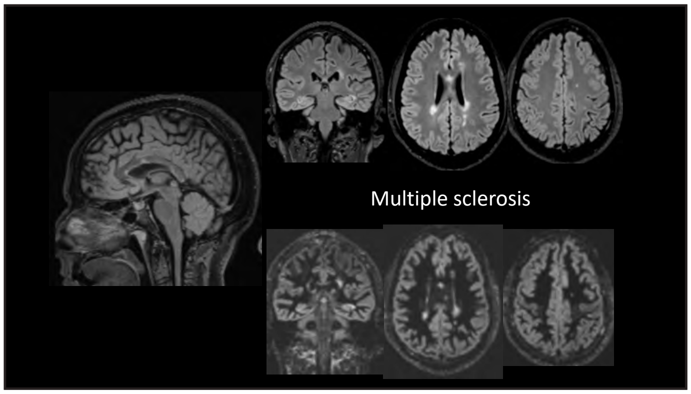

ML
ML+DL

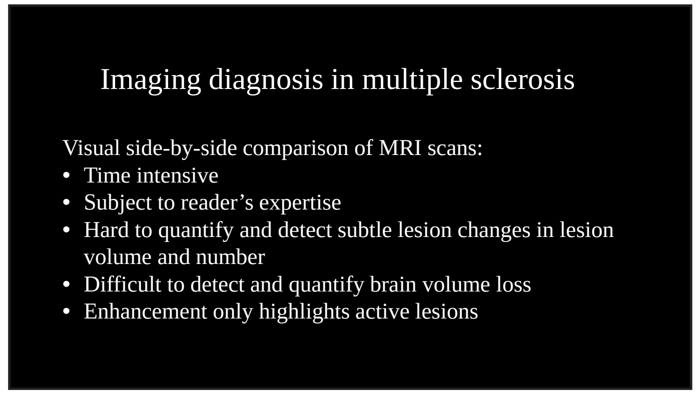

Programming
and DL
Full Deep
Learning


Synergy of
ML and DL
Courtesy S Bash MD and Icometrix

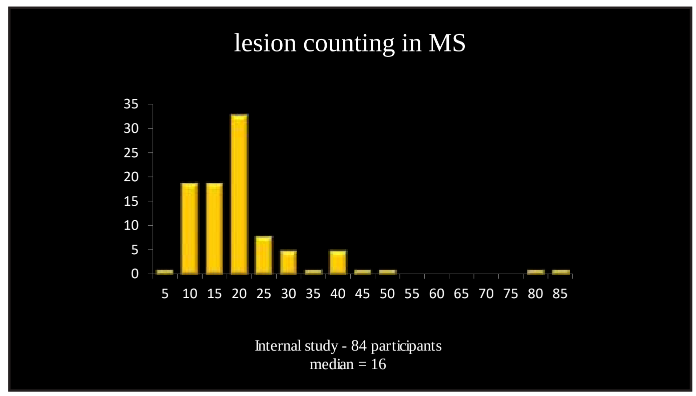

Attention gated DL for juxtacortical and infratentorial lesions
ML
Original
ML+DL
Courtesy S Bash MD and Icometrix

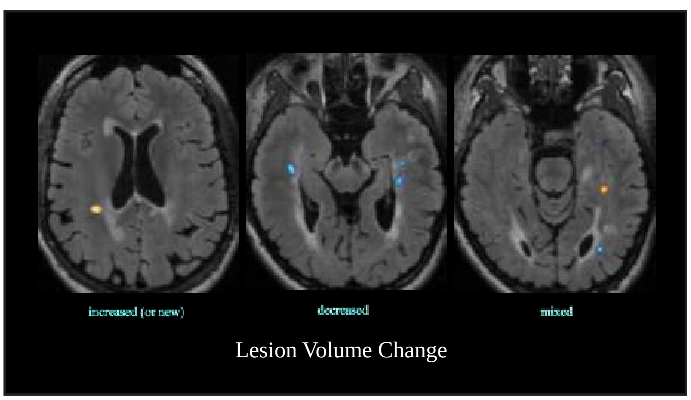

5.0
5.1
Courtesy S Bash MD and Icometrix

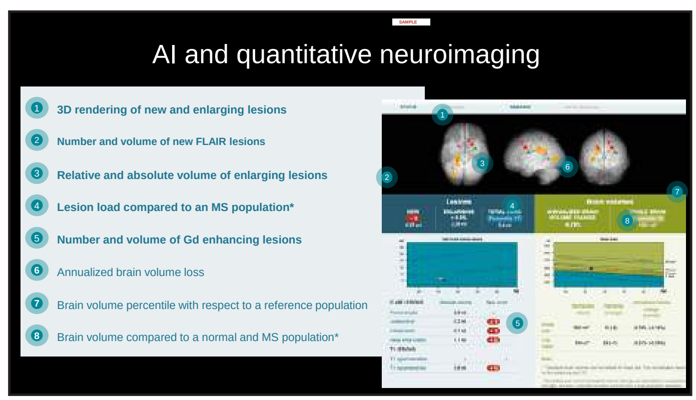

Multiple sclerosis

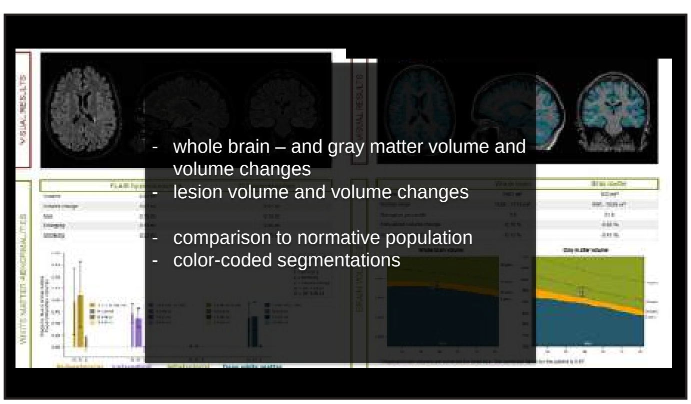

Imaging diagnosis in multiple sclerosis
Visual side-by-side comparison of MRI scans:
• Time intensive
• Subject to reader's expertise
• Hard to quantify and detect subtle lesion changes in lesion volume and number
• Difficult to detect and quantify brain volume loss
• Enhancement only highlights active lesions

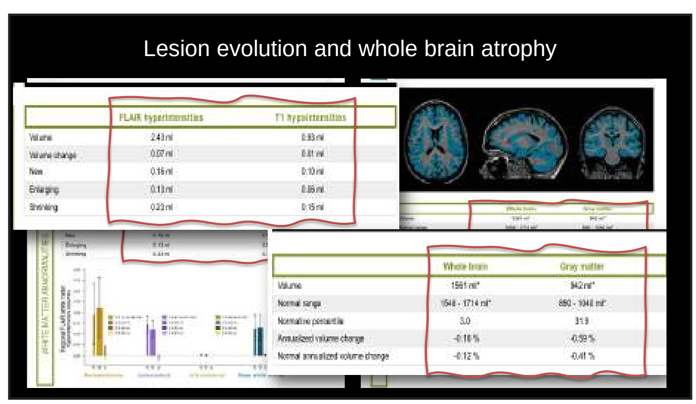

COUNT THE SPOTS
TIME

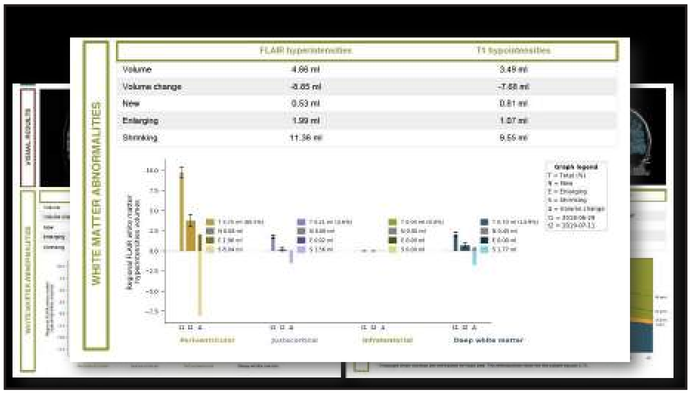

lesion counting in MS
35
30
25
20
15
10
5
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Internal study - 84 participants
median = 16

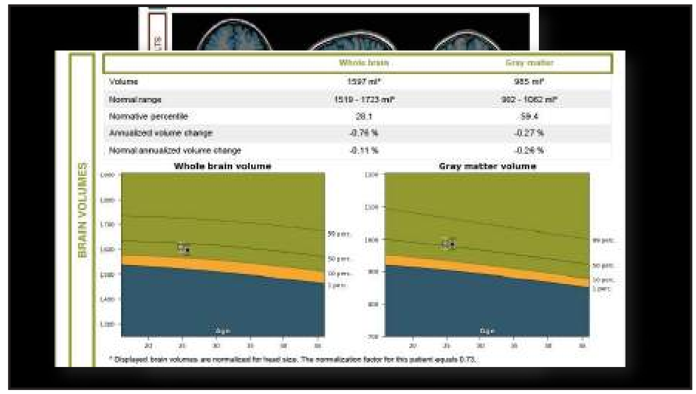

increased (or new)
decreased
mixed
Lesion Volume Change

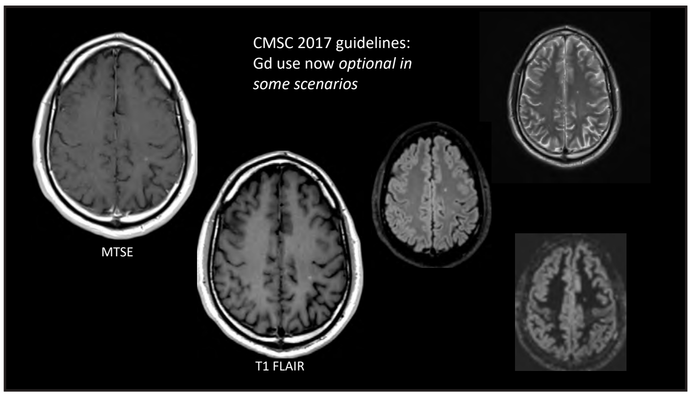

AI and quantitative neuroimaging
1 3D rendering of new and enlarging lesions
2 Number and volume of new FLAIR lesions
3 Relative and absolute volume of enlarging lesions
4 Lesion load compared to an MS population*
5 Number and volume of Gd enhancing lesions
6 Annualized brain volume loss
7 Brain volume percentile with respect to a reference population
8 Brain volume compared to a normal and MS population*

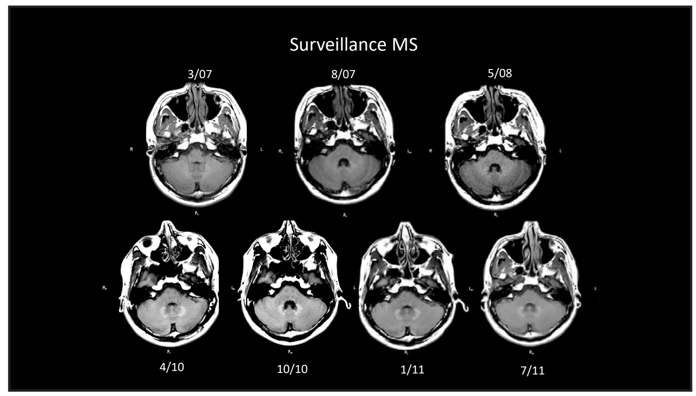

- whole brain – and gray matter volume and volume changes
- lesion volume and volume changes
- comparison to normative population
- color-coded segmentations

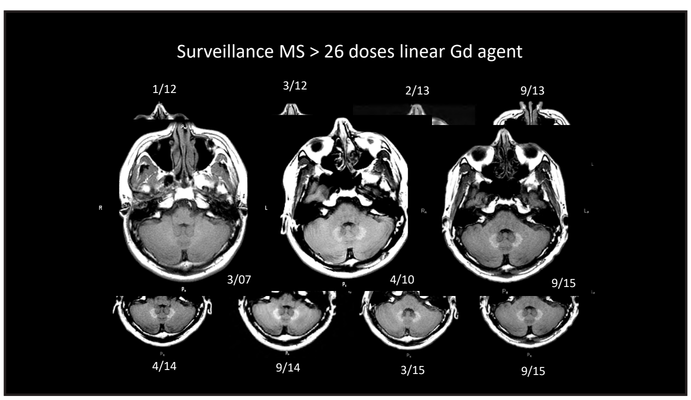

Lesion evolution and whole brain atrophy

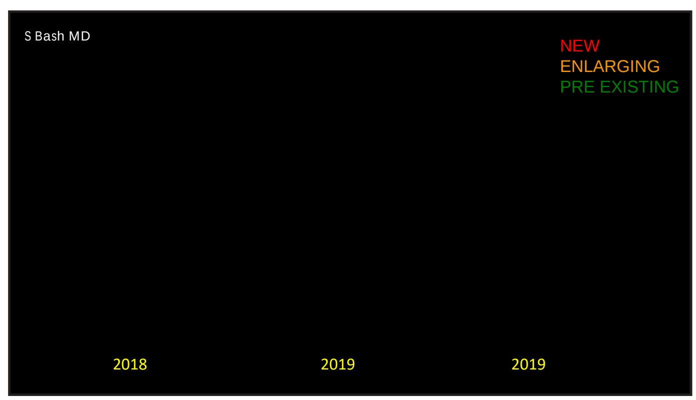

WHITE MATTER ABNORMALITIES
FLAIR hyperintensities
T1 hypointensities
Volume 4.66 ml 3.49 ml
Volume change -8.85 ml -7.68 ml
New 0.53 ml 0.81 ml
Enlarging 1.90 ml 1.07 ml
Shrinking 11.36 ml 9.55 ml

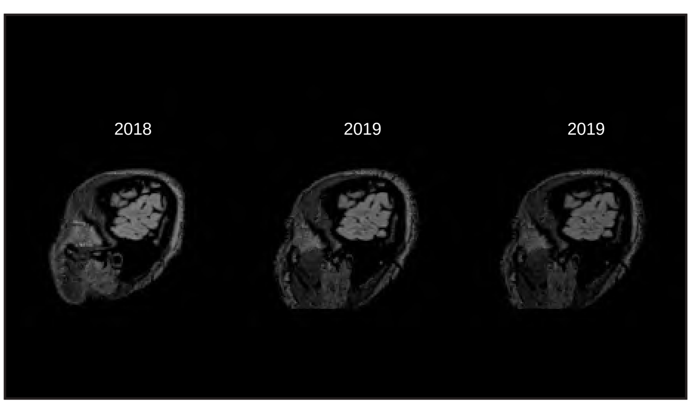

BRAIN VOLUMES
Whole brain
Gray matter
Volume 1597 ml* 985 ml*
Normal range 1519 - 1723 ml* 902 - 1062 ml*
Normative percentile 28.1 59.4
Annualized volume change -0.76 % -0.27 %
Normal annualized volume change -0.11 % -0.26 %
Whole brain volume
Gray matter volume

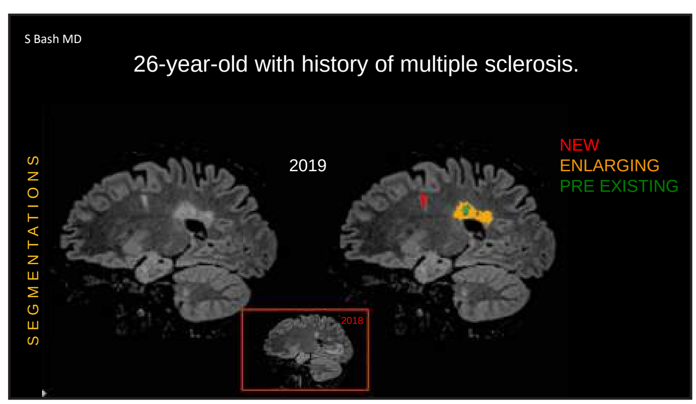

CMSC 2017 guidelines:
Gd use now *optional in some scenarios*
MTSE
T1 FLAIR


Surveillance MS
3/07
8/07
5/08
4/10
10/10
1/11
7/11


Surveillance MS > 26 doses linear Gd agent
1/12
3/12
2/13
9/13
3/07
4/10
9/15
4/14
9/14
3/15
9/15


S Bash MD
NEW
ENLARGING
PRE EXISTING
2018
2019
2019


2018
2019
2019

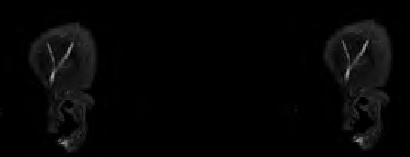

S Bash MD
26-year-old with history of multiple sclerosis.
SEGMENTATIONS
2019
NEW
ENLARGING
PRE EXISTING
2018

AI assisted MRI for QNI and MS

- Standardize and speed reporting
  - Dickerson et al. 2016
  - Lee et al. 2020
  - Alessandrino et al. 2018
- Enhance sensitivity
  - Van Heerden et al. 2015
  - Beadnall et al. 2017
  - Sima et al. 2020

QNI in Multiple Sclerosis – Conventional Reporting

Case Study of a 50y male with confirmed MS



Report from the experience Neuroradiologist:
Known MS. Repeat MR at 11 months. Moderate to severe lesion load. After co-registration in the axial and sagittal plane, **no new lesions, no enhancing lesions, no new black holes. No increase of cortical atrophy**.
Conclusion: Stable disease. No signs of inflammatory activity.

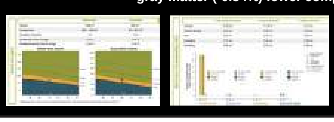
QNI in Multiple Sclerosis – Human and Machine

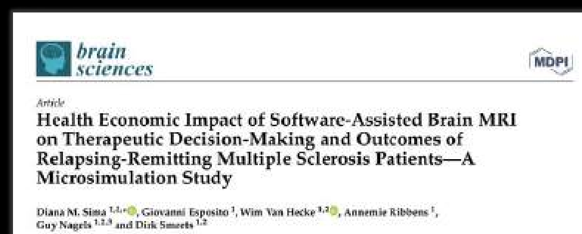
Case Study of a 50y male with confirmed MS

AI AUGMENTED REPORT :

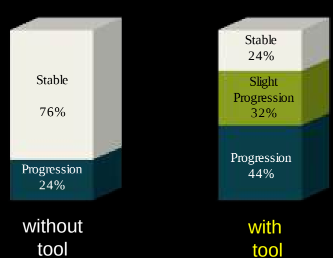
IMPRESSIONS:
1. Periventricular, juxtacortical, deep white matter white matter lesions, consistent with the diagnosis of multiple sclerosis.
2. No lesion(s) showing contrast enhancement.
3. **Over the course of 11 months, there is a lesion volume change compared to the prior study:**
   - **Total volume change: 0.33mL.**
   - **Volume change vs. prior study: 2.4 %**
   - **2 new lesions**
4. **Low brain volume, with annualized atrophy for:**
   - **whole brain (-0.45%) lower compared to controls (-0.24%).**
   - **gray matter (-0.54%) lower compared to controls (-0.3%).**

NEW
ENLARGING
PRE EXISTING




brain sciences
MDPI
Article
Health Economic Impact of Software-Assisted Brain MRI on Therapeutic Decision-Making and Outcomes of Relapsing-Remitting Multiple Sclerosis Patients—A Microsimulation Study
Diana M. Sima [1,2,*], Giovanni Esposito [1], Wim Van Hecke [1,2], Annemie Ribbens [1], Guy Nagels [1,2,3] and Dirk Smeets [1,2]

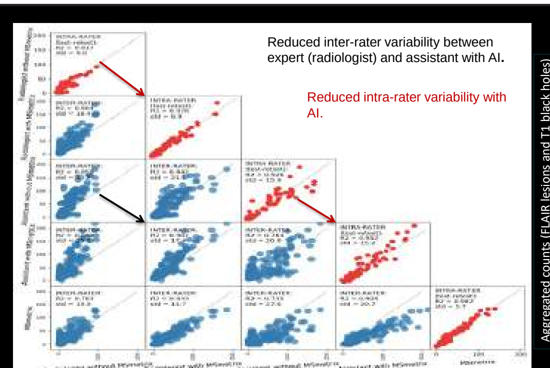
Increased sensitivity



+32% slight progression
+20% progression

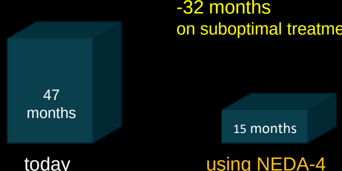
Sima et al. 2019

Quantification increases consistency



Sima et al. 2018

Reduce time on suboptimal treatment



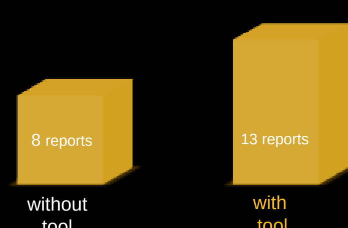
-32 months
on suboptimal treatment

Today, ±25% of patients starts on a suboptimal treatment.

In addition to relapses, disability progression, and MRI activity, NEDA-4 includes change in brain volume over time.

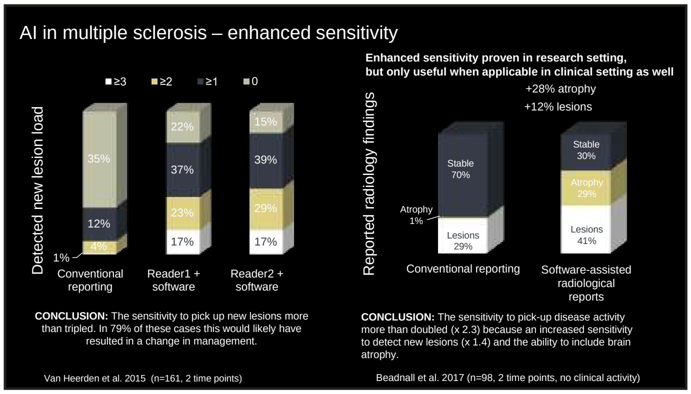
Smeets et al 2017, Sat et al. 2014, Rio et al 2012, Rojas et al. 2014,

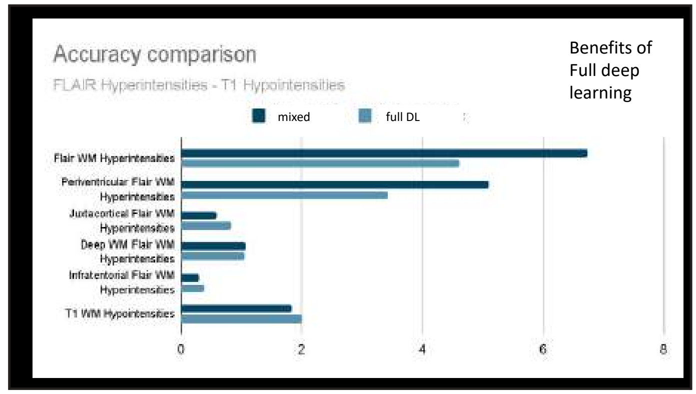
Enhanced productivity

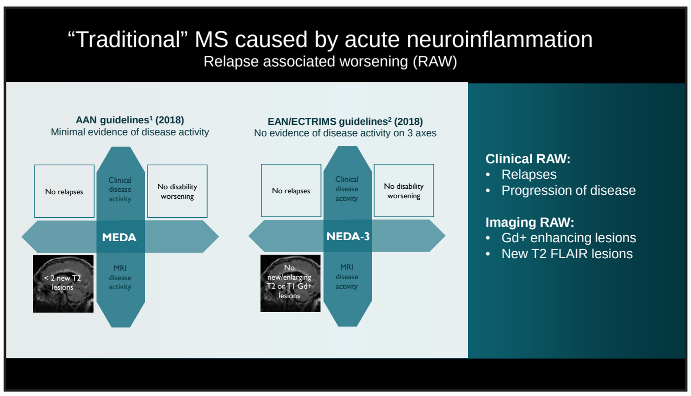


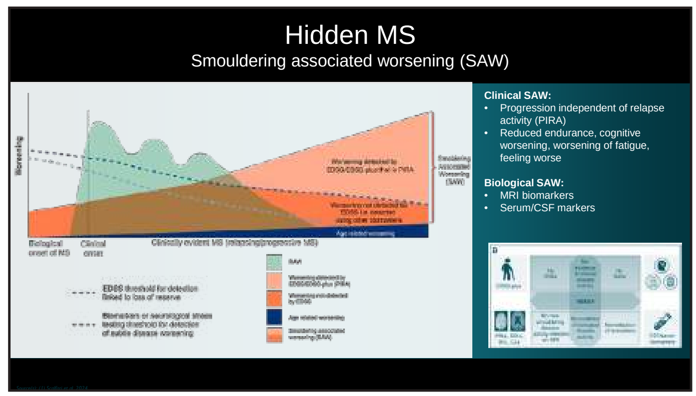
+ 60% reports per hour with AI assist and NLR

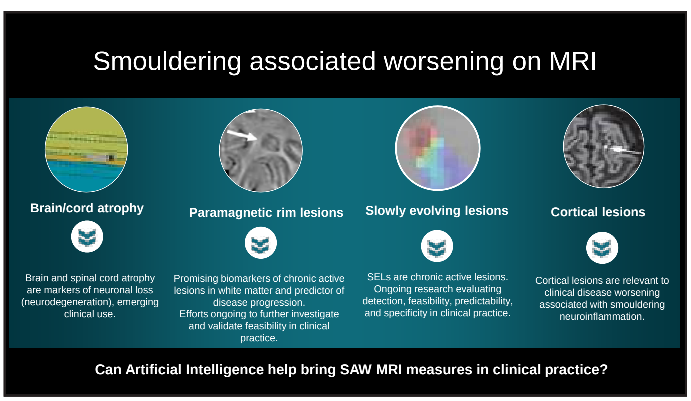
Sima et al. 2019

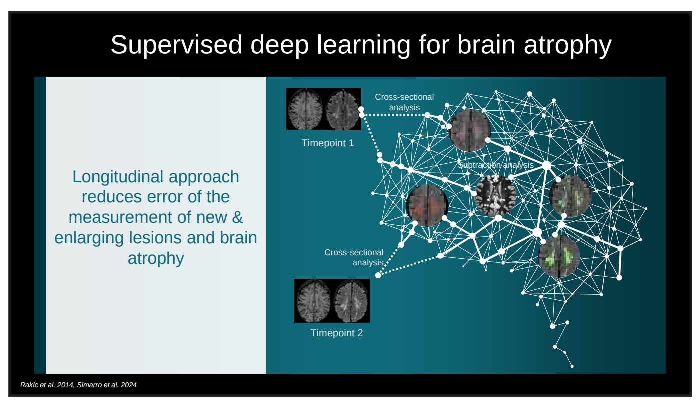

AI in multiple sclerosis – enhanced sensitivity
≥3 ≥2 ≥1 0
Detected new lesion load
35%
12%
4%
1%
22%
37%
23%
17%
15%
39%
29%
17%
Conventional reporting
Reader1 + software
Reader2 + software
CONCLUSION: The sensitivity to pick up new lesions more than tripled. In 79% of these cases this would likely have resulted in a change in management.
Van Heerden et al. 2015 (n=161, 2 time points)
Enhanced sensitivity proven in research setting, but only useful when applicable in clinical setting as well
+28% atrophy
+12% lesions
Reported radiology findings
Stable 70%
Atrophy 1%
Lesions 29%
Stable 30%
Atrophy 29%
Lesions 41%
Conventional reporting
Software-assisted radiological reports
CONCLUSION: The sensitivity to pick-up disease activity more than doubled (x 2.3) because an increased sensitivity to detect new lesions (x 1.4) and the ability to include brain atrophy.
Beadnall et al. 2017 (n=98, 2 time points, no clinical activity)

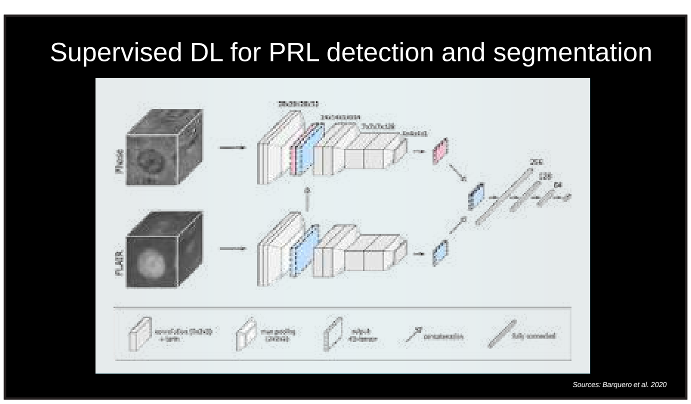

Accuracy comparison
FLAIR Hyperintensities - T1 Hypointensities
Benefits of Full deep learning
mixed
full DL
Flair WM Hyperintensities
Periventricular Flair WM Hyperintensities
Juxtacortical Flair WM Hyperintensities
Deep WM Flair WM Hyperintensities
Infratentorial Flair WM Hyperintensities
T1 WM Hypointensities
0
2
4
6
8

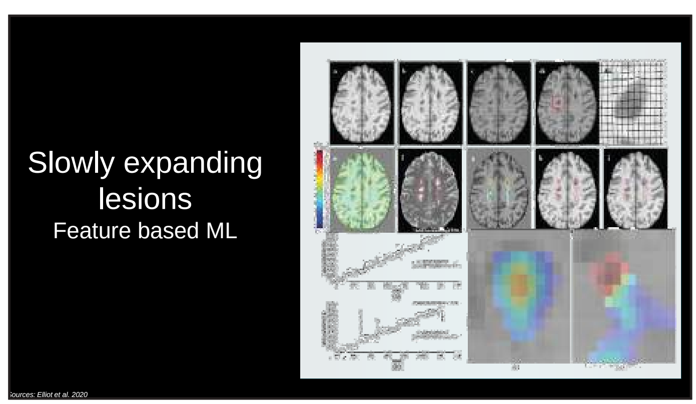

"Traditional" MS caused by acute neuroinflammation
Relapse associated worsening (RAW)
AAN guidelines¹ (2018)
Minimal evidence of disease activity
No relapses
Clinical disease activity
No disability worsening
MEDA
MRI disease activity
< 2 new T2 lesions
EAN/ECTRIMS guidelines² (2018)
No evidence of disease activity on 3 axes
No relapses
Clinical disease activity
No disability worsening
NEDA-3
MRI disease activity
No new/enlarging T2 or T1 Gd+ lesions
Clinical RAW:
Relapses
Progression of disease
Imaging RAW:
Gd+ enhancing lesions
New T2 FLAIR lesions

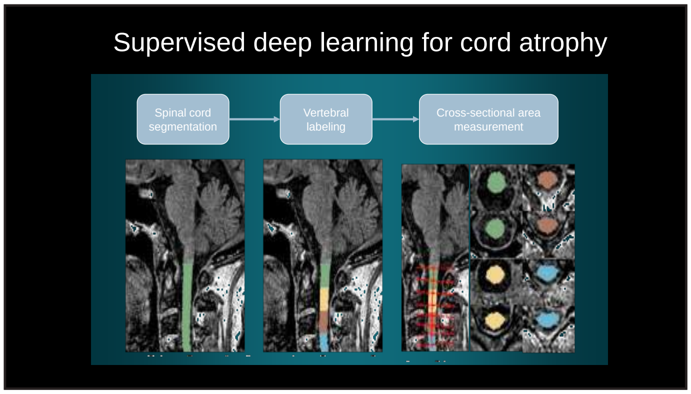

Hidden MS
Smouldering associated worsening (SAW)
Clinical SAW:
Progression independent of relapse activity (PIRA)
Reduced endurance, cognitive worsening, worsening of fatigue, feeling worse
Biological SAW:
MRI biomarkers
Serum/CSF markers

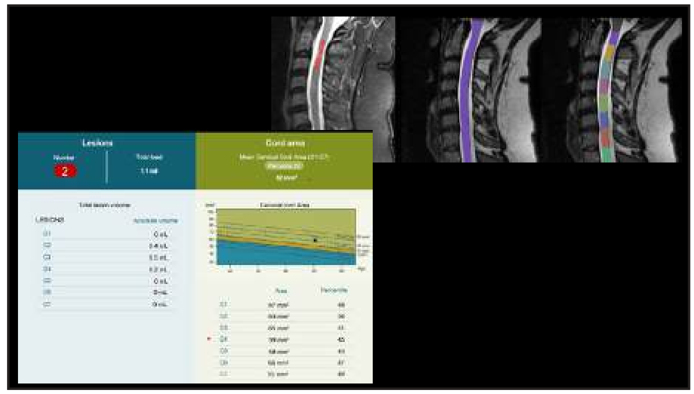

Smouldering associated worsening on MRI
Brain/cord atrophy
Brain and spinal cord atrophy are markers of neuronal loss (neurodegeneration), emerging clinical use.
Paramagnetic rim lesions
Promising biomarkers of chronic active lesions in white matter and predictor of disease progression.
Efforts ongoing to further investigate and validate feasibility in clinical practice.
Slowly evolving lesions
SELs are chronic active lesions.
Ongoing research evaluating detection, feasibility, predictability, and specificity in clinical practice.
Cortical lesions
Cortical lesions are relevant to clinical disease worsening associated with smouldering neuroinflammation.
Can Artificial Intelligence help bring SAW MRI measures in clinical practice?

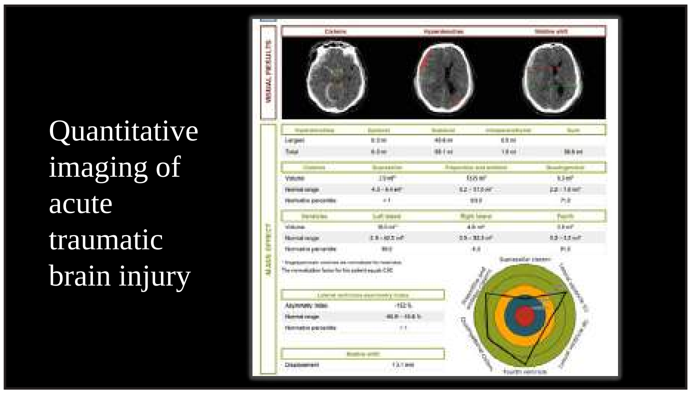

Supervised deep learning for brain atrophy
Longitudinal approach reduces error of the measurement of new & enlarging lesions and brain atrophy
Cross-sectional analysis
Timepoint 1
Subtraction analysis
Cross-sectional analysis
Timepoint 2
Rakic et al. 2014, Simarro et al. 2024

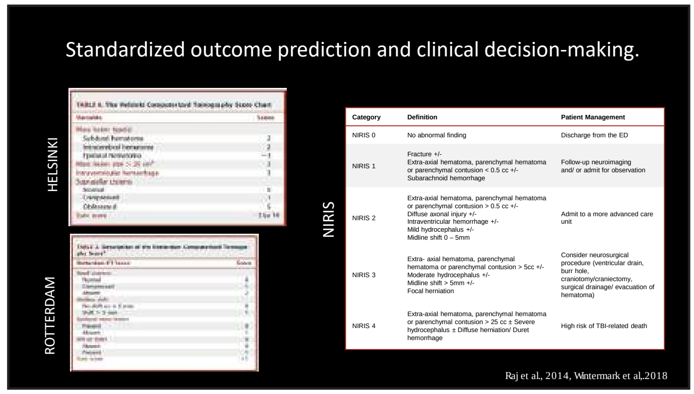

Supervised DL for PRL detection and segmentation
Phase
FLAIR
Sources: Barquero et al. 2020

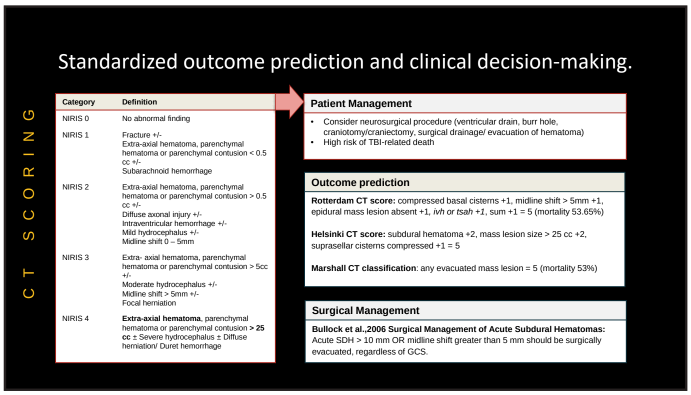

Slowly expanding lesions
Feature based ML
Sources: Elliot et al. 2020

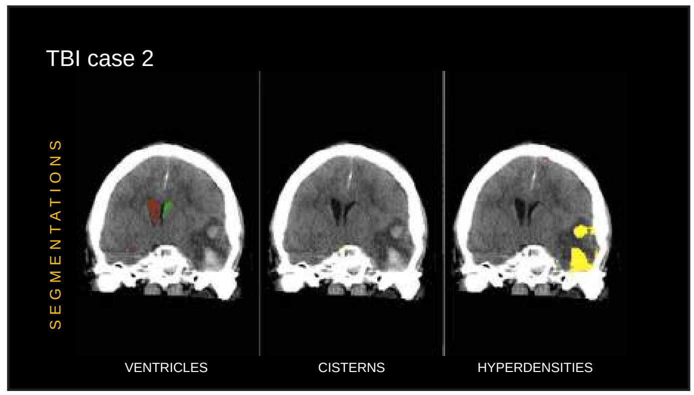

Supervised deep learning for cord atrophy
Spinal cord segmentation
Vertebral labeling
Cross-sectional area measurement

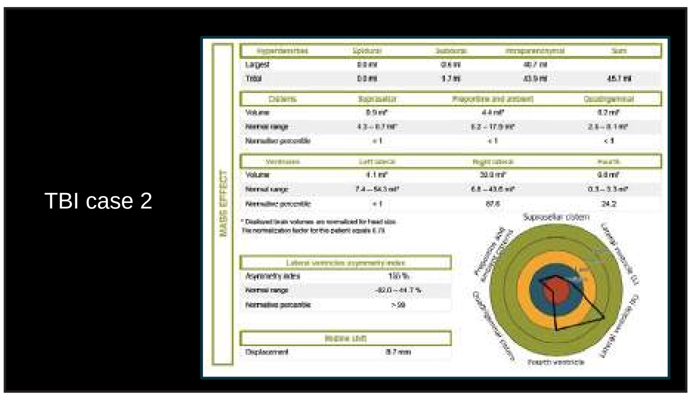

Lesions
Cord area
LESIONS

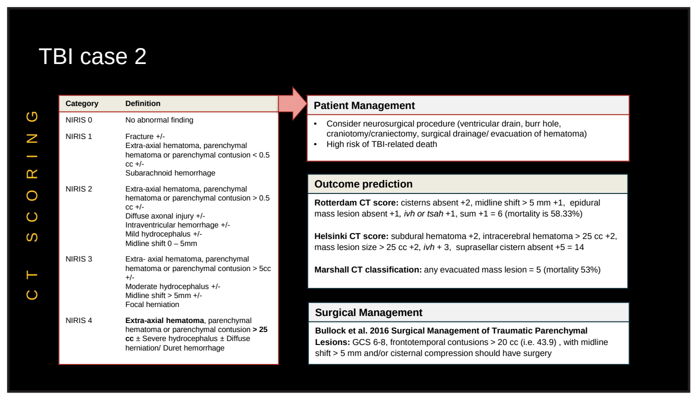

Quantitative imaging of acute traumatic brain injury
VISUAL RESULTS
MASS EFFECT


Standardized outcome prediction and clinical decision-making.
HELSINKI
ROTTERDAM
NIRIS
Category | Definition | Patient Management
NIRIS 0 | No abnormal finding | Discharge from the ED
NIRIS 1 | Fracture +/- Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc +/- Subarachnoid hemorrhage | Follow-up neuroimaging and/ or admit for observation
NIRIS 2 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc +/- Diffuse axonal injury +/- Intraventricular hemorrhage +/- Mild hydrocephalus +/- Midline shift 0 – 5mm | Admit to a more advanced care unit
NIRIS 3 | Extra- axial hematoma, parenchymal hematoma or parenchymal contusion > 5cc +/- Moderate hydrocephalus +/- Midline shift > 5mm +/- Focal herniation | Consider neurosurgical procedure (ventricular drain, burr hole, craniotomy/craniectomy, surgical drainage/ evacuation of hematoma)
NIRIS 4 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 25 cc ± Severe hydrocephalus ± Diffuse herniation/ Duret hemorrhage | High risk of TBI-related death
Raj et al., 2014, Wintermark et al,.2018

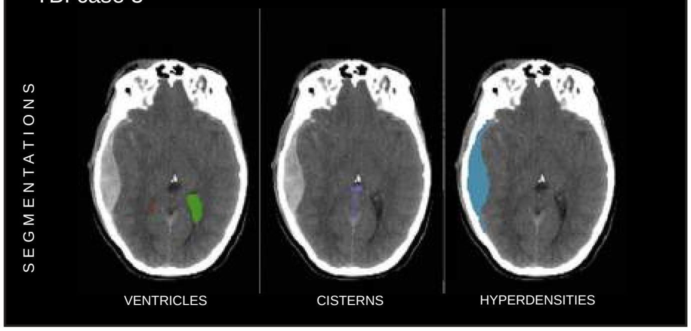

Standardized outcome prediction and clinical decision-making.
CT SCORING
Category | Definition
NIRIS 0 | No abnormal finding
NIRIS 1 | Fracture +/- Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc +/- Subarachnoid hemorrhage
NIRIS 2 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc +/- Diffuse axonal injury +/- Intraventricular hemorrhage +/- Mild hydrocephalus +/- Midline shift 0 – 5mm
NIRIS 3 | Extra- axial hematoma, parenchymal hematoma or parenchymal contusion > 5cc +/- Moderate hydrocephalus +/- Midline shift > 5mm +/- Focal herniation
NIRIS 4 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 25 cc ± Severe hydrocephalus ± Diffuse herniation/ Duret hemorrhage
Patient Management
• Consider neurosurgical procedure (ventricular drain, burr hole, craniotomy/craniectomy, surgical drainage/ evacuation of hematoma)
• High risk of TBI-related death
Outcome prediction
Rotterdam CT score: compressed basal cisterns +1, midline shift > 5mm +1, epidural mass lesion absent +1, ivh or tsah +1, sum +1 = 5 (mortality 53.65%)
Helsinki CT score: subdural hematoma +2, mass lesion size > 25 cc +2, suprasellar cisterns compressed +1 = 5
Marshall CT classification: any evacuated mass lesion = 5 (mortality 53%)
Surgical Management
Bullock et al.,2006 Surgical Management of Acute Subdural Hematomas: Acute SDH > 10 mm OR midline shift greater than 5 mm should be surgically evacuated, regardless of GCS.


TBI case 2
SEGMENTATIONS
VENTRICLES
CISTERNS
HYPERDENSITIES

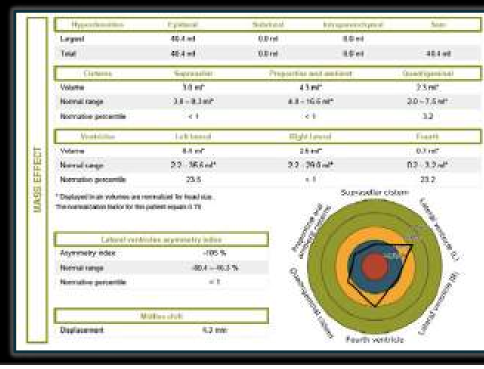

TBI case 2
MASS EFFECT
Suprasellar cistern
Fourth ventricle


TBI case 2
CT SCORING
Category | Definition
NIRIS 0 | No abnormal finding
NIRIS 1 | Fracture +/- Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc +/- Subarachnoid hemorrhage
NIRIS 2 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc +/- Diffuse axonal injury +/- Intraventricular hemorrhage +/- Mild hydrocephalus +/- Midline shift 0 – 5mm
NIRIS 3 | Extra- axial hematoma, parenchymal hematoma or parenchymal contusion > 5cc +/- Moderate hydrocephalus +/- Midline shift > 5mm +/- Focal herniation
NIRIS 4 | Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 25 cc ± Severe hydrocephalus ± Diffuse herniation/ Duret hemorrhage
Patient Management
• Consider neurosurgical procedure (ventricular drain, burr hole, craniotomy/craniectomy, surgical drainage/ evacuation of hematoma)
• High risk of TBI-related death
Outcome prediction
Rotterdam CT score: cisterns absent +2, midline shift > 5 mm +1, epidural mass lesion absent +1, ivh or tsah +1, sum +1 = 6 (mortality is 58.33%)
Helsinki CT score: subdural hematoma +2, intracerebral hematoma > 25 cc +2, mass lesion size > 25 cc +2, ivh + 3, suprasellar cistern absent +5 = 14
Marshall CT classification: any evacuated mass lesion = 5 (mortality 53%)
Surgical Management
Bullock et al. 2016 Surgical Management of Traumatic Parenchymal Lesions: GCS 6-8, frontotemporal contusions > 20 cc (i.e. 43.9) , with midline shift > 5 mm and/or cisternal compression should have surgery

TBI case 3



TBI case 3



Quantitative imaging of traumatic brain injury

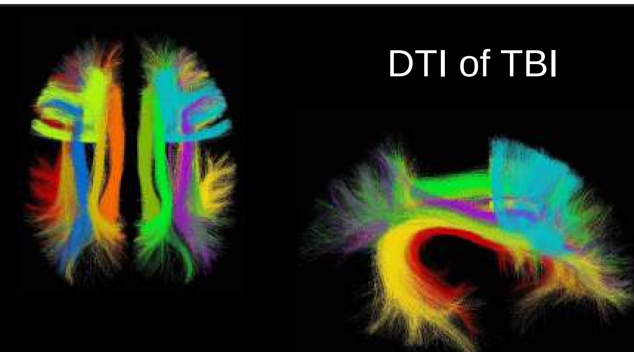
Standardized interpretation of acute non-contrast head CTs

Bridges the gap between clinical practice and CT scoring systems

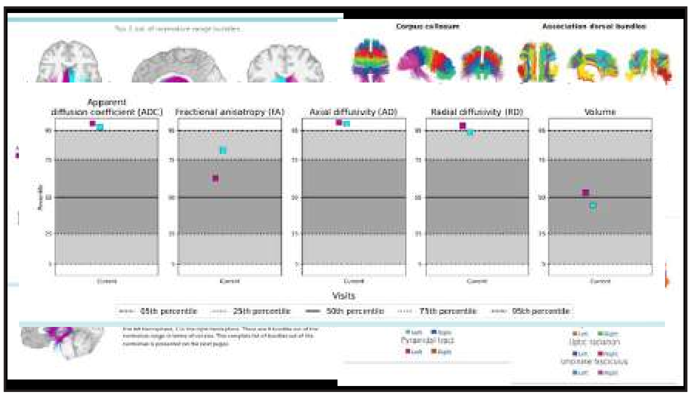
Quantitative analysis together with CT scoring systems offers a clinical-decision support tool[1]

[1]Wintemark et al., 2018

DTI of TBI



Courtesy Imeka



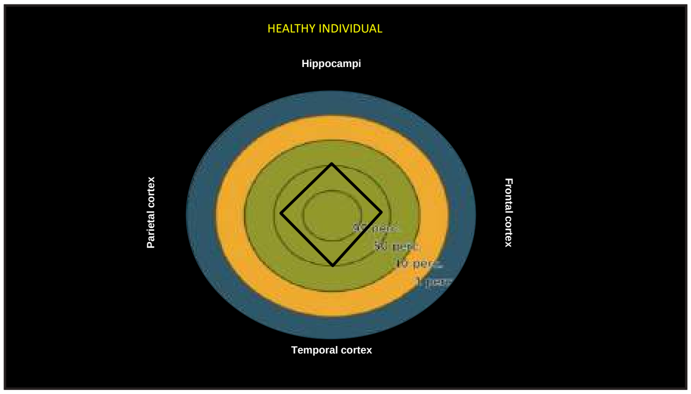
Quantitative imaging of dementias

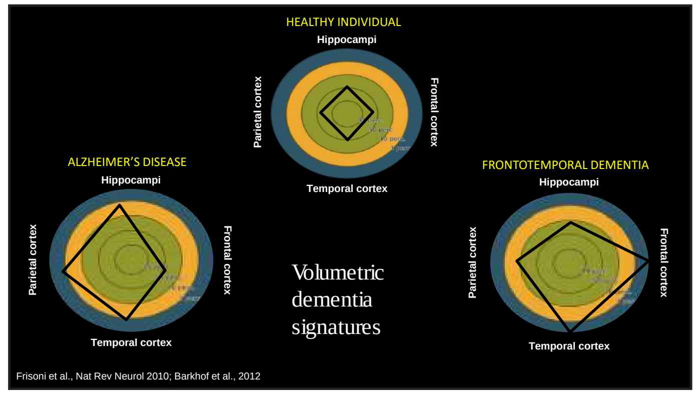
Quantitative imaging in Dementia diagnosis

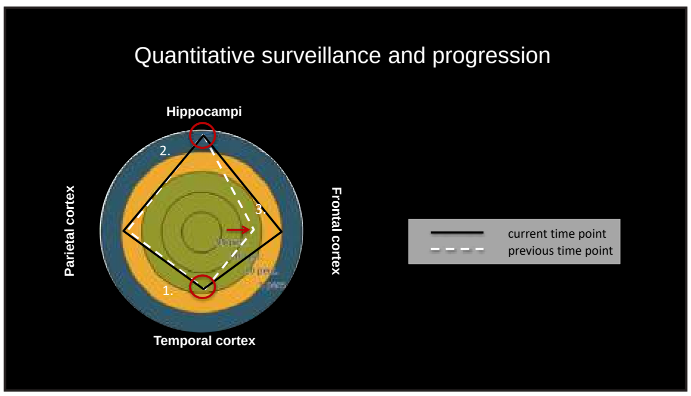
- Differential diagnosis using brain volumetrics based on structure involvement
- Comparison with healthy age and sex matched population

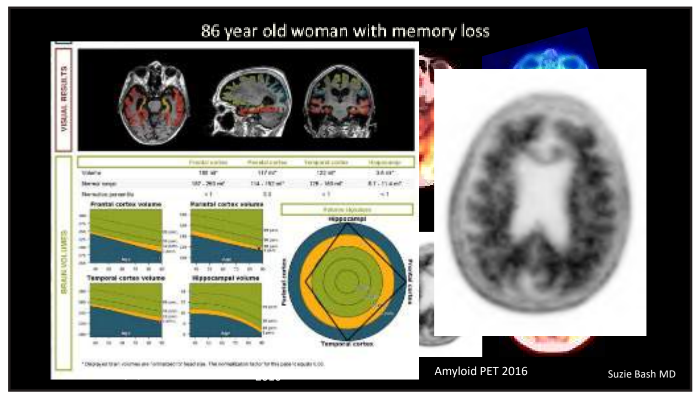
Volume loss phenotypes

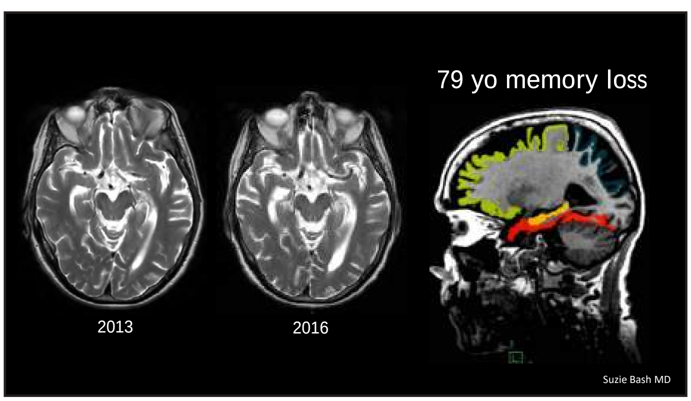
	AD	VaD	FTD	DLB
Hippocampal atrophy	+++	++	++	-
Temporal atrophy	++	+	+++	-
Frontal atrophy	-	+	+++	-
Parietal atrophy	++	+	-	-
WML's	-	+++	-	-

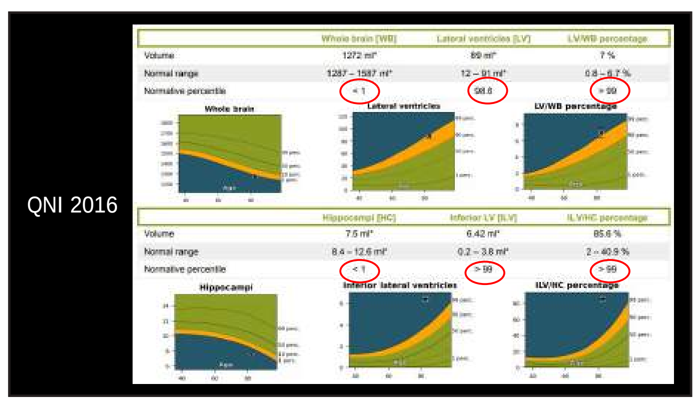

HEALTHY INDIVIDUAL
Hippocampi
Parietal cortex
Frontal cortex
90 perc.
50 perc.
10 perc.
1 perc.
Temporal cortex

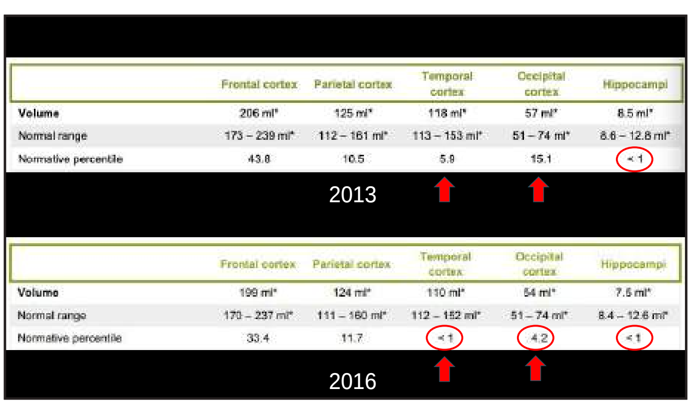

HEALTHY INDIVIDUAL
Hippocampi
Parietal cortex
Frontal cortex
Temporal cortex
ALZHEIMER'S DISEASE
Hippocampi
Parietal cortex
Frontal cortex
Temporal cortex
Volumetric dementia signatures
FRONTOTEMPORAL DEMENTIA
Hippocampi
Parietal cortex
Frontal cortex
Temporal cortex
Frisoni et al., Nat Rev Neurol 2010; Barkhof et al., 2012

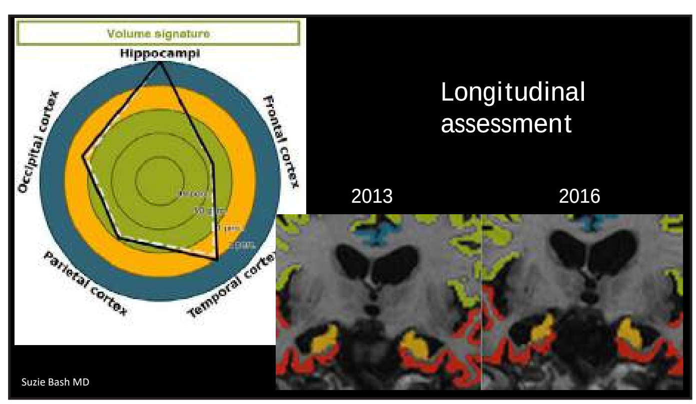

Quantitative surveillance and progression
Hippocampi
Parietal cortex
Frontal cortex
Temporal cortex
1.
2.
3.
current time point
previous time point

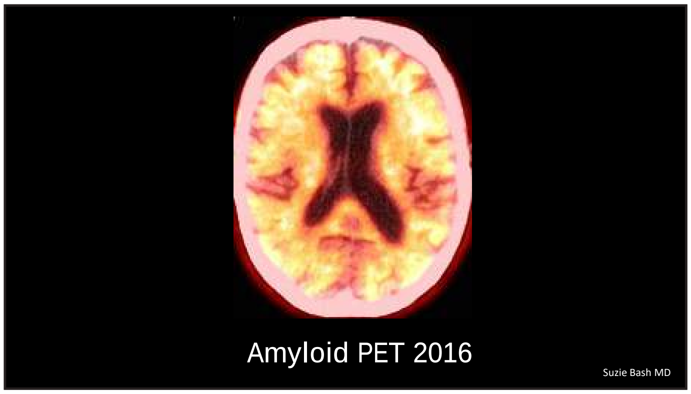

86 year old woman with memory loss
VISUAL RESULTS
BRAIN VOLUMES
Frontal cortex volume
Parietal cortex volume
Temporal cortex volume
Hippocampal volume
Volume signature
Hippocampi
Parietal cortex
Frontal cortex
Temporal cortex
Amyloid PET 2016
Suzie Bash MD

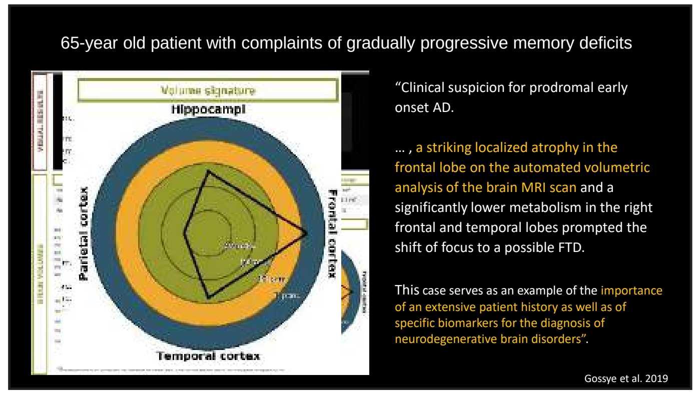

79 yo memory loss
2013
2016
Suzie Bash MD

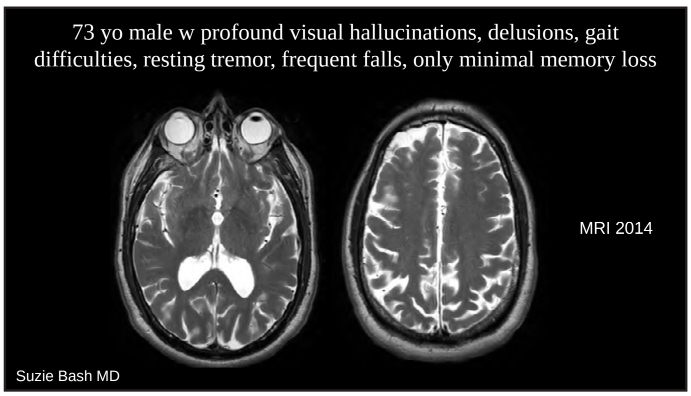

QNI 2016
Whole brain [WB] | Lateral ventricles [LV] | LV/WB percentage
Volume 1272 ml* | 89 ml* | 7 %
Normal range 1287 – 1587 ml* | 12 – 91 ml* | 0.8 – 6.7 %
Normative percentile < 1 | 98.8 | > 99
Whole brain
Lateral ventricles
LV/WB percentage
Hippocampi [HC] | Inferior LV [ILV] | ILV/HC percentage
Volume 7.5 ml* | 6.42 ml* | 85.6 %
Normal range 8.4 – 12.6 ml* | 0.2 – 3.8 ml* | 2 – 40.9 %
Normative percentile < 1 | > 99 | > 99
Hippocampi
Inferior lateral ventricles
ILV/HC percentage

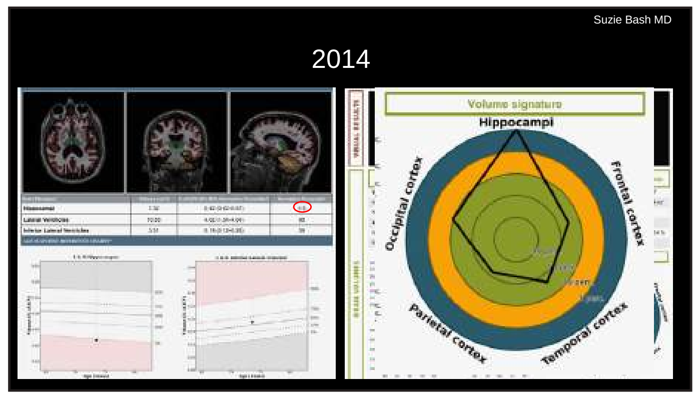

Frontal cortex | Parietal cortex | Temporal cortex | Occipital cortex | Hippocampi
Volume 206 ml* | 125 ml* | 118 ml* | 57 ml* | 8.5 ml*
Normal range 173 – 239 ml* | 112 – 161 ml* | 113 – 153 ml* | 51 – 74 ml* | 8.6 – 12.8 ml*
Normative percentile 43.8 | 10.5 | 5.9 | 15.1 | < 1
2013
Frontal cortex | Parietal cortex | Temporal cortex | Occipital cortex | Hippocampi
Volume 199 ml* | 124 ml* | 110 ml* | 54 ml* | 7.5 ml*
Normal range 170 – 237 ml* | 111 – 160 ml* | 112 – 152 ml* | 51 – 74 ml* | 8.4 – 12.6 ml*
Normative percentile 33.4 | 11.7 | < 1 | 4.2 | < 1
2016

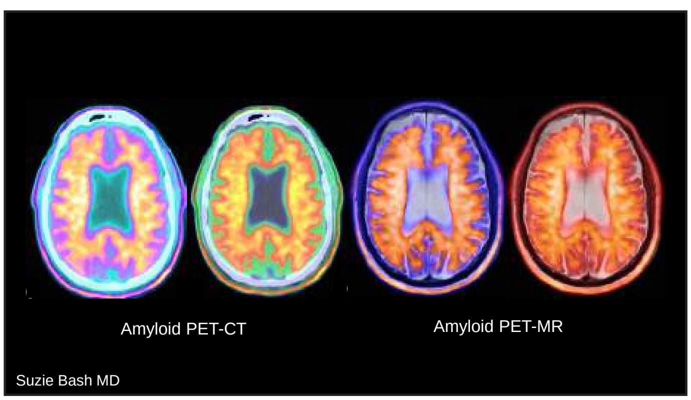

Volume signature
Hippocampi
Occipital cortex
Frontal cortex
Parietal cortex
Temporal cortex
Longitudinal assessment
2013
2016
Suzie Bash MD

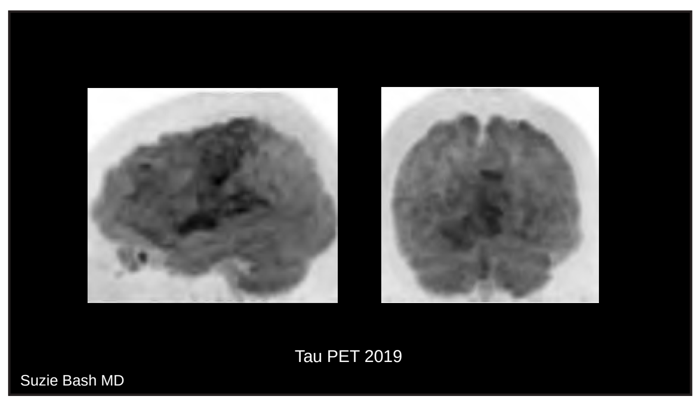

Amyloid PET 2016
Suzie Bash MD


65-year old patient with complaints of gradually progressive memory deficits
Volume signature
Hippocampi
Frontal cortex
Parietal cortex
Temporal cortex
"Clinical suspicion for prodromal early onset AD.
… , a striking localized atrophy in the frontal lobe on the automated volumetric analysis of the brain MRI scan and a significantly lower metabolism in the right frontal and temporal lobes prompted the shift of focus to a possible FTD.
This case serves as an example of the importance of an extensive patient history as well as of specific biomarkers for the diagnosis of neurodegenerative brain disorders".
Gossye et al. 2019

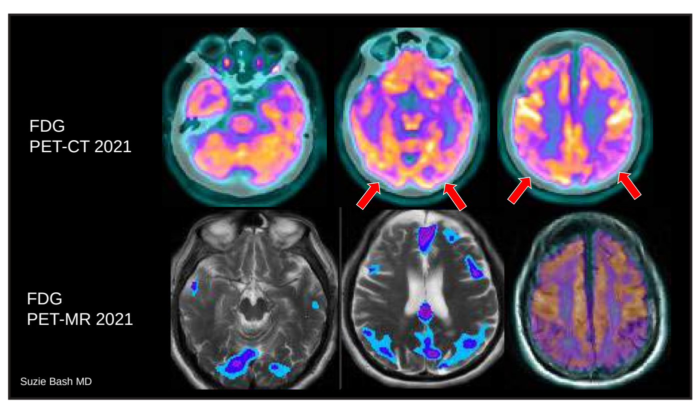

73 yo male w profound visual hallucinations, delusions, gait difficulties, resting tremor, frequent falls, only minimal memory loss
MRI 2014
Suzie Bash MD

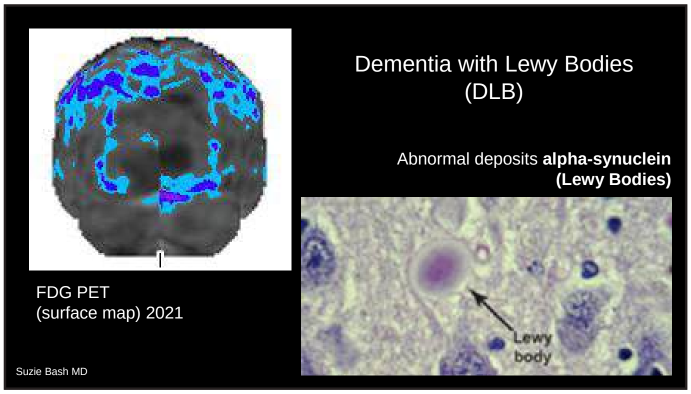

Suzie Bash MD
2014
Volume signature
Hippocampi
Frontal cortex
Occipital cortex
Parietal Cortex
Temporal cortex


Amyloid PET-CT
Amyloid PET-MR
Suzie Bash MD


Tau PET 2019
Suzie Bash MD

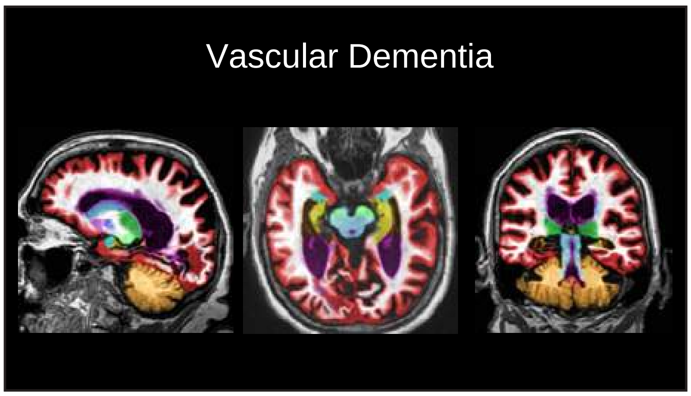

Suzie Bash MD
MRI 2021

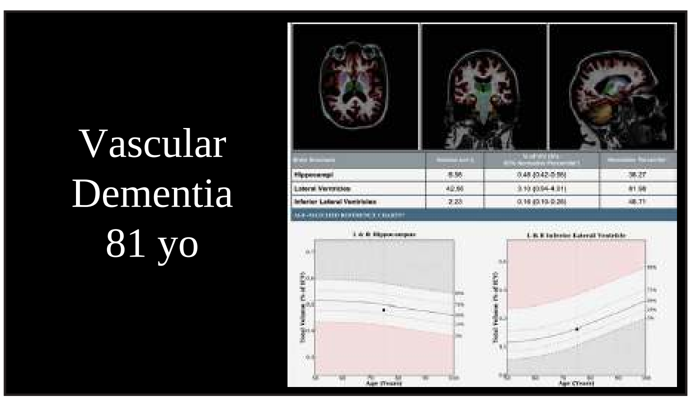

FDG
PET-CT 2021
FDG
PET-MR 2021
Suzie Bash MD

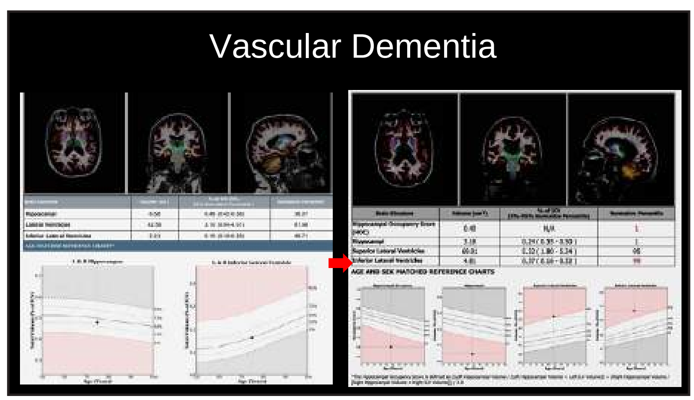


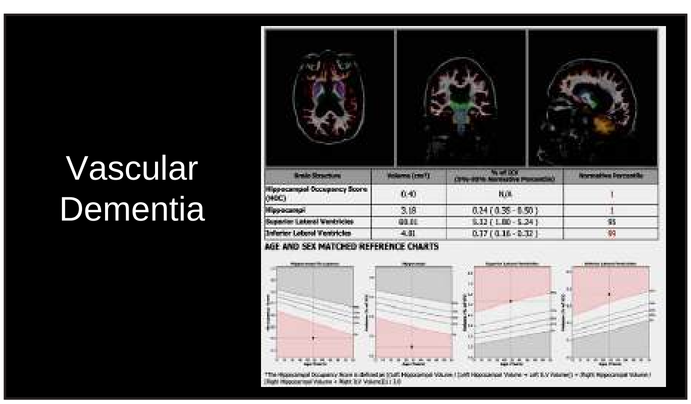
Dementia with Lewy Bodies (DLB)

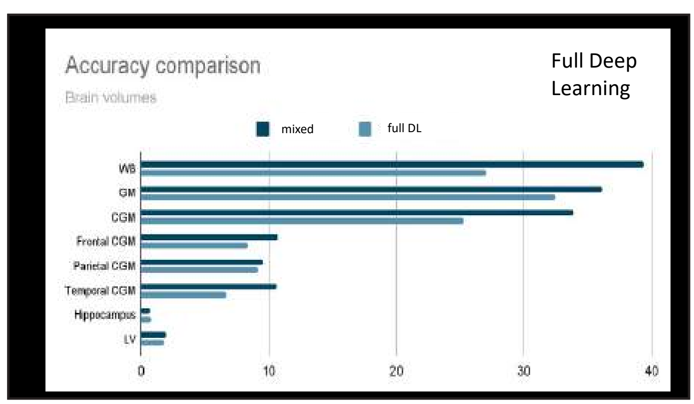
- Less common than AD (1M DLB vs. 6M AD in USA)
- Survival rate typically 5-8 years after diagnosis
- Visual hallucinations in 80%, often first presenting symptom
- Abnormal deposits **alpha-synuclein (Lewy Bodies)**
- Can have B-Amyloid Plaques and Neurofibrillary Tangles in DLB

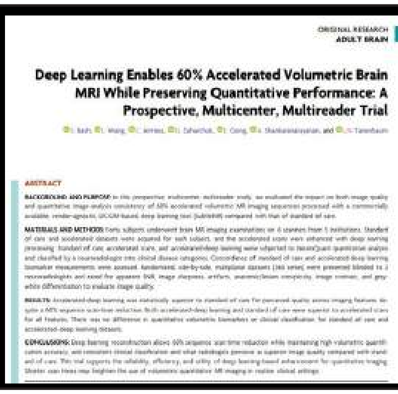










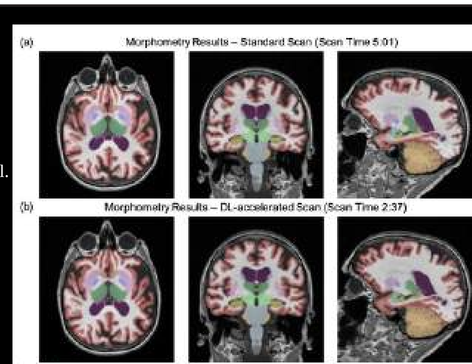

ORIGINAL RESEARCH
ADULT BRAIN

Deep Learning Enables 60% Accelerated Volumetric Brain MRI While Preserving Quantitative Performance: A Prospective, Multicenter, Multireader Trial

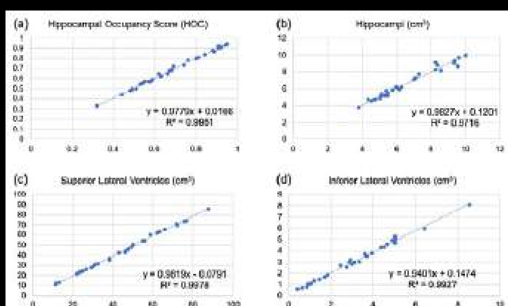
American Journal of Neuroradiology
8/2022

Deep learning and quantitative imaging
Bash, Tanenbaum et al.

Aunt Minnie
Winner
Image of the Year
Semifinalist
Paper of the Year



Quantitative Comparisons: Linear Regression



Alzheimer's Disease and Society

- Almost 7 million Americans suffer from Alzheimer's disease
  - 1/9 people over age 65
- Prevalence doubles every 5 years after the age of 60.
- 1 in 3 seniors will die of dementia.
- Up to 420,000 adults in the prime of life — including people as young as 30 — suffer from early-onset Alzheimer's.

Bash and Tanenbaum App Radiology 2023

Alzheimer's Disease and Society

- Major health population issue.
  - The number of new cases of dementia are expected to double by 2050
  - Since the year 2000, death from heart disease has decreased by 7%, but death from Alzheimer's disease has increased by 145%.

Bash and Tanenbaum Applied Radiology 2023

Alzheimer's Disease and Society

- 355 billion in US Cost in 2021
- Expected to climb to $1.1 trillion U.S. dollars in direct costs by the year 2050 (1)

1. Stefanacci Am J Manag Care 2011;17(suppl 13):S356–S362.

Alzheimer's Disease

- Two types
  - Early Onset (familial <5%)
  - Late Onset (sporadic 95%)
- Risk factors
  - Age
  - Gender (F)
  - Genetics
    - **APOE ε4** is most common genetic risk factor for AD
    - Several genes linked to AD (PSEN1, PSEN2, APP=definite)

S Bash MD

Alzheimer's Disease
modifiable risk factors

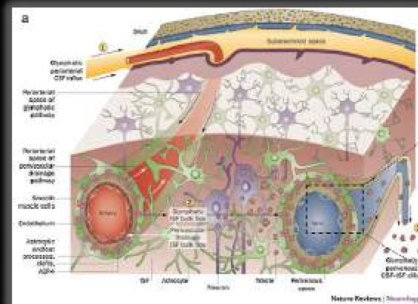
- Smoking
- ETOH
- Obesity/Poor diet
- Lack of exercise
- Poor sleep
- Depression
- Low cognitive engagement / social isolation
- HTN
- DM
- TBI

S Bash MD

APOE and AD

- Apolipoproteins play a role in lipid and cholesterol homeostasis
- 3 APOE gene alleles (ε2, ε3, ε4)
  - ε3 most common (>50% population), ε2 rare and protective
- **APOE ε4 strongest genetic risk factor for AD**
  - Impaired clearance of Aβ plaques
  - 25% of population carries 1 APOE ε4 allele (heterozygous)
    - 3x's risk AD
  - 2-3% of population carries 2 APOE ε4 alleles (homozygous)
    - 12x's risk AD

S Bash MD

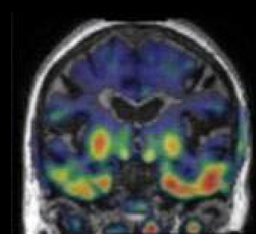


Glymphatic Clearance Pathway

AD pathophysiology
Senile plaques

- Senile plaques are extracellular nonvascular aggregates of Aβ-40 & 42.
  - abnormal processing of amyloid precursor protein by the β-and γ-secretases
  - **imbalance in the production and clearance pathways**.
- Aβ monomers are cleared through enzymatic breakdown and perivascular drainage but may aggregate into larger protein complexes like oligomers, protofibrils, and mature fibrils.
- **Complexes deposit in the brain as amyloid plaques.**
  - Aβ-40 prototype tends to deposit in the vessel wall
    - **cerebral amyloid angiopathy (CAA)**
  - Aβ-42 deposits in the brain parenchyma as **plaques**.

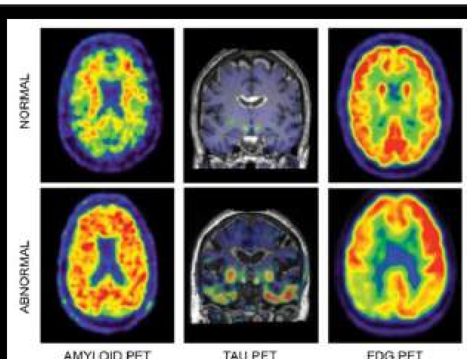
Alzheimer's pathophysiology
Neurofibrillary tangles



- Characterized by intraneuronal protein inclusions resulting from misfolded and abnormally phosphorylated **τ protein** aggregation.
- Most commonly seen in the **entorhinal cortex and hippocampal system** and have the lowest concentration in the sensorimotor regions.

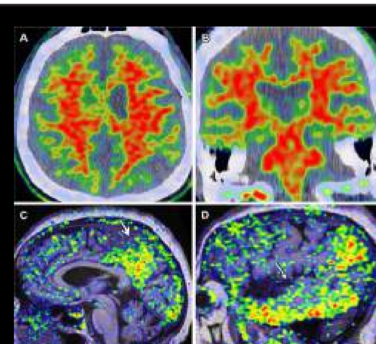
Sevigny et al., Nature 2016

Metabolic imaging signatures in AD



Sevigny et al., Nature 2016

72 yo man with AD



Amyloid

Tau

Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009

RadioGraphics

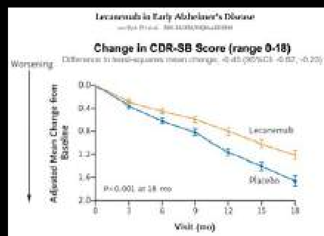
Quantitative PET imaging
centiloids

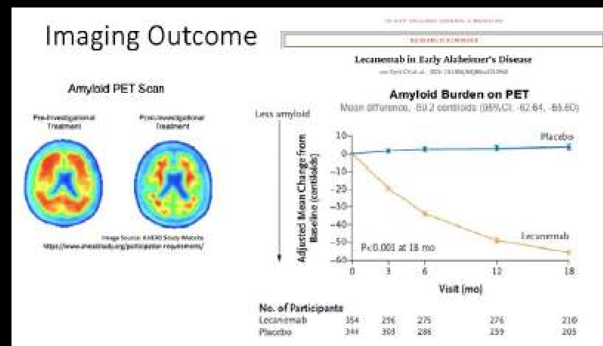
Alzheimer's Disease and Therapy

- **The first therapies are monoclonal antibodies that target, mobilize and promote clearance of Aβ.**
- Hypothesis is that Aβ aggregates trigger critical pathophysiologic events including aggregation of τ tangles, synaptic dysfunction, inflammation, and downstream neurodegeneration and cognitive decline.

Alzheimer's Disease and Therapy
Lecanemab

- First anti-amyloid medication to receive full FDA approval (7/23)
  - accelerated approval 1/23
- Trial patients with mild cognitive impairment and mild AD dementia showed a **27% slower rate of cognitive decline** based on Clinical Dementia Rating Sum of Boxes (CDR-SB).
  - Phase 3 CLARITY AD trial





Alzheimer's Disease and Therapy
Lecanemab

- Eisai expects the $26,500-per-year drug to bring in $360 million in fiscal year 2024
- Patient volumes
  - Eisai hoped to expand to 10,000 patients by 4/24.
  - By 1/26/24, just 2,000 patients were taking the drug, with another 8,000 or so on a waiting list.

Alzheimer's Disease and Therapy
Lecanemab

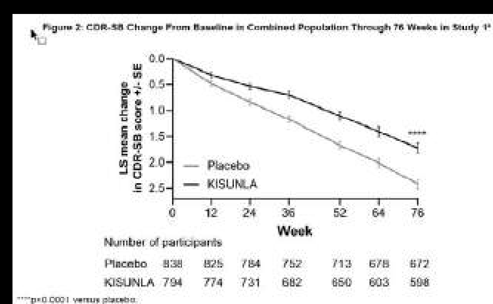
- Pending FDA submission for Leqembi as an IV maintenance therapy, which could be dosed once a month versus every two weeks.
- SQ formulation was more effective than the IV version at clearing amyloid with a similar ARIA risk

Alzheimer's Disease and Therapy
Donanemab – Kisunla (FDA 7/24)

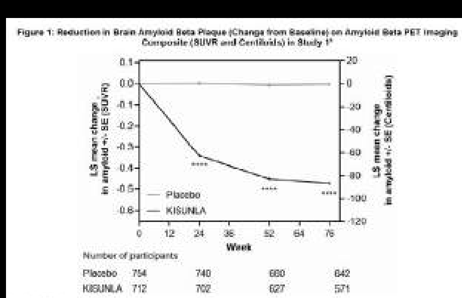
- Dramatic reduction in plasma P-tau217
- 29% slowing of cognitive decline at 18 months.
- 35% slowing in patients with low/medium τ burden
- Nearly half of the lower τ burden group were considered stable per CDR-SB test results at 1 year
- No disease progression at 1 year in early half of patients

TRAILBLAZER-ALZ 2 phase 3 clinical trial

Efficacy Kisunla PI CDR-SB



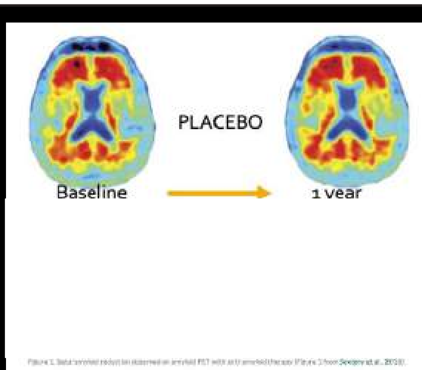
Efficacy Kisunla PI Clearance



Alzheimer's Disease and Therapy
Donanemab – Kisunla (7/24)

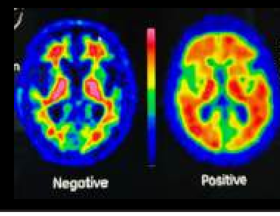
- 12-month monthly infusion course of the drug costs $32,000
  - Price varies since it is administered until it clears the majority of amyloid plaques
  - Infusions of Leqembi, given every two weeks indefinitely, cost $26,500 per year.
- FDA recommended patients get tested for APOE.
  - People who carry two copies of APOE4 have a higher chance of developing Alzheimer's, and are more susceptible to ARIA.

Donanemab



Role of PET in ATT/Alzheimer's Disease

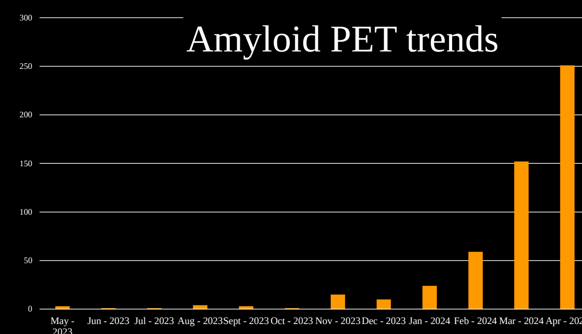
- Confirmation of amyloid burden is required
  - Amyloid PET
  - Lumbar puncture / CSF



Reimbursement for PET in AD

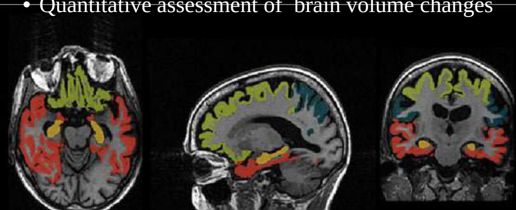
- Negative NCD rescinded 10/23 and no new national coverage decision anticipated
- CMS believes there will be consistent evidence based coverage via administrative contractors or MACs
- Payments occurring nationwide

Amyloid PET trends



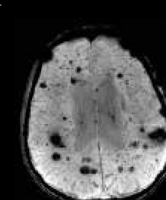
Historic Role of MRI in Alzheimer's Disease

- Exclude "treatable causes" of cognitive impairment
- Quantitative assessment of brain volume changes

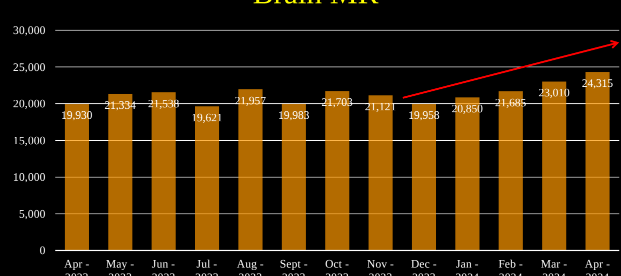


Role of MRI in ATT/Alzheimer's Disease

- Recent MRI required pre-treatment to screen for conditions that increase risk of hemorrhage
  - Prior bleeding
  - Stroke
  - Vascular lesions



Brain MR



WARNING: AMYLOID RELATED IMAGING ABNORMALITIES

Monoclonal antibodies directed against aggregated forms of beta amyloid, including LEQEMBI, can cause amyloid related imaging abnormalities (ARIA), characterized as ARIA with edema (ARIA-E) and ARIA with hemosiderin deposition (ARIA-H). Incidence and timing of ARIA vary among treatments. ARIA usually occurs early in treatment and is usually asymptomatic, although serious and life-threatening events rarely can occur. Serious intracerebral hemorrhages, some of which have been fatal, have been observed in patients treated with this class of medications *[see Warnings and Precautions (5.1), Adverse Reactions (6.1)]*.

ApoE ε4 Homozygotes

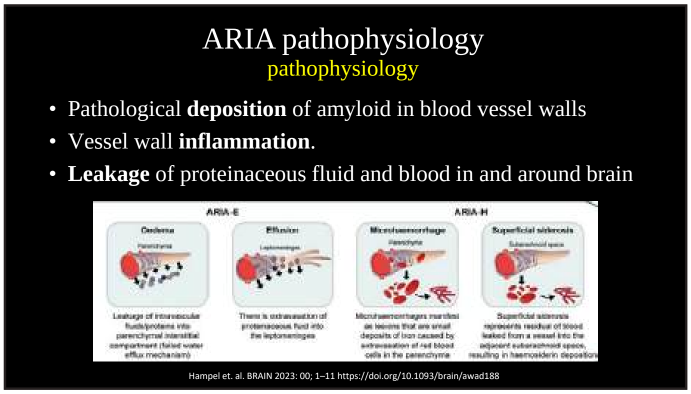
Patients who are apolipoprotein E ε4 (ApoE ε4) homozygotes (approximately 15% of Alzheimer's disease patients) treated with this class of medications, including LEQEMBI, have a higher incidence of ARIA, including symptomatic, serious, and severe radiographic ARIA, compared to heterozygotes and noncarriers. Testing for ApoE ε4 status should be performed prior to initiation of treatment to inform the risk of developing ARIA. Prior to testing, prescribers should discuss with patients the risk of ARIA across genotypes and the implications of genetic testing results. Prescribers should inform patients that if genotype testing is not performed they can still be treated with LEQEMBI; however, it cannot be determined if they are ApoE ε4 homozygotes and at higher risk for ARIA *[see Warnings and Precautions (5.1)]*.

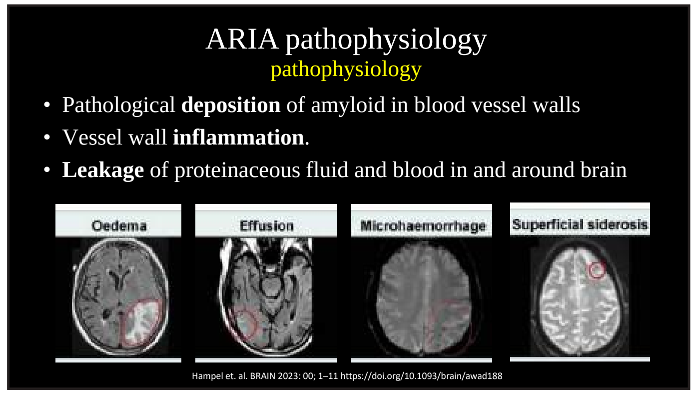
Consider the benefit of LEQEMBI for the treatment of Alzheimer's disease and potential risk of serious adverse events associated with ARIA when deciding to initiate treatment with LEQEMBI *[see Warnings and Precautions (5.1) and Clinical Studies (14)]*.

ARIA

Amyloid Related Imaging Abnormalities

Leqembi PI


ARIA pathophysiology
pathophysiology
Pathological **deposition** of amyloid in blood vessel walls
Vessel wall **inflammation.**
Leakage of proteinaceous fluid and blood in and around brain
ARIA-E
ARIA-H
Oedema
Effusion
Microhaemorrhage
Superficial siderosis
Hampel et. al. BRAIN 2023: 00; 1–11 https://doi.org/10.1093/brain/awad188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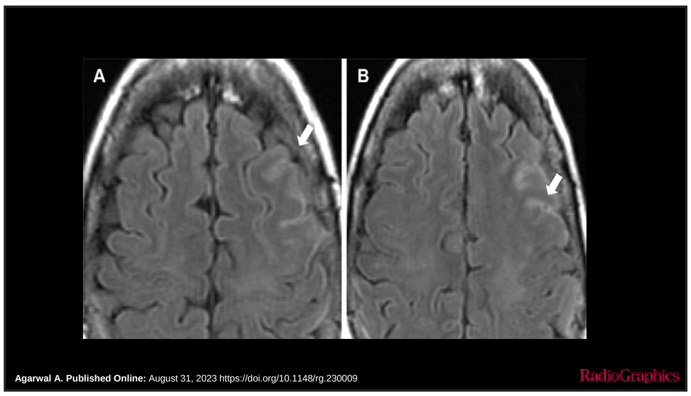
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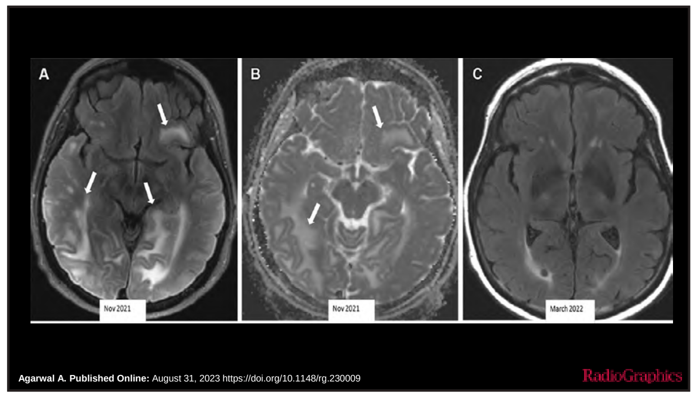
Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009
RadioGraphics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Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009
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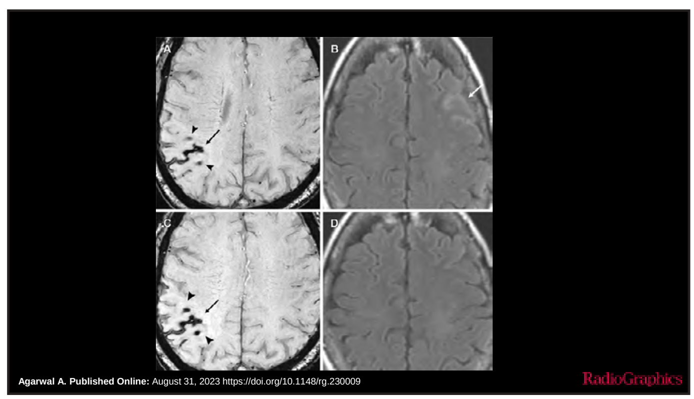
ARIA surveillance
C
AJNR
P.M. Cogswell et al. AJNR Am J Neuroradiol 2022;43:E19-E35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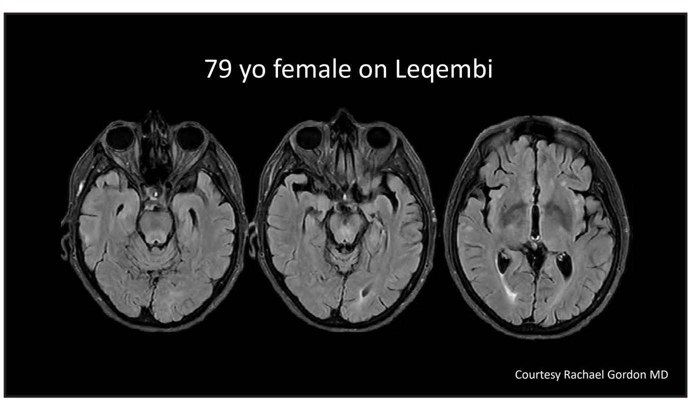
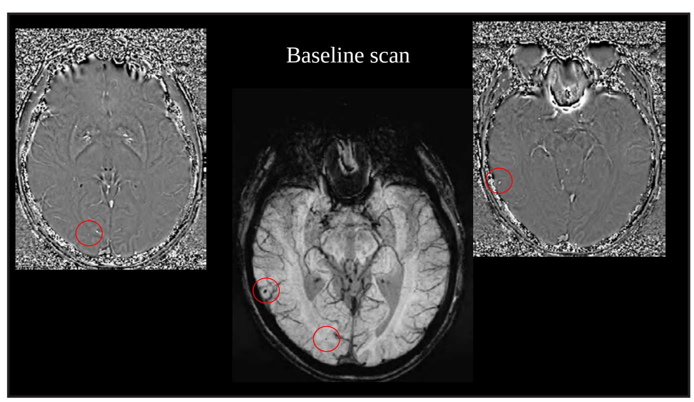
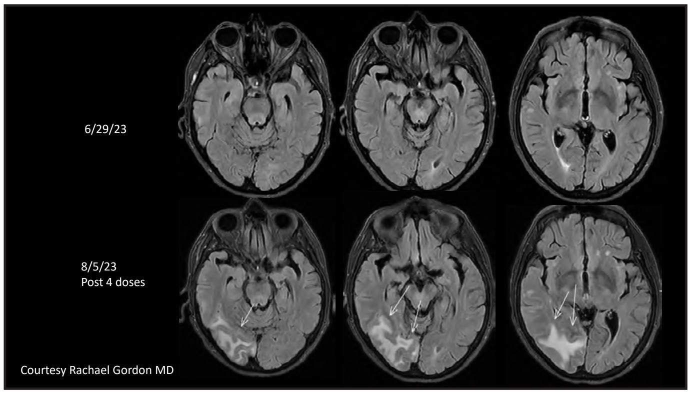
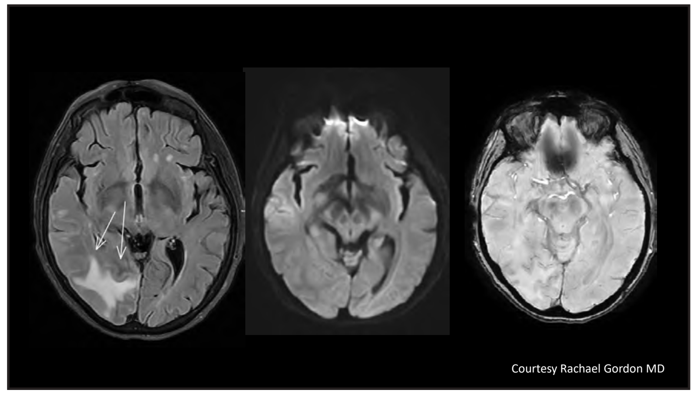
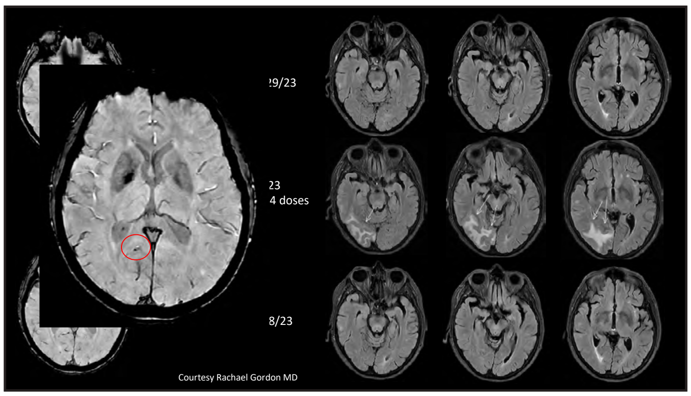
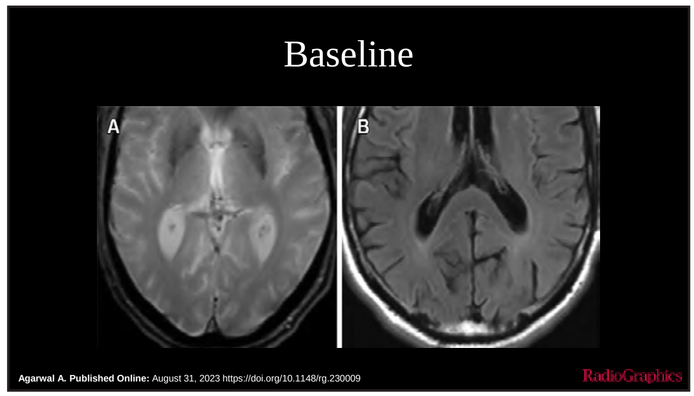

79 yo female on Leqembi
Courtesy Rachael Gordon MD

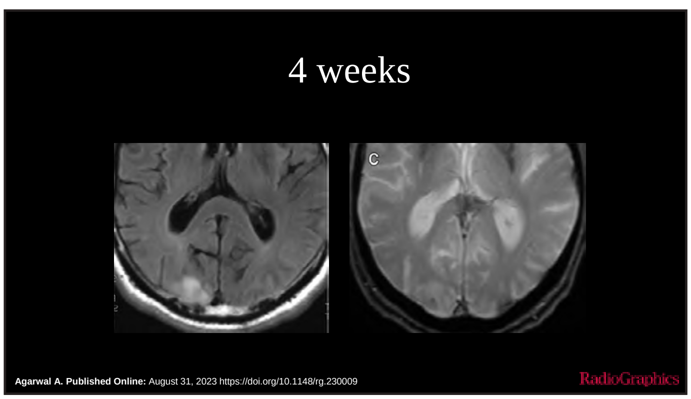

Baseline scan

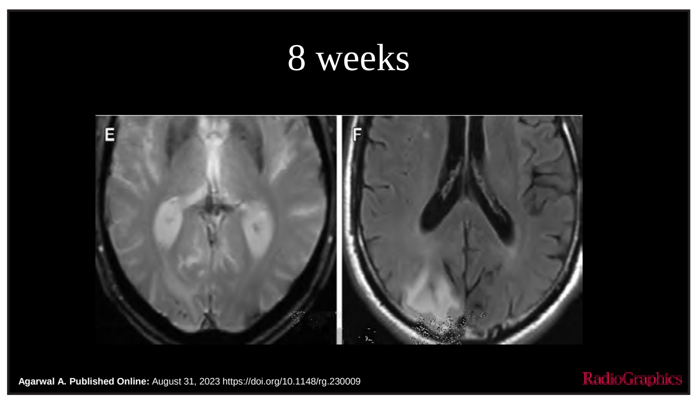












ARIA

- Majority of ARIA events are mild and self-limited
- Serious events have been reported
  - 2.9% of patients with ARIA-E, 0.8% for those with ARIA-H
  - 3 cases of death in the phase 3 trial of Lecanemab
  - 3 deaths deemed related to ARIA in Donanemab Phase 3 (N=853), 2 more in OLE only one deemed related to the drug.
- Risk increased in APOE-ε4 carriers (esp. homozygotes) and underlying amyloid angiopathy

ARIA risk

- ~2x more likely to develop ARIA on Kisunla.
  - Kisunla 37%
  - Leqembi 21%
- ARIA-E
  - 24% of people on Kisunla
  - 12.6% of people on Leqembi.
- ARIA-H
  - 31.4% of people on Kisunla
  - 17.3% of people on Leqembi.

ARIA surveillance - Lecanemab

- MRI Safety monitoring
  - Before the **5th, 7th, and 14th biweekly doses** of lecanemab per prescriber information.
  - Clinical guidelines may suggest additional scanning at 6 month intervals
- More time points for certain groups such as APOE-e4 carriers (15% of AD) and those with prior episodes of ARIA.

ARIA monitoring - Donanemab

- Safety monitoring with MRI before **the 2^{nd}, 3^{rd}, 4^{th} and 7^{th} monthly doses**.
- Clinical guidelines may suggest additional scanning at 6 month intervals
- More time points for certain groups such as APOE-e4 carriers and those with prior episodes of ARIA.

Detection and quantification

	MILD	MODERATE	SEVERE
Siderosis (new)	1	2	> 2
Microbleeds (new)	</= 4	5-9	10+
Edema/effusion	Uni < 5cm	Multi or 5-10 cm	> 10cm

Dosing and ARIA-E monitoring

Continue dosing
Mild ARIA-E and (mild*or) absent symptoms

Suspend dosing
Moderate to severe ARIA-E / symptoms

	MILD	MODERATE	SEVERE
Siderosis	1	2	> 2
Microbleeds	</= 4	5-9	10+
Edema/effusion	Unifocal < 5cm	Multi or 5-10 cm	> 10cm

Dosing and ARIA-H monitoring

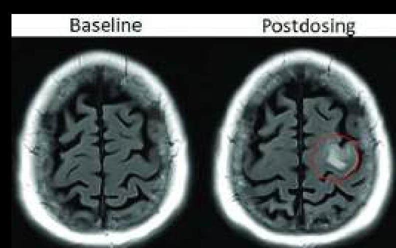
Continue dosing
Mild ARIA-H and absent symptoms

Suspend dosing
Any symptoms or moderate to severe ARIA.

	MILD	MODERATE	SEVERE
Siderosis	1	2	> 2
Microbleeds	</= 4	5-9	10+
Edema/effusion	Unifocal < 5cm	Multi or 5-10 cm	> 10cm

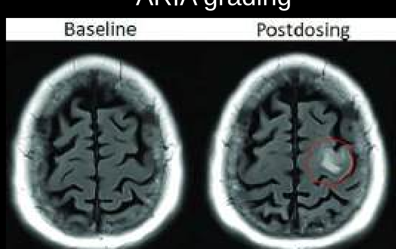
*Focal hemorrhage >1cm suspend dosing

ARIA surveillance



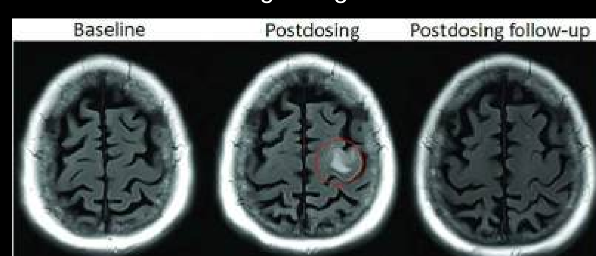
P.M. Cogswell et al. AJNR Am J Neuroradiol 2022;43:E19-E35

ARIA grading



Uni < 5cm	Multi or 5-10 cm	> 10cm

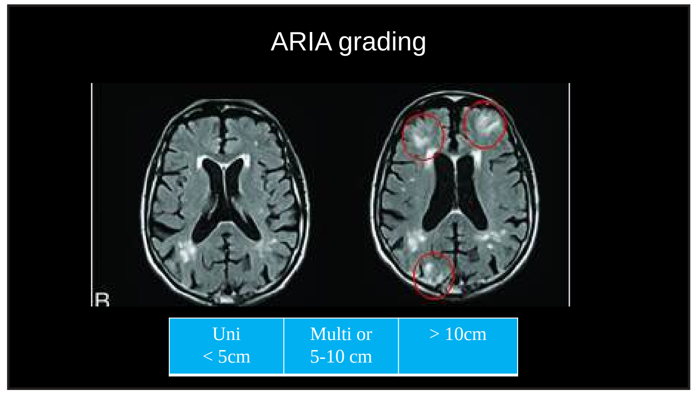
ARIA grading - MILD



Uni < 5cm	Multi or 5-10 cm	> 10cm

→ Continue therapy


ARIA surveillance
R
AJNR
P.M. Cogswell et al. AJNR Am J Neuroradiol 2022;43:E19-E35


ARIA grading
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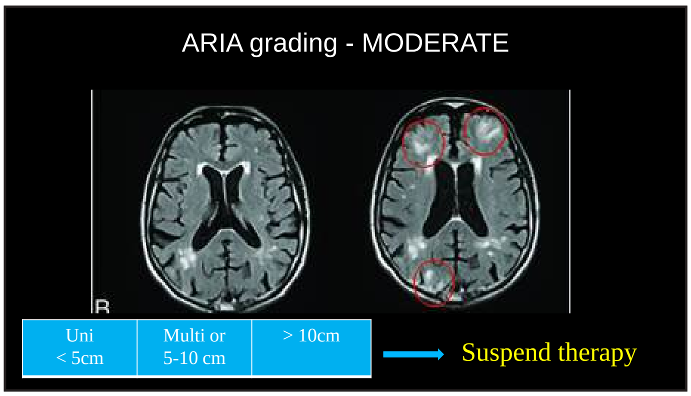
ARIA grading - MODERATE
R
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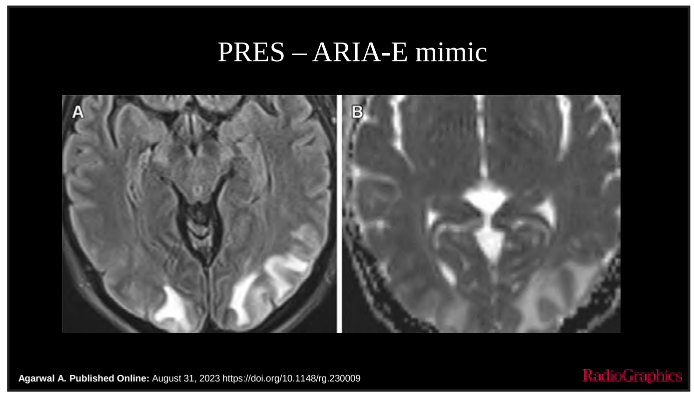
Multi or
5-10 cm
> 10cm
Suspend therapy


PRES – ARIA-E mimic
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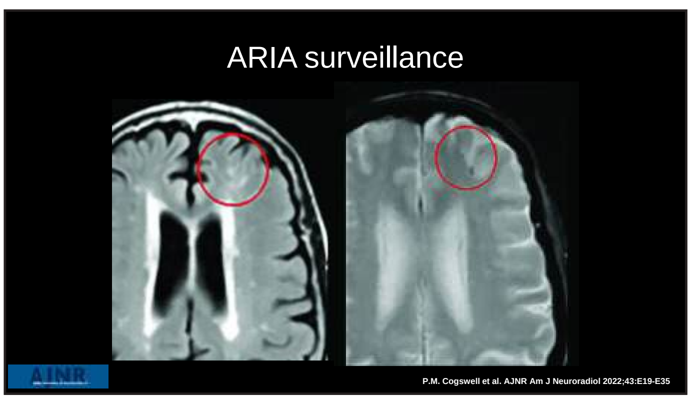
ARIA surveillance
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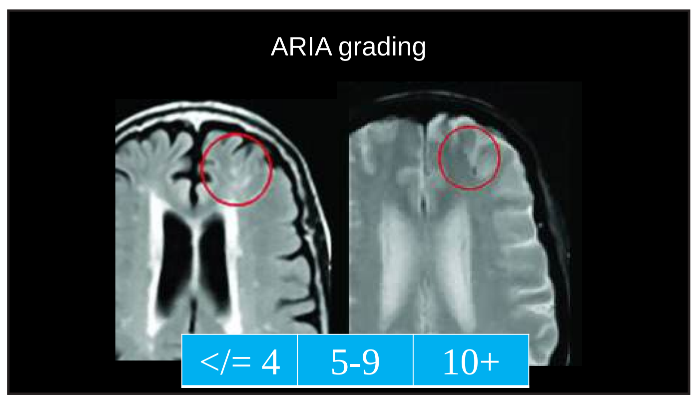
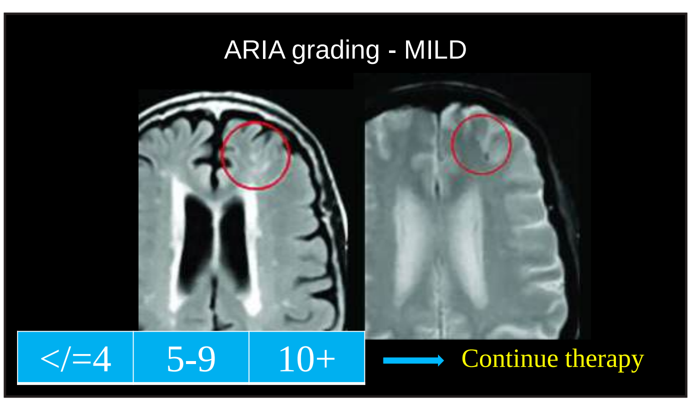
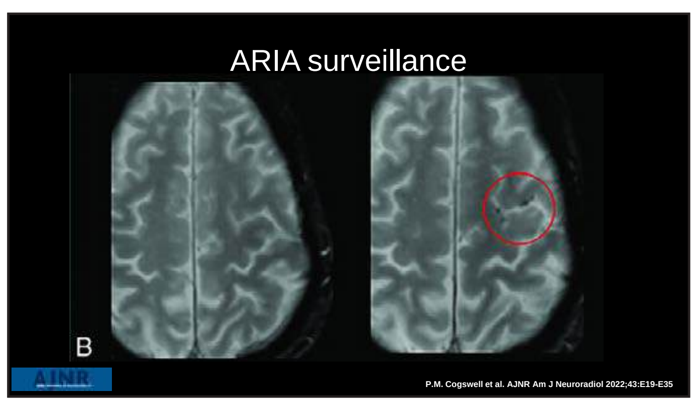
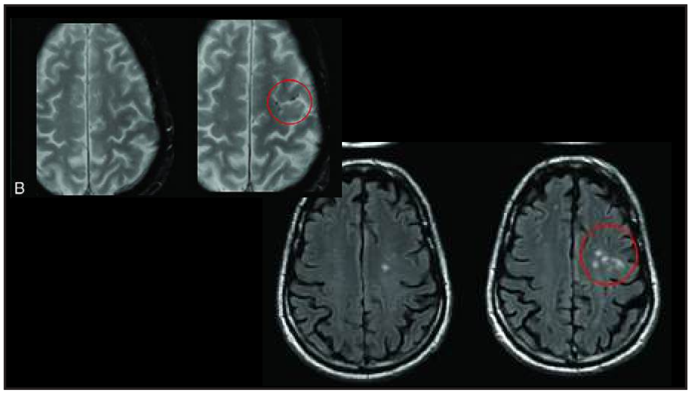
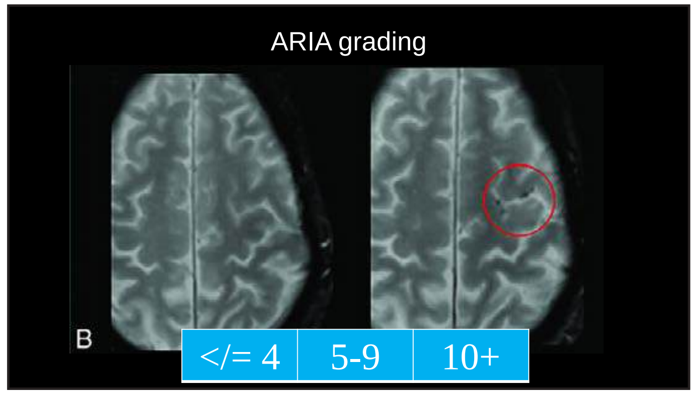
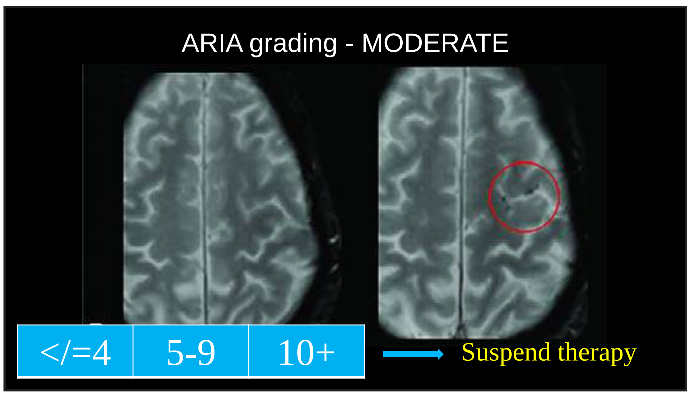

ARIA grading
</= 4
5-9
10+

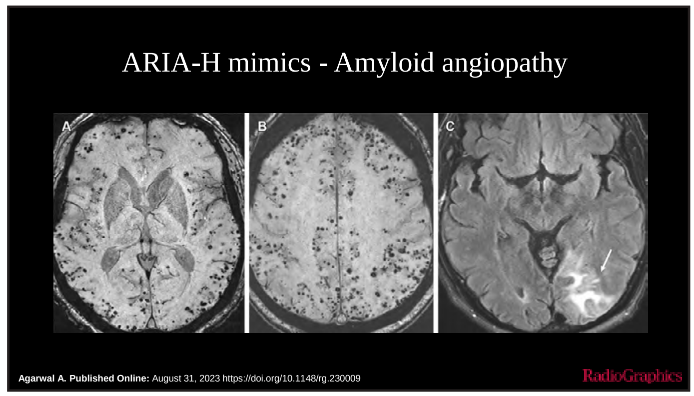

ARIA grading - MILD
</=4
5-9
10+
Continue therapy

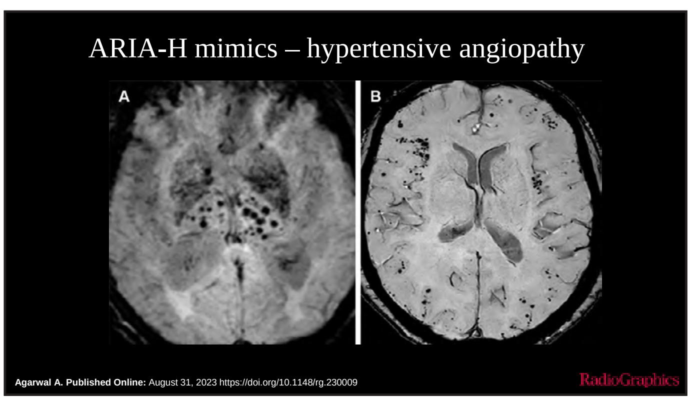

ARIA surveillance
B
AJNR
P.M. Cogswell et al. AJNR Am J Neuroradiol 2022;43:E19-E35

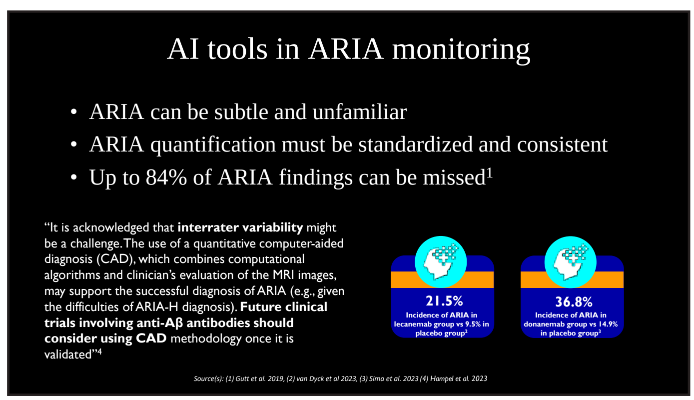

B

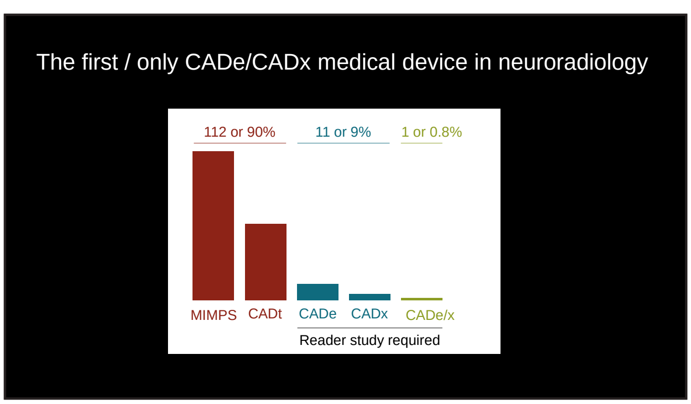

ARIA grading
B
</= 4
5-9
10+

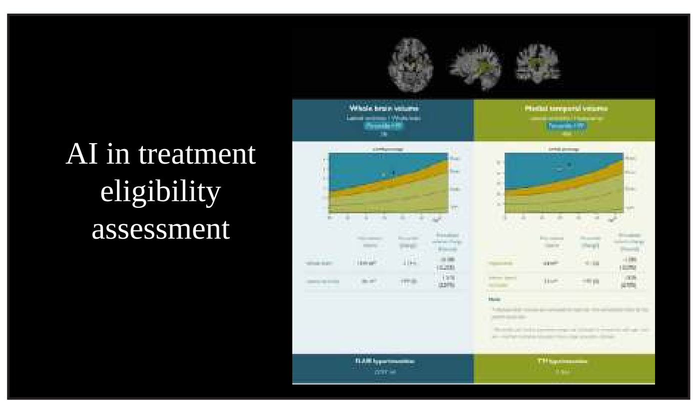

ARIA grading - MODERATE
</=4
5-9
10+
Suspend therapy

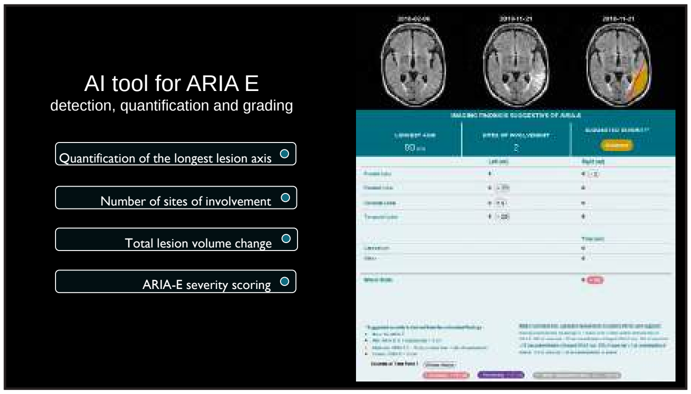

ARIA-H mimics - Amyloid angiopathy
A
B
C
Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009
RadioGraphics

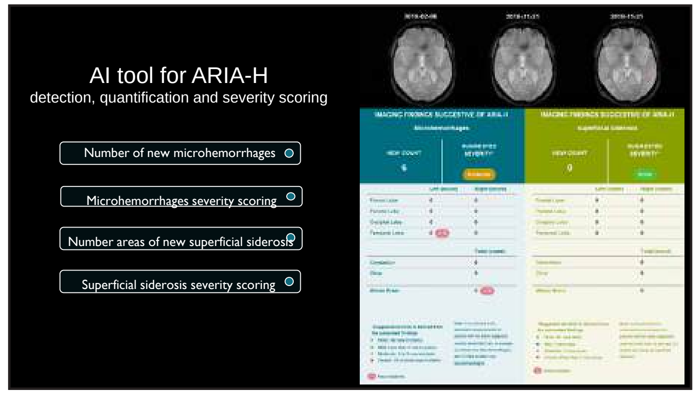

ARIA-H mimics – hypertensive angiopathy
A
B
Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009
RadioGraphics

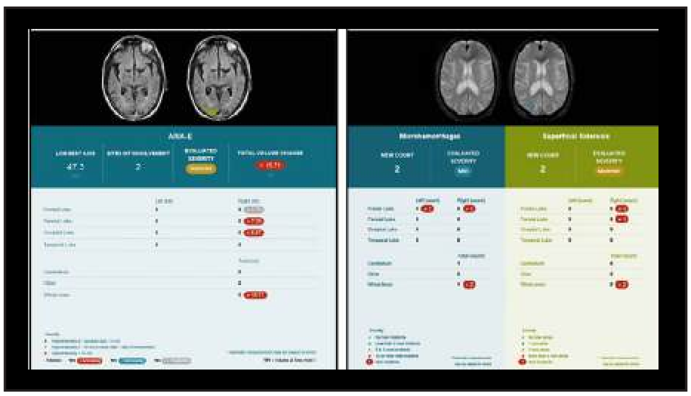

AI tools in ARIA monitoring
• ARIA can be subtle and unfamiliar
• ARIA quantification must be standardized and consistent
• Up to 84% of ARIA findings can be missed[1]
"It is acknowledged that interrater variability might be a challenge. The use of a quantitative computer-aided diagnosis (CAD), which combines computational algorithms and clinician's evaluation of the MRI images, may support the successful diagnosis of ARIA (e.g., given the difficulties of ARIA-H diagnosis). Future clinical trials involving anti-Aβ antibodies should consider using CAD methodology once it is validated"[4]
21.5%
Incidence of ARIA in lecanemab group vs 9.5% in placebo group[2]
36.8%
Incidence of ARIA in donanemab group vs 14.9% in placebo group[3]
Source(s): (1) Gutt et al. 2019, (2) van Dyck et al 2023, (3) Sims et al. 2023 (4) Hampel et al. 2023

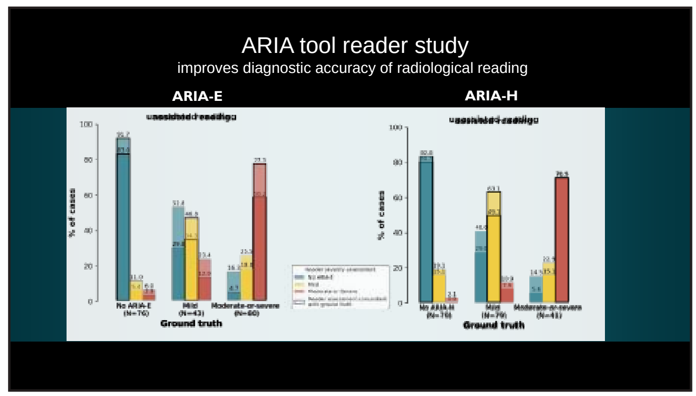

The first / only CADe/CADx medical device in neuroradiology
112 or 90%
11 or 9%
1 or 0.8%
MIMPS
CADt
CADe
CADx
CADe/x
Reader study required

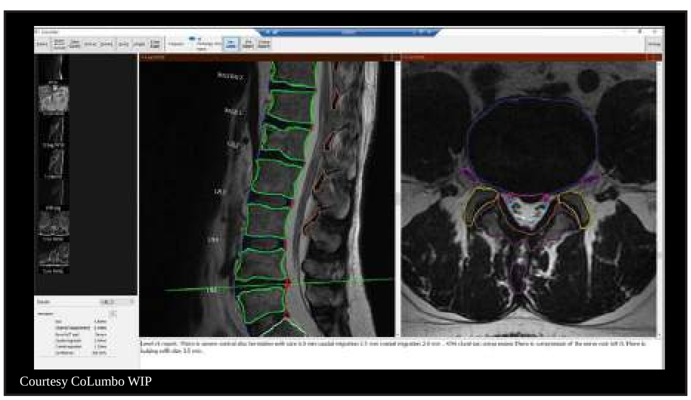

AI in treatment eligibility assessment

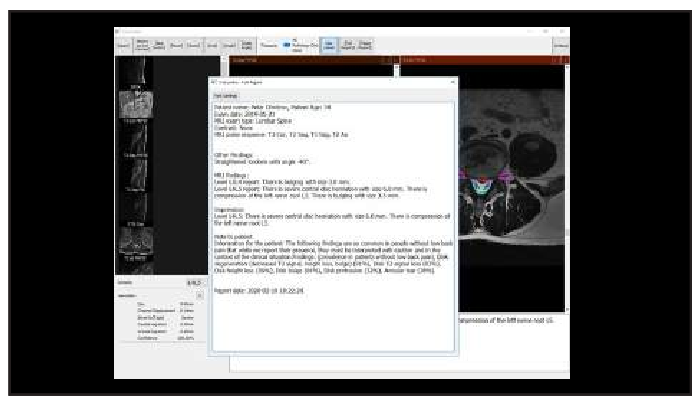

AI tool for ARIA E
detection, quantification and grading
Quantification of the longest lesion axis
Number of sites of involvement
Total lesion volume change
ARIA-E severity scoring

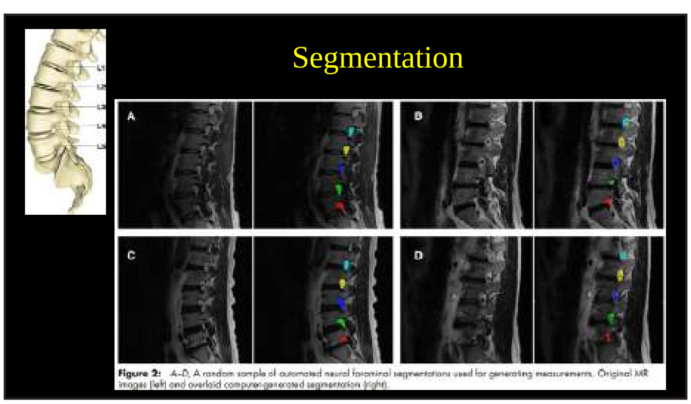

AI tool for ARIA-H
detection, quantification and severity scoring
Number of new microhemorrhages
Microhemorrhages severity scoring
Number areas of new superficial siderosis
Superficial siderosis severity scoring

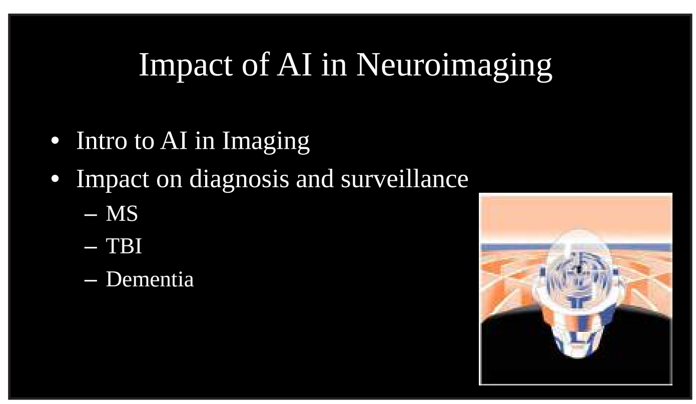



ARIA tool reader study
improves diagnostic accuracy of radiological reading
ARIA-E
ARIA-H
% of cases
Ground truth
Ground truth


Courtesy CoLumbo WIP




Segmentation
Figure 2: A–D, A random sample of automated neural foraminal segmentations used for generating measurements. Original MR images (left) and overlaid computer-generated segmentations (right).


Impact of AI in Neuroimaging
• Intro to AI in Imaging
• Impact on diagnosis and surveillance
– MS
– TBI
– Dementia

SELF EVALUATION

AI and Quantitative Neuroimaging

1. Place these technologies in chronological order of their development:

a. Machine learning
b. Agents
c. Neural networks
d. Foundational models
e. Large language models

2. Current or potential benefits of AI in the imaging enterprise. Which is least correct?

a. Utilization and no-show management
b. Medical record review
c. Protocol selection
d. Independent image review and reporting
e. On device triage
f. Enhanced Image reconstruction
g. Assisted report generation

3. AI for image reconstruction. Which is false?

a. Improve accuracy of image reporting
b. Improve the SNR or reduce the scan times of MR
c. Reduce the dose necessary for CT
d. Enhance spatial resolution
e. Maintain the quantitative accuracy of traditional reconstruction

4. Which is false?

a. AI enhanced QNI tools improve intra and inter-reader agreement and highlight changes over time.
b. DL based image reconstruction techniques corrupt quantitation but denoise, sharpen and reduce scan times.
c. Paradoxically, AI makes hard problems easy and excels especially when context is important.
d. Machine performance now exceeds that of humans in image and speech recognition
e. Volumetric scanning techniques in a range of contrasts including T1, and FLAIR enhance quantification.

5. AI in quantitative neuroimaging: which is false

a. Image segmentation may benefit from both machine learning and deep learning enhancement.
b. Quantitative tools can add value in detection, characterization, and workflow.
c. Quantitative assessment can add value in improving communication with treatment team, streamlining clinical decision making and informing outcomes
d. Dementias have characteristic volume loss 'phenotypes' and AI can assist in detecting regionally specific volume loss in Lewy body dementia.
e. White matter lesions are the most characteristic feature of vascular dementia.

Answer Key: 1. a, c, e, d, b, 2. D, 3. A, 4. C, 5. D

Pediatric GU Emergencies
Summer L. Kaplan, MD

Objectives

After this presentation, the participant will be able to:

1. Discuss imaging of non-traumatic, non-oncological urinary tract emergencies in children
2. List features used for grading neonatal urinary tract obstruction
3. Describe non-traumatic, non-oncological gonadal emergencies that occur in children


14-year old w/ flank pain, fever

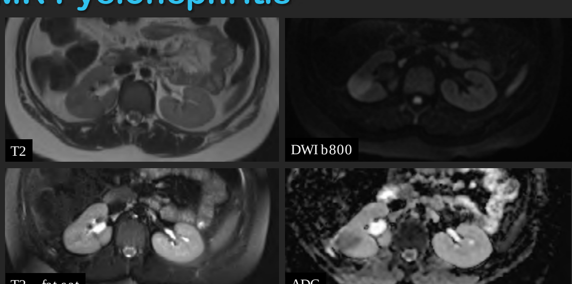
9-year old, flank pain and dysuria

Pyelonephritis

14-year old w/ flank pain, fever

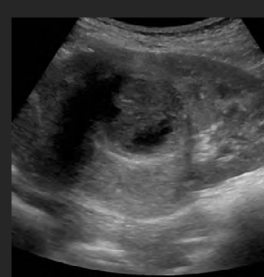
- Warrants evaluation for vesicoureteral reflux
- US sensitivity low
  - Improved using power Doppler, B-mode, or very low doppler gain
- Incidental on CT or MR

MR Pyelonephritis



15-year old w/ right abdominal pain

Renal Abscess



5-month old w/ fever

Cystitis

- Diagnosis of exclusion
- US swirling debris
  - Infection, blood products, precipitates
- Bladder thick walled, hyperemic = low specificity
- Related to constipation
  - Assess rectosigmoid stool burden

1-month old w fever

Pyonephrosis

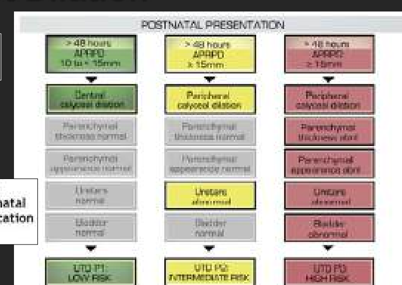
1-month old w fever

- Not closed system
  - Treated medically
  - Evaluate for vesicoreteral reflux
- US findings
  - Swirling debris
  - Urothelial thickening may be infectious or chemical irritation

Urinary Tract Dilation

Anterior-Posterior Renal Pelvis Diameter (APRPD)

Multidisciplinary consensus on the classification of prenatal and postnatal urinary tract dilation (UTD classification system)

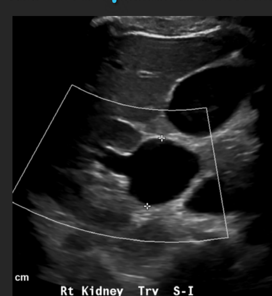


Nguyen HT et al, J Pediatr Urology 2014

Ureteral dilation

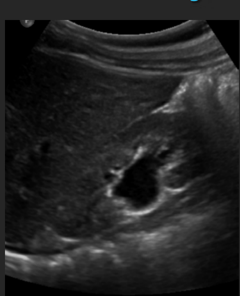
- Degree of dilation may depend on bladder fullness
- Assess
  - Complex debris
  - Urothelial thickening
  - Tortuosity

Renal pelvis dilation



- Transverse plane
  - Antero-posterior
  - Measure at the hilum
  - < 1 cm diameter is normal
- Age < 48-hours old may be falsely enlarged from residual antenatal circulating volumes
- May be falsely normal in first month of life
  - Follow up at 6 month for high suspicion

Central calyceal dilation



- Collection system within parenchyma
- Does not outline the renal pyramids
- Assess debris, urothelial thickening

Peripheral calyceal dilation

- Branches from central calyx
  - Outlines renal pyramids
- Assess parenchymal thinning
- Assess parenchymal echogenicity
  - Infant kidney normally echogenic to liver
  - Compare with other side

UTD vs VUR

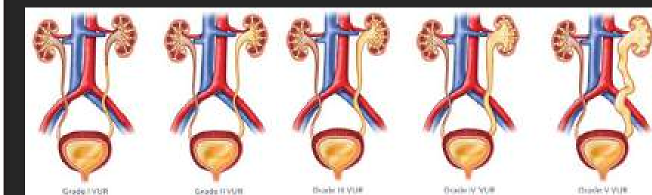
Urinary Tract Dilation (UTD) grades urological risk

Vesicoureteral reflux (VUR) is a disease process

UTD P3: High risk

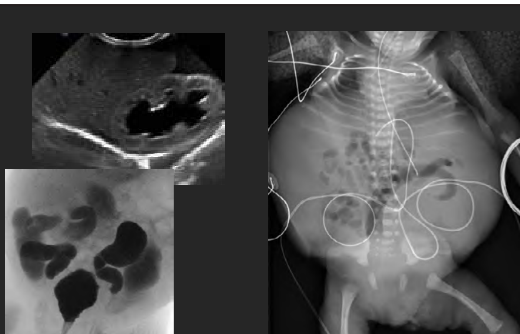
Grade 5 VUR

Vesicoureteral reflux (VUR)



www.chop.edu/conditions-diseases/vesicoureteral-reflux-vur#

Assessed with fluoroscopic voiding cystourethrogram (VCUG) or contrast-enhanced voiding urosonography (ceVUS)



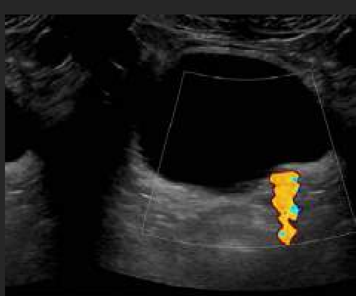
0-day old w/ prenatal abnormalities

Prune Belly Syndrome

0-day old w/ prenatal abnormalities

- "Eagle-Barrett Syndrome"
- Triad:
  - Absent abdominal wall muscles
  - Lower urinary tract obstruction (LUTO)
  - Cryptorchidism (<5% female)
- LUTO due to smooth muscle deficiency, ineffective peristalsis

Ureterovesicular Junction Obstruction



- Obstrution vs reflux
  - Assess for shadow, twinkle, ureteral jets
  - Can also look for reflux with color Doppler
- Consider scarring from prior inflammation or instrumentation

Ureteropelvic Junction Obstruction

- Often crossing vessel
  - Symptomatic with body growth
- Detect w US
- Diagnose w CTA

US appearance of stones

- Echogenicity
- Posterior shadowing
- Twinkle

- 60% false pos

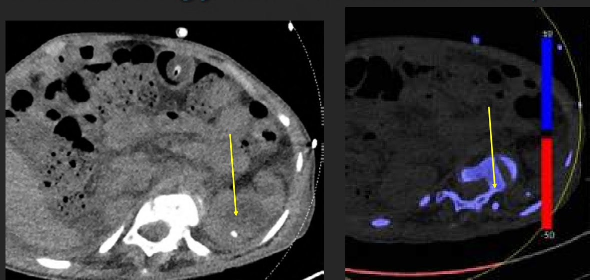
All 3 findings
- 95% specific
- 31% sensitive

Pediatric Urolithiasis

- Positive family history
- Solute excretion abnormality
- Urinary tract malformations
- Inflammatory bowel
- Cystic fibrosis
- Immobility

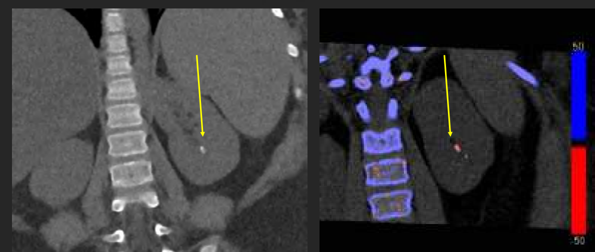
Types
- Calcium oxalate
- Struvite (infectious)
- Uric acid
- Cystine

Dual Energy CT - Calcium Map



Calcium Oxalate

Dual Energy CT - Calcium Map

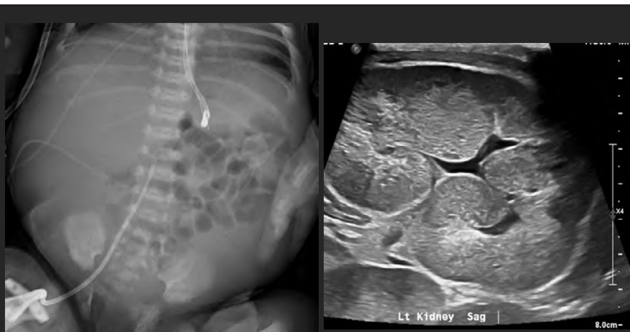


Uric Acid

Medullary nephrocalcinosis

Neonatal Tamm-Horsfall Proteins

- "Uromodulin"
- Protein accumulation at distal tubules
  - Maternal circulating creatinine
- Appear like "milk of calcium"
- Normal variant
  - 0 – 3-months old



2-do, abdominal distention

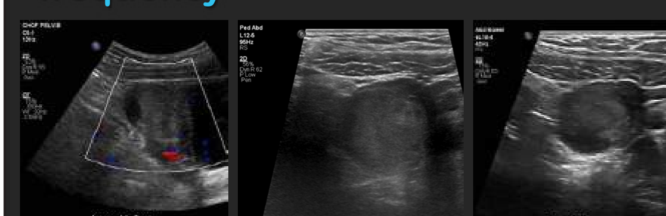
Autosomal Recessive PCKD

- Autosomal recessive polycystic kidney disease
- PKHD1 mutation, with renal cysts and early hepatic fibrosis
  - Ciliopathy
- Respiratory cause of death may occur due to underdevelopment of lung

Pelvis US in Girls

- Transabdominal – fill the bladder
  - ≤ 6-years old = 75 ml
  - 7-years old – menarche = 150 ml
  - Menarchal = 250 ml
- TV only if sexually active, but may not be advisable
- MR is useful
  - Contrast for torsion or mass

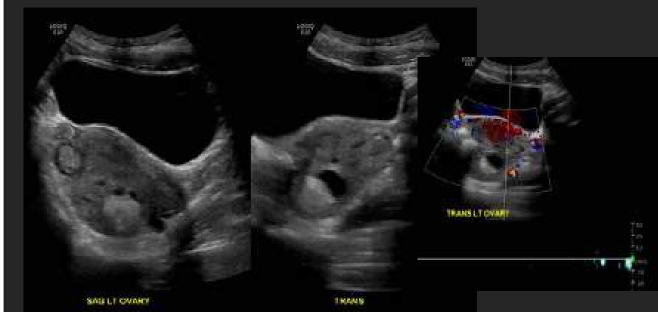
Troubleshooting: Use higher frequency



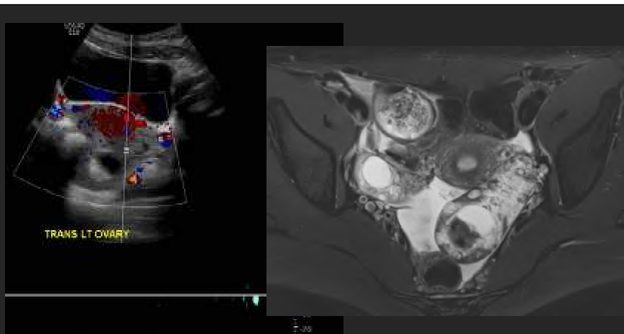
5-1 12-5 18-4

Hemorrhagic Ovarian Cyst

11-year old w/ left lower quadrant pain

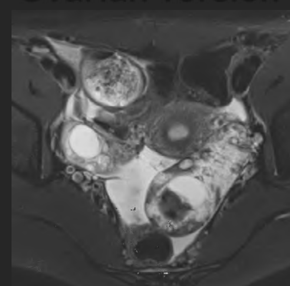


15-year old w/ left lower quadrant pain



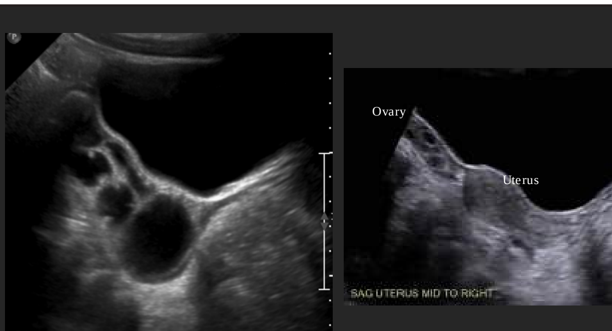
15-year old w/ left lower quadrant pain

Ovarian Torsion



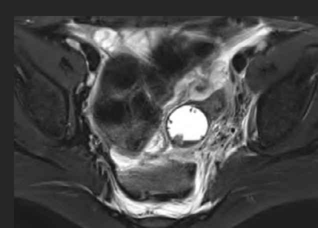
- Absent venous flow
- Absent arterial flow
- Ovary > 2.5x larger than other
- Follicles peripheral and round
- Postero-medial location

15-year old w/ left lower quadrant pain

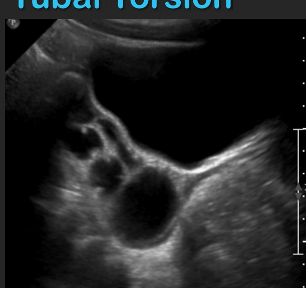


15-year old w/ right lower quadrant pain

Tubal Torsion

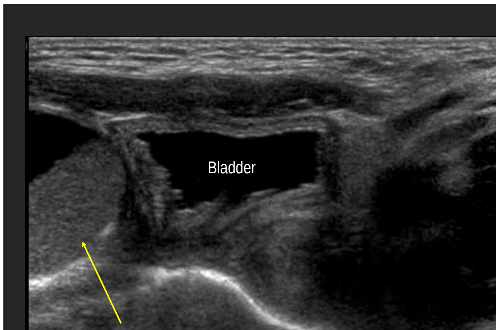


Tubal Torsion



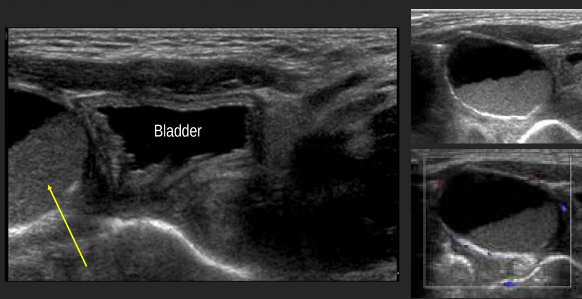
- Signs of tubal torsion
  - “spokewheel”
- Often associated with paratubal/adnexal cyst
  - Ovary normal
- Tubular or fluid-filled cysts in pediatric adnexa are tubal torsion until proven otherwise

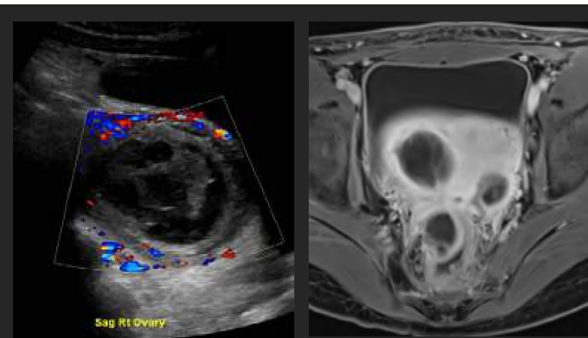
15-year old w/ right lower quadrant pain



0-day old w/ abdominal distention

Prenatal ovarian torsion





12-year old, abdominal pain, fever

Tubo-Ovarian Abscess

12-year old, abdominal pain, fever

- Child abuse evaluation
- However!
  - Non-STD TOA can occur
  - Typically R-side, history of prior appendicitis
  - Immunodeficiency
- Organism e.coli or atypical

14-year old w/ right scrotal pain

14-year old w/ right scrotal pain

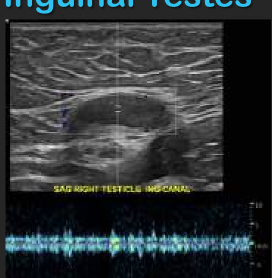
Testicular torsion

14-year old w/ right scrotal pain

- Absent flow
- Whirlpool of cord
- Parenchymal edema
- Transverse position/lie

- 91% accurate combined signs:
  - Decreased/absent flow
  - Whirlpool sign
  - Lacking avascular nodule (appendage torsion)

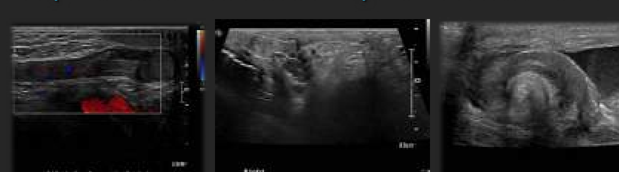
Inguinal Testes



7-month old w/ scrotal pain

- Flow may be difficult to detect
  - Position
  - Patient motion
- Attention to cord

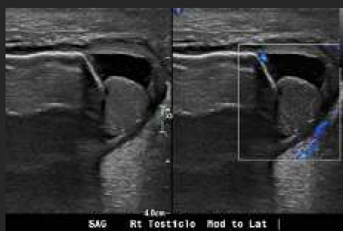
Spermatic Cord for Equivocal Torsion



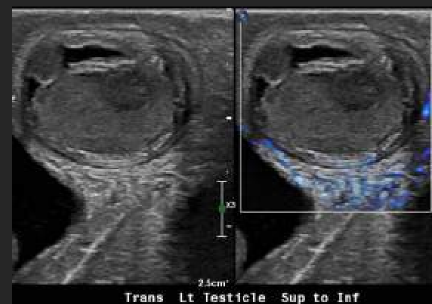
Normal spermatic cord (sagittal) | Twisting cord (transverse) | "Snail Sign" (transverse)

No further imaging | Further imaging not typically required (clinical assessment)

Inguinal obstruction testicular flow

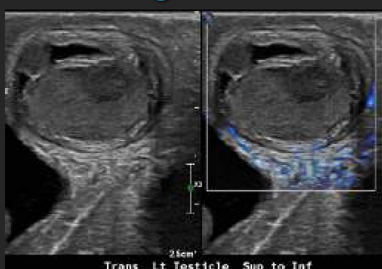


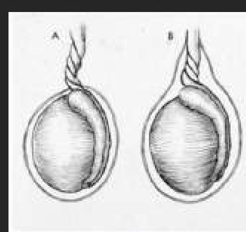
3-weeks old, fussy



4-day old, w/ L testis firm, ecchymotic

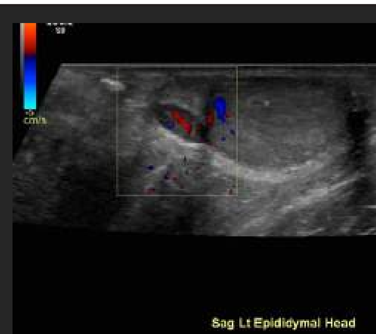
Extravaginal testicular torsion





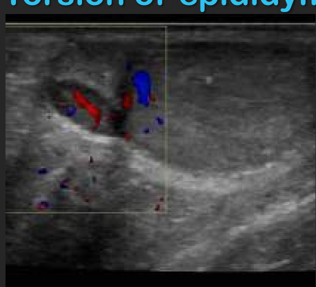
Testicular torsion: (A) extravaginal; (B) intravaginal.

4-day old, w/ L testis firm, ecchymotic



12-year old w/ left testicular pain

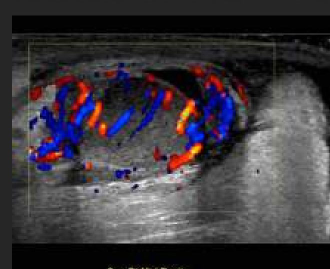
Torsion of epididymal appendage



12-year old w/ left testicular pain

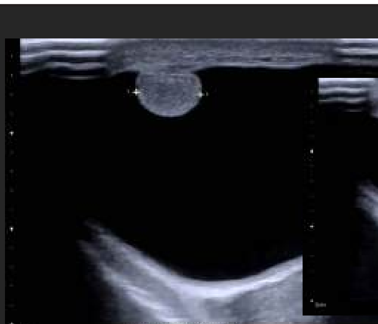
- "Nutmeg" appearance appendage
- Color Doppler usually absent
- Common clinical mimic of testicular torsion

Epididymitis/Orchitis



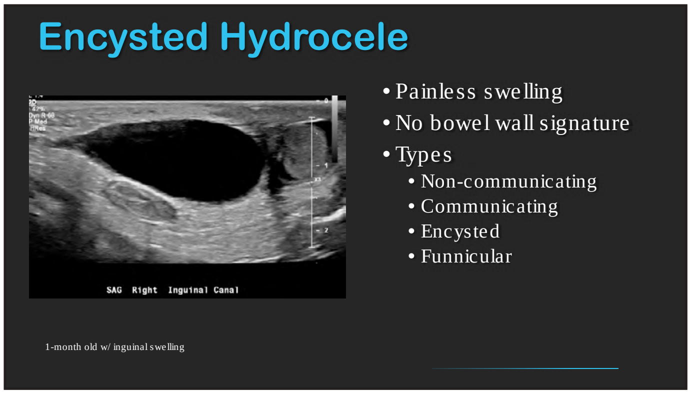
7-year old w/ right testicular pain

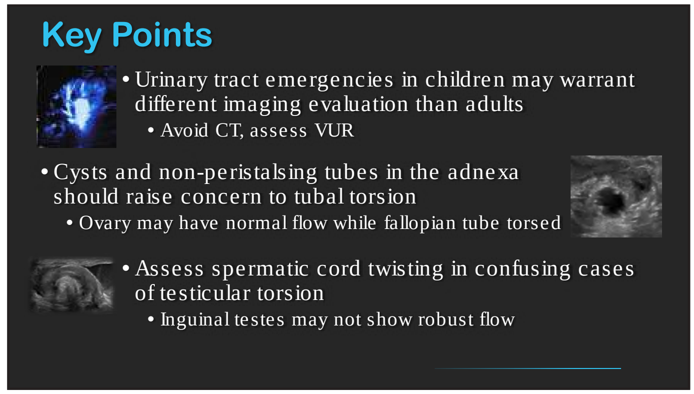
- Hyperemic, hydrocele
- Due to GI flora in children
- Ddx torsion/detorsion
  - Assess spermatic cord
  - Serial evaluations
  - Close follow-ups

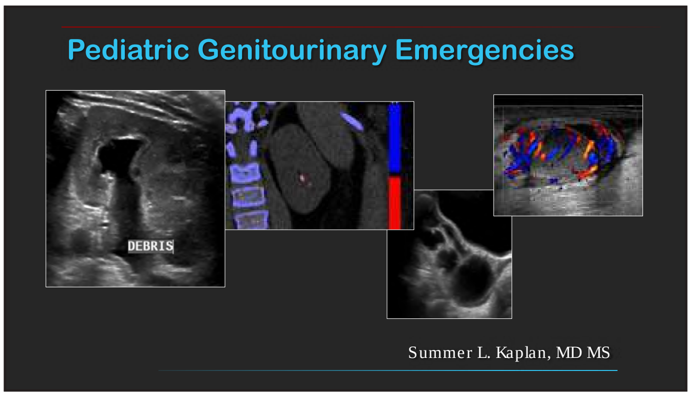


0-day old w/ scrotal swelling

1-month old w/ inguinal swelling


Encysted Hydrocele
SAG Right Inguinal Canal
• Painless swelling
• No bowel wall signature
• Types
• Non-communicating
• Communicating
• Encysted
• Funnicular
1-month old w/ inguinal swelling


Key Points
• Urinary tract emergencies in children may warrant different imaging evaluation than adults
• Avoid CT, assess VUR
• Cysts and non-peristalsing tubes in the adnexa should raise concern to tubal torsion
• Ovary may have normal flow while fallopian tube torsed
• Assess spermatic cord twisting in confusing cases of testicular torsion
• Inguinal testes may not show robust flow


Pediatric Genitourinary Emergencies
DEBRIS
Summer L. Kaplan, MD MS

SELF EVALUATION

Pediatric GU Emergencies

1. The urinary tract dilation consensus classification describes:

a. the degree of vesicoureteral reflux
b. the function of the neonatal kidney
c. the risk of renal impairment
d. the timing of surgery

2. Ureteropelvic junction obstruction is often caused by

a. a crossing vessel
b. anomalous insertion of the ureter
c. ureteral mass
d. atresia

3. T/F - MR can diagnose ovarian torsion

4. Which of the following is true of fallopian tube torsion?

a. It is not emergent
b. The contralateral side may also be torsed
c. It is most common in neonates
d. The ovary may have normal blood flow

5. T/F - Spermatic cord twisting can indicate testicular torsion even when testicular flow remains present.

Answer Key: 1. C, 2. A, 3. T, 4. D, 5. T

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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Lung Cancer Screening Review

Lung Cancer Screening

- Rationale and Importance of Lung cancer screening
- Scientific evidence for Lung cancer screening
- Current recommendations for Lung cancer screening
- How do we screen? LDCT Technique
- Reporting of Lung Cancer Screening
- Potential harms and uncertainties of Lung cancer screening

Rationale and Importance of lung cancer screening

- Leading cause of cancer death worldwide and in the US. 28% of cancer deaths, exceeds the number of deaths from cancers of the breast, colon and prostate combined
- Most important risk factor is smoking (~ 90% of all U.S. Lung ca cases)
- Large population at risk. 37% of U.S. adults are current or former smokers
- Increasing age is also an important risk factor for lung cancer
- Poor prognosis. 90% of patients with Lung ca die of the disease.20.5% 5 yr survival rate
- Early-stage Lung cancer has a better prognosis and is more amenable to treatment. 5-year survival for early stage I NSCLC is 68%.

Lung cancer screening background

- Early randomized screening trials that assessed combinations of CXR and sputum cytology were inconclusive in showing a mortality benefit from screening
- Multidetector helical CT (MDCT) enables the entire lung to be imaged in one breath hold
- **Low dose CT scan (LDCT).** Inherent high contrast between aerated lung and soft tissues, low radiation dose preserves the detection of focal lung lesions despite higher image noise

Lung Cancer Screening

Scientific evidence for Lung cancer screening


The NEW ENGLAND JOURNAL of MEDICINE
Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening

National Lung Screening Trial (NLST)

Largest RCT of Lung cancer screening to date

Provides the most robust scientific data on the benefit of LDCT for Lung cancer screening

Randomized trial of screening with LDCT vs Chest radiography

US National Cancer institute (NCI) funded study, administered by the NCI division of cancer prevention and the ACRIN

Multicenter randomized trial at 33 U.S. sites

NLST Design

Primary objective	**To determine if screening with LDCT reduces lung cancer mortality compared to chest radiography**
Enrollment period	August 2002- April 2004. Data collected on cases of lung cancer and deaths from lung cancer through December 2009
Participants	N = 53,454. CT 26,722. CXR 26,732
Criteria for participation	Age 55-74 yrs. Cigarette smoking history of at least 30 pack years Former smokers must have quit within the last 15 yrs
Intervention	3 annual screens of LDCT vs single view PA CXR
Definition of a positive result	Non calcified Lung nodule > 4mm on LDCT Radiographic non calcified nodule or mass Other findings such as lymphadenopathy or effusion could be classified as a positive result

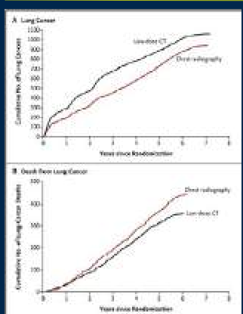
NSLT End points

Primary	**Lung cancer specific mortality**
Secondary	All cause mortality Lung cancer incidence Lung cancer stage distribution Diagnostic performance Adverse impact of diagnostic evaluation

NLST key findings

Rate of adherence to screening	> 90%
Rate of positive screening tests over all three rounds	24.2% with LDCT 6.9% with Radiography
Lung cancer incidence	645 cases per 100,000 person yrs (1060) LDCT 572 cases per 100,000 person yrs (941) radiography group
Lung cancer deaths	247 per 100,000 person years LDCT group (356) 309 per 100,000 person years radiography group (443) **20% Relative reduction in Lung cancer mortality with LDCT**
All cause mortality	6.7% reduction in the LDCT group vs radiography group
False positives	96.4% LDCT 94.5% Radiography

NLST. Cumulative Numbers of Lung Cancers and of Deaths from Lung Cancer



The National Lung Screening Trial Research Team . N Engl J Med 2011;365:395-409.

Relative reduction in mortality from lung cancer with LDCT screening of 20%

- 63% of lung ca detected by LDCT were stage I; 29% stages III or IV
- 47.6% of lung cancers detected by CXR were stage I and 43.2% stage III or IV

The NEW ENGLAND JOURNAL of MEDICINE

The NEW ENGLAND JOURNAL of MEDICINE

Reduced Lung-Cancer Mortality with Volume CT Screening in a Randomized Trial

Abstract

NELSON Trial

13,195 Males, aged 50-74 years who had smoked >15 cigarettes a day for >25 years or >10 cigarettes a day for >30 years, and had not quit >10 years ago

4 rounds of LDCT (at 0, 1, 3 and 5.5 years) vs. no screening

24% relative risk reduction in lung cancer mortality

I- ELCAP (International Early Lung Cancer Action Program)

Radiology

A 20-year Follow-up of the International Early Lung Cancer Action Program (I-ELCAP)

CT Screening significantly improves survival in Lung Cancer

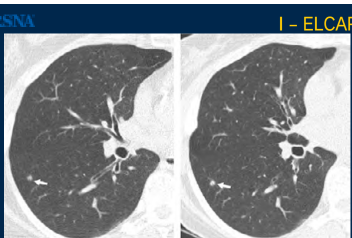
Among 89,404 participants in the International Early Lung Cancer Action Program (I-ELCAP) annual program of low-dose CT screening, 20-year lung cancer-specific survival for 1257 (1.4%)participants diagnosed with a first primary lung cancer under annual screening was 81% (95% CI: 78, 83), and in the subset of 181 participants who underwent surgical resection and had T1aN0M0 lung cancer confirmed via pathology, 20-year lung cancer specific survival was 95% (95% CI: 91, 98).

ELCAP

- In 1999, the initial results of the Early Lung Cancer Action Program (ELCAP) provided evidence supporting the benefit of annual LDCT as a screening modality for lung cancer in a predefined high-risk population
- Starting in 1992, 1000 participants aged 60 years or older with a cigarette smoking history of at least 10 pack-years were prospectively enrolled in a cohort study that compared annual LDCCT with annual chest radiography at two New York City institutions
- Results of the baseline round of screening, reported in1999, found that 85% of the participants with newly diagnosed lung cancer detected with low-dose CT had stage I lung cancer while 82% of these low-dose CT–detected stage I cancers had not been identified on chest radiographs obtained at the same time as the LDCT. The results gave renewed hope to people at risk for lung cancer and led to LDCT screening research throughout the world

RSNA

I – ELCAP



By 2006, the International ELCAP (I-ELCAP), a multinational collaboration, and the expanded New York Early Lung Cancer Action Program (NY-ELCAP) provided sufficient long-term follow-up to estimate the cure rate in 484 participants diagnosed with a first primary lung cancer under annual screening among 31,567 participants using the 10-year Kaplan-Meier lung cancer-specific survival, which was 80% (95% CI: 74, 85)

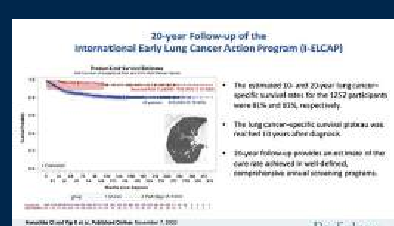
Figure 2: **(A, B)** Two annual repeat low-dose CT scans in a woman who was 60 years old at baseline enrollment in 1999. At baseline enrollment, she was currently smoking and had a 30-pack-year smoking history. No nodules were identified on baseline low-dose CT scans. On the sixth annual low-dose CT scan **(B)**, a right lower lobe solid nodule (arrow) measuring 4.5 mm in maximum diameter was identified. The nodule could be identified in retrospect on the prior annual CT scan (arrow in **A**), when it measured 2.0 mm in maximum diameter. Estimated tumor volume doubling time was 161 days. Lobectomy was performed 2 months later, and diagnosis of stage 1aN0M0 moderately differentiated adenocarcinoma measuring 6.0 mm in maximum diameter was made. Expert pathologic panel review (22) of the pathologic specimen updated the diagnosis to adenocarcinoma with mixed subtype (80% acinar, 20% bronchoalveolar carcinoma components) with 5 mm of invasion.

Henschke CI. Henschke CI. Published Online: November 07, 2023
https://doi.org/10.1148/radiol.231988

Radiology

RSNA

I- ELCAP



In the subgroup with pathologic stage T1aN0M0, 20-year lung cancer-specific survival was 95%

Most screen-detected, treated patients had long-term cure

The extended follow-up is the longest reported for any cohort of CT-screened smokers

To reach this high cure rate of 80%, however, requires that LDCT follows a well-defined regularly up-dated protocol for the work-up of CT findings, a comprehensive data management system for the entire screening program, and training to ensure appropriate follow-up and adherence to continued annual screening

Henschke CI. Henschke CI. Published Online: November 07, 2023
https://doi.org/10.1148/radiol.231988

VA Data

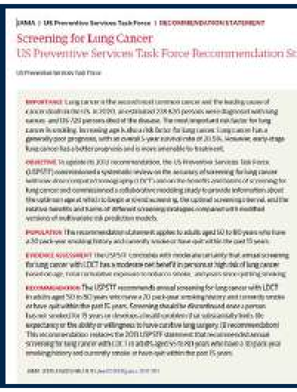
Of 57,919 individuals diagnosed with lung cancer in the VA system between 2011 and 2018, 2167 (3.9%) underwent screening before diagnosis.

Patients with screening had higher rates of stage I diagnoses (52% vs. 27%; $p \leq .0001$) compared to those who had no screening.

Screened patients had improved 5-year overall survival rates (50.2% vs. 27.9%) and 5-year lung cancer-specific survival (59.0% vs. 29.7%) compared to unscreened patients

Lung Cancer Screening

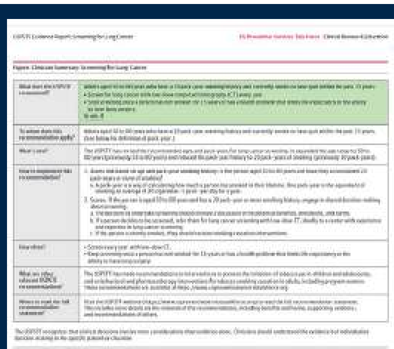
What are the current recommendations for lung cancer screening?



Lung Cancer Screening US Preventive Services Task Force Recommendation Statement

JAMA. 2021;325(10):962-970. doi:10.1001/jama.2021.1117

- The USPSTF recommends annual screening for lung cancer with LDCT in adults aged 50 to 80 years who have a 20 pack-year smoking history and currently smoke or have quit within the past 15 years
- Screening should be discontinued once a person has not smoked for 15 years or develops a health problem that substantially limits life expectancy or the ability or willingness to have curative lung surgery
- This recommendation replaces the 2013 USPSTF statement that recommended annual screening for lung cancer with LDCT in adults aged 55 to 80 years who have a 30 pack-year smoking history and currently smoke or have quit within the past 15 years



LDCT Lung cancer screening in high-risk individuals recommended by other professional societies

- American college of Chest Physicians
- American Society of Clinical oncology
- American Thoracic Society
- American association for Thoracic Surgery
- American Cancer Society
- American college of Radiology
- Society of Thoracic Radiology
- NCCN
- AAFP

LDCT Lung cancer screening in high-risk individuals recommended by other professional societies

- The **ACS** recommends annual LCS with low-dose computed tomography for asymptomatic individuals aged 50–80 years who currently smoke or formerly smoked and have a ≥20 pack-year smoking history (*strong recommendation*, *moderate quality of evidence*)
- Before the decision is made to initiate LCS, individuals should engage in a shared decision-making discussion with a qualified health professional
- **For individuals who formerly smoked, the number of YSQ is not an eligibility criterion to begin or to stop screening**

CMS.gov

Centers for Medicare & Medicaid Services

- The Centers for Medicare & Medicaid Services (CMS) has updated the national coverage determination (NCD) for Medicare coverage of screening for lung cancer with low dose computed tomography (LDCT) if certain eligibility requirements are met, effective February 10, 2022

Beneficiary eligibility criteria:

- Age 50 – 77 years;
- Asymptomatic (no signs or symptoms of lung cancer);
- Tobacco smoking history of at least 20 pack-years (one pack-year = smoking one pack per day for one year; 1 pack = 20 cigarettes);
- Current smoker or one who has quit smoking within the last 15 years; and
- Receive an order for lung cancer screening with LDCT

CMS.gov

Counseling and Shared Decision-Making Visit

Before the beneficiary's first lung cancer LDCT screening, the beneficiary must receive a counseling and shared decision-making visit that meets all of the following criteria, and is appropriately documented in the beneficiary's medical records:

- Determination of beneficiary eligibility;
- Shared decision-making, including the use of one or more decision aids;
- Counseling on the importance of adherence to annual lung cancer LDCT screening, impact of comorbidities and ability or willingness to undergo diagnosis and treatment; and
- Counseling on the importance of maintaining cigarette smoking abstinence if former smoker; or the importance of smoking cessation if current smoker and, if appropriate, furnishing of information about tobacco cessation interventions.

Reading Radiologist Eligibility Criteria

- For purposes of Medicare coverage of lung cancer screening with LDCT, the reading radiologist must have board certification or board eligibility with the American Board of Radiology or equivalent organization.

Radiology Imaging Facility Eligibility Criteria

- For purposes of Medicare coverage, lung cancer screening with LDCT must be furnished in a radiology imaging facility that utilizes a standardized lung nodule identification, classification and reporting system.

The above policy simplifies requirements for the counseling and shared decision-making visit, removes the restriction that it must be furnished by a physician or non-physician practitioner, reduces the eligibility criteria for the reading radiologist, and reduces the radiology imaging facility eligibility criteria (including removes the requirement that facilities participate in a registry)

Lung Cancer Screening

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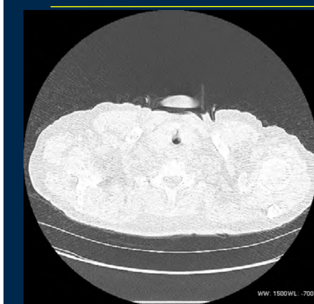
- Reporting of Lung Cancer Screening
- Potential harms and uncertainties of Lung cancer screening

Low dose CT (LDCT)



Dose Report

eries	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S22.000-I318.000	2.17	84.01	Body 32
			Total Exam DLP:	84.01	

CTDIvol ≤3mGy for a standard patient (5' 7" and 155 lb)
Effective dose 0.6-1.5mSv (DLP x 0.014)

What is a Low dose CT scan (LDCT) ?

- **Radiation dose**

Mean effective radiation dose is 0.6- 1.5mSv vs 6- 10 mSv for a conventional CT chest.

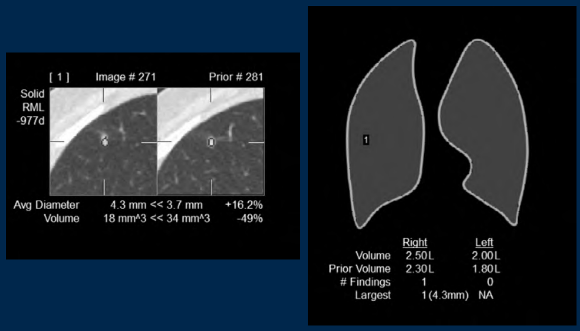
- **Basic Technique**

- Non contrast
- 20-60 mAs (100- 120kvp)
- Helical single breath hold acquisition in full inspiration (≥16 MDCT)
- Thin section reconstructions (≤ 2.5mm with ≤ 1 mm preferred)

Low dose CT (LDCT) for Lung Cancer Screening Technique

Other considerations

- Maximum intensity projection (MIP) reconstruction is a technique that may be useful to increase the sensitivity for lung nodule detection
- Multiplanar reconstruction (MPR) may be useful to further characterize nodules, particularly nodules located along the pleural surfaces (also known as perifissural nodules
- The use of computer-assisted nodule detection and volumetric assessment of nodule size and growth by computer workstation analysis can be valuable adjuncts to the evaluation and should be utilized, if available



Lung Cancer Screening

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Lung-RADS 2022

- The Lung CT Screening Reporting and Data System (Lung-RADS) was created by the ACR to standardize reporting and management recommendations for lung cancer screening and facilitate evaluation of quality and outcomes
- Since 2014, two updates have been released: Lung-RADS version 1.1 in 2019 and Lung-RADS version 2022 in November 2022
- Each iteration aims to incorporate knowledge gained from the latest lung nodule, lung cancer, and lung cancer screening research; clarify or include topics not addressed in previous versions; and reduce overdiagnosis

Lung-RADS 2022

- Specific aspects of Lung-RADS have been validated in numerous studies with the primary benefits of survival associated with a shift to earlier-stage lung cancer detection (stage shift) and reducing false-positive screens and unnecessary follow-up
- There has been widespread adoption of Lung-RADS for LCS CT reporting throughout the United States as the only CMS-approved reporting and classification system for LCS. Lung-RADS has also been implemented in other countries or used as a foundation for international reporting systems

ACR Lung- RADS v2022

- ACR Lung-RADS v2022 introduces important evidence-based updates to the classification and management of findings at LCS CT including criteria for atypical pulmonary cysts, juxtapleural nodules, infectious or inflammatory findings, and airway nodules
- Provides additional clarity through data and expert consensus on the role of volumetrics, the definition of nodule growth, the classification and management of slow-growing nodules, and use of the S modifier
- Introduces the concept of stepped management for Lung-RADS category 3 and 4A nodules while clarifying that follow-up LDCT management recommendations are from the date of the current examination
- Additional guidance is provided for addressing the role of interval diagnostic CTs in LCS patients and the management of nodules in patients no longer eligible for LCS

The American College of Radiology (ACR) Lung Imaging Reporting and Data System (Lung-RADS®) is the product of the ACR Lung Cancer Screening Committee subgroup on Lung-RADS®

This system is a quality assurance tool designed to standardize lung cancer screening CT reporting and management recommendations, reduce confusion in lung cancer screening CT interpretations and facilitate outcome monitoring

http://www.acr.org/Quality-Safety/Resources/LungRADS

Lung-RADS 0 . Incomplete

Lung-RADS	Category Descriptor	Findings	Management
0	**Incomplete** Estimated Population Prevalence: ~1%	Prior chest CT examination being located for comparison (see note 9)	Comparison to prior chest CT;
		Part or all of lungs cannot be evaluated	Additional lung cancer screening CT imaging needed;
		Findings suggestive of an inflammatory or infectious process (see note 10)	1-3 month LDCT

Lung-RADS 1. Negative. 12 month LDCT

1	**Negative** Estimated Population Prevalence: 39%	**No lung nodules OR**	
		Nodule with benign features: • Complete, central, popcorn, or concentric ring calcifications **OR** • Fat containing	

Lung-RADS 2. Benign. 12 month LDCT

2	**Benign** Based on imaging features or indolent behavior Estimated Population Prevalence: 45%	**Juxtapleural nodule:** • < 10 mm (524 mm^3) mean diameter at baseline or new **AND** • Solid; smooth margins; and oval, lentiform, or triangular shape	12-month screening LDCT
		Solid nodule: • < 6 mm (< 113 mm^3) at baseline **OR** • New < 4 mm (< 34 mm^3)	
		Part-solid nodule: • < 6 mm total mean diameter (< 113 mm^3) at baseline	
		Non-solid nodule (GGN): • < 30 mm (< 14,137 mm^3) at baseline, new, or growing **OR** • ≥ 30 mm (≥ 14,137 mm^3) stable or slow-growing (see note 7)	
		Airway nodule, subsegmental at baseline, new, or stable (see note 11)	
		Category 3 nodule that is stable or decreased in size at 6-month follow-up CT, **OR** Category 3 or 4A nodules that resolve on follow-up, **OR** Category 4B findings proven to be benign in etiology following appropriate diagnostic workup	

Lung-RADS 3. Probably Benign. 6 month LDCT

3	**Probably Benign** Based on imaging features or behavior Estimated Population Prevalence: 9%	**Solid nodule:** • ≥ 6 to < 8 mm (≥ 113 to < 268 mm^3) at baseline **OR** • New 4 mm to < 6 mm (34 to < 113 mm^3)	6-month LDCT
		Part-solid nodule: • ≥ 6 mm total mean diameter (≥ 113 mm^3) with solid component < 6 mm (< 113 mm^3) at baseline **OR** • New < 6 mm total mean diameter (< 113 mm^3)	
		Non-solid nodule (GGN): • ≥ 30 mm (≥ 14,137 mm^3) at baseline or new	
		Atypical pulmonary cyst: (see note 12) • Growing cystic component (mean diameter) of a thick-walled cyst	
		Category 4A nodule that is stable or decreased in size at 3-month follow-up CT (excluding airway nodules)	

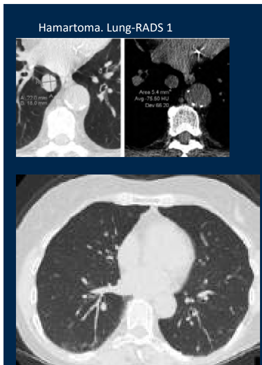
Lung-RADS 4A. Suspicious.

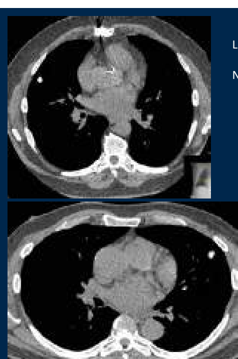
4A	**Suspicious** Estimated Population Prevalence: 4%	**Solid nodule:** • ≥ 8 to < 15 mm (≥ 268 to < 1,767 mm^3) at baseline **OR** • Growing < 8 mm (< 268 mm^3) **OR** • New 6 to < 8 mm (113 to < 268 mm^3)	3-month LDCT; PET/CT may be considered if there is a ≥ 8 mm (≥ 268 mm^3) solid nodule or solid component
		Part-solid nodule: • ≥ 6 mm total mean diameter (≥ 113 mm^3) with solid component ≥ 6 mm to < 8 mm (≥ 113 to < 268 mm^3) at baseline **OR** • New or growing < 4 mm (< 34 mm^3) solid component	
		Airway nodule, segmental or more proximal at baseline or new (see note 11)	
		Atypical pulmonary cyst: (see note 12) • Thick-walled cyst **OR** • Multilocular cyst at baseline **OR** • Thin- or thick-walled cyst that becomes multilocular	

Lung-RADS 4B. Very Suspicious.

4B	**Very Suspicious** Estimated Population Prevalence: 2%	**Airway nodule**, segmental or more proximal, and stable or growing (see note 11)	Referral for further clinical evaluation
		Solid nodule: • ≥ 15 mm (≥ 1767 mm^3) at baseline **OR** • New or growing ≥ 8 mm (≥ 268 mm^3)	Diagnostic chest CT with or without contrast; PET/CT may be considered if there is a ≥ 8 mm (≥ 268 mm^3) solid nodule or solid component; tissue sampling; and/or referral for further clinical evaluation Management depends on clinical evaluation, patient preference, and the probability of malignancy (see note 13)
		Part-solid nodule: • Solid component ≥ 8 mm (≥ 268 mm^3) at baseline **OR** • New or growing ≥ 4 mm (≥ 34 mm^3) solid component	
		Atypical pulmonary cyst: (see note 12) • Thick-walled cyst with growing wall thickness/nodularity **OR** • Growing multilocular cyst (mean diameter) **OR** • Multilocular cyst with increased loculation or new/increased opacity (nodular, ground glass, or consolidation)	
		Slow-growing solid or part-solid nodule that demonstrates growth over multiple screening exams (see note 8)	
4X	Estimated Population Prevalence: < 1%	Category 3 or 4 nodules with additional features or imaging findings that increase suspicion for lung cancer (see note 14)	

Hamartoma. Lung-RADS 1

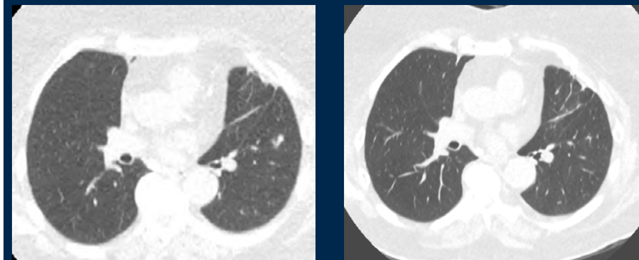


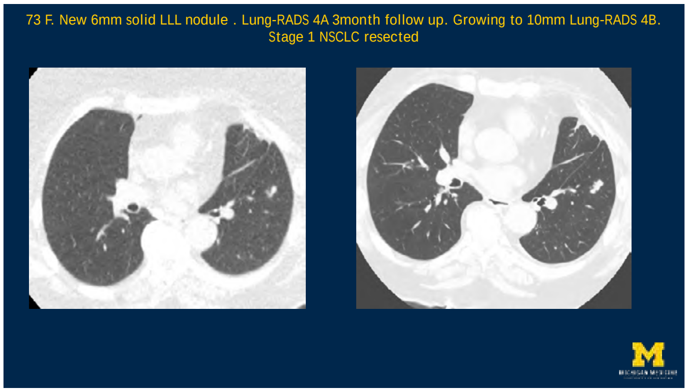


Lung Rads 1 and 2 –

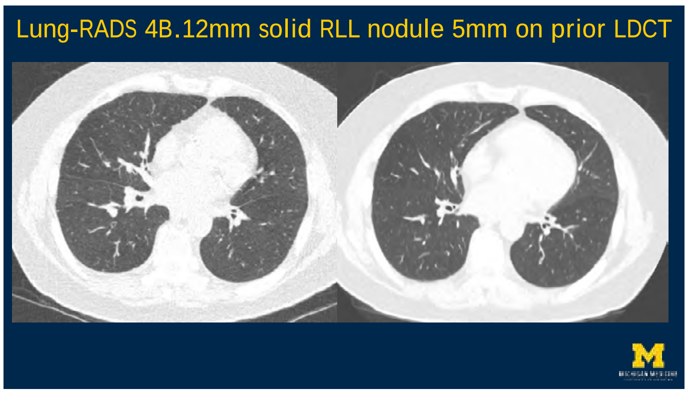
Negative or Benign

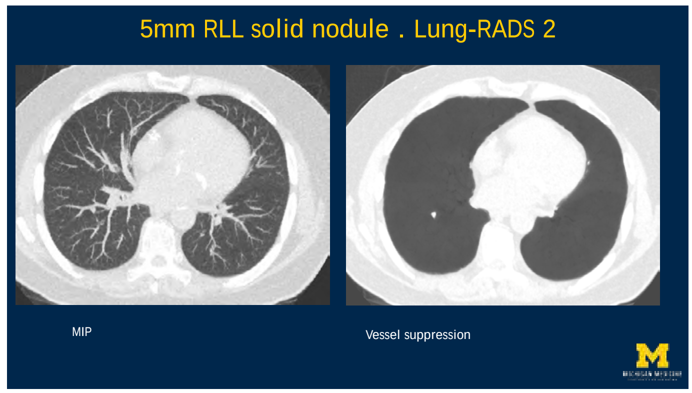
73 F. New 6mm solid LLL nodule . Lung-RADS 4A

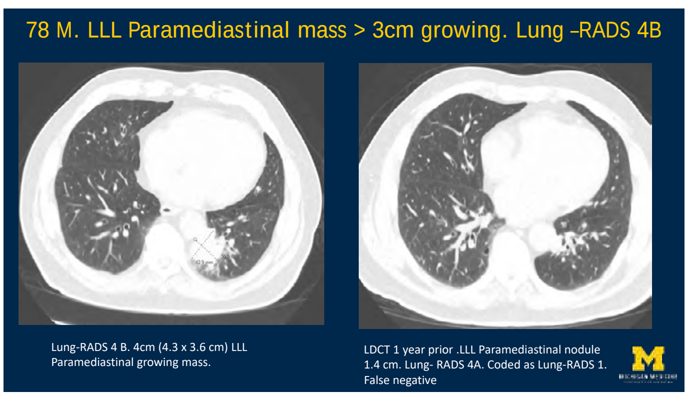


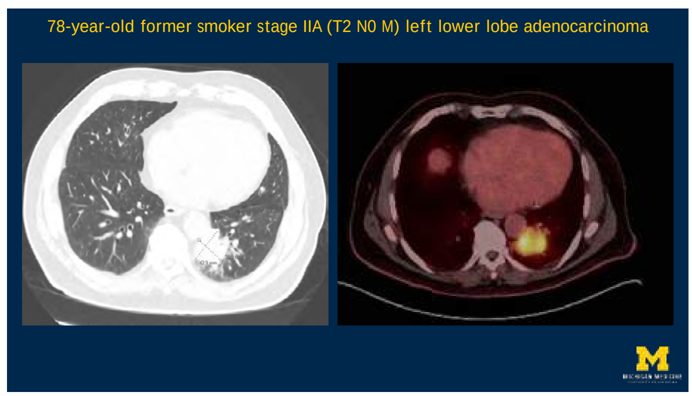

73 F. New 6mm solid LLL nodule . Lung-RADS 4A 3month follow up. Growing to 10mm Lung-RADS 4B. Stage 1 NSCLC resected

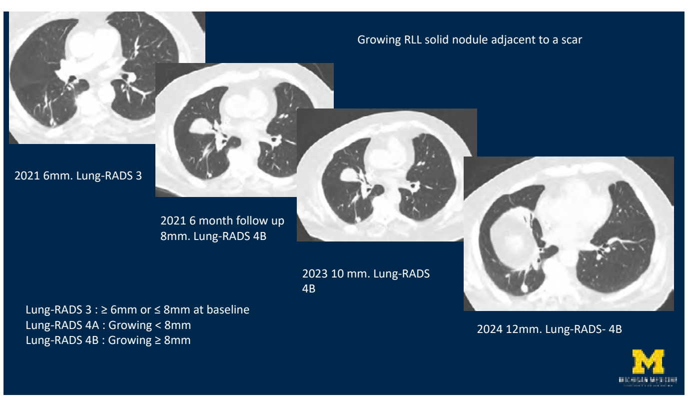

73. 50 Pack years. New RLL solid nodule 16 x 12mm . Lung-Rads 4B
Baseline LDCT
CT urogram 2 years prior

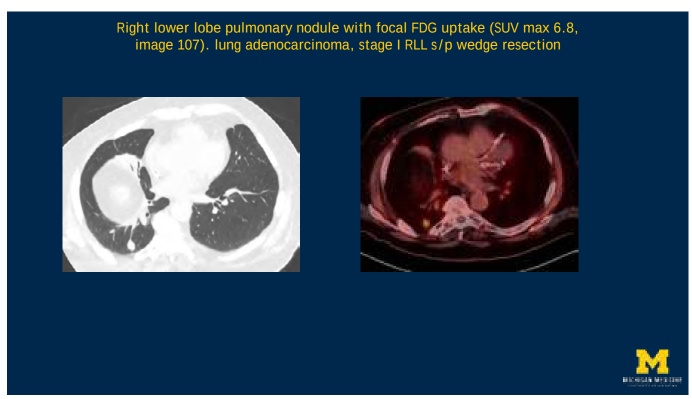

Lung-RADS 4B.12mm solid RLL nodule 5mm on prior LDCT


5mm RLL solid nodule . Lung-RADS 2
MIP
Vessel suppression


78 M. LLL Paramediastinal mass > 3cm growing. Lung –RADS 4B
Lung-RADS 4 B. 4cm (4.3 x 3.6 cm) LLL Paramediastinal growing mass.
LDCT 1 year prior .LLL Paramediastinal nodule 1.4 cm. Lung- RADS 4A. Coded as Lung-RADS 1. False negative


78-year-old former smoker stage IIA (T2 N0 M) left lower lobe adenocarcinoma


Growing RLL solid nodule adjacent to a scar
2021 6mm. Lung-RADS 3
2021 6 month follow up 8mm. Lung-RADS 4B
2023 10 mm. Lung-RADS 4B
2024 12mm. Lung-RADS- 4B
Lung-RADS 3 : ≥ 6mm or ≤ 8mm at baseline
Lung-RADS 4A : Growing < 8mm
Lung-RADS 4B : Growing ≥ 8mm


Right lower lobe pulmonary nodule with focal FDG uptake (SUV max 6.8, image 107). lung adenocarcinoma, stage I RLL s/p wedge resection

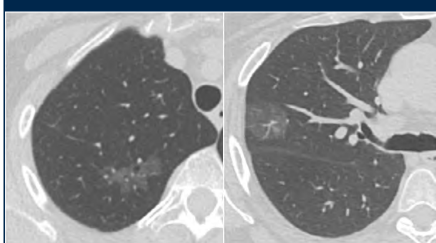
Lung-RADS 4X- 2.3 cm **spiculated** LUL nodule on baseline LDCT

Category 4X: Category 3 or 4 nodules with additional imaging findings that increase the suspicion of lung cancer, such as spiculation, lymphadenopathy, frank metastatic disease, a GGN that doubles in size in 1 year, etc. 4X is a distinct Lung-RADS category; X should not be used as a modifier

Part-solid and non-solid (GGN)nodules

- Subsolid nodules, which may be divided into pure ground glass and part-solid nodules, are increasingly identified at CT
- Subsolid nodules have higher risk of malignancy than solid nodules and represent lesions along the adenocarcinoma spectrum
- Subsolid adenocarcinomas are more indolent than solid adenocarcinomas.

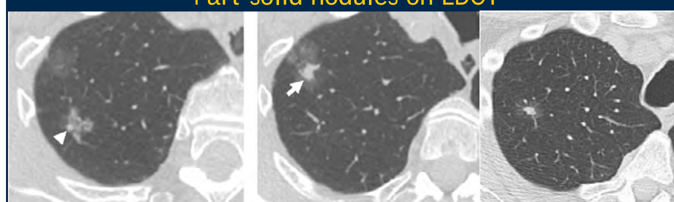
Non –solid nodules (GGN) on LDCT



Lung-RADS 2

Lung-RADS 3

Part-solid nodules on LDCT



16 mm with 3 mm solid component. Lung-RADS 3

29 mm with 9 mm solid component Lung-RADS 4B

15 mm with 6 mm solid component Lung-RADS 4 A

Part-solid nodule: Lung-RADS 2
- < 6 mm total mean diameter (< 113 mm³) at baseline

Lung-RADS 3

Lung-RADS 4A

Lung-RADS 4B

Lung-RADS V 2022. Important updates and clarifications

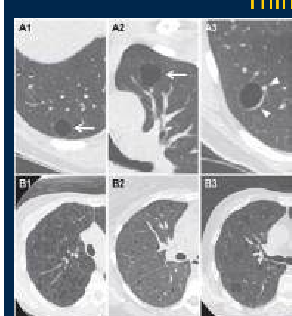
- Atypical Pulmonary cysts
- Juxtapleural nodules
- Infectious or inflammatory findings
- Airway nodules
- Nodule volumetrics
- Definition of nodule growth
- Stepped management
- Interval diagnostic CT
- Use of the S modifier

Christensen J, Prosper AE, Wu CC, Chung J, Lee E, Elicker B, Hunsaker AR, Petranovic M, Sandler KL, Stiles B, Mazzone P, Yankelevitz D, Aberle D, Chiles C, Kazerooni E. ACR Lung-RADS v2022: Assessment Categories and Management Recommendations. J Am Coll Radiol. 2024 Mar;21(3):473-488. doi: 10.1016/j.jacr.2023.09.009. Epub 2023 Oct 10. PMID: 37820837.

Atypical Pulmonary Cysts

- Lung cancers associated with cysts are not uncommon
- Precursor lesions of cystic lung cancers are often represented by unilocular thick-walled cysts, cysts with associated nodularity, or multilocular cysts
- New criteria for the classification and management of atypical pulmonary cysts are introduced in Lung-RADS® 2022

Thin-walled cysts

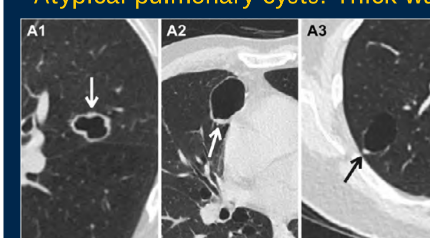


Thin-walled cysts, defined as unilocular cysts with wall thickness < 2 mm, are considered benign and are not classified or managed in Lung-RADS. Multiple pulmonary cysts may indicate a diffuse cystic lung disease; however, these conditions are not classified in Lung-RADS unless a cyst with concerning features is identified

(A) Simple cysts are unilocular with a wall thickness < 2 mm (arrows) and are not classified or managed in Lung CT Screening Reporting and Data System (Lung-RADS). Care should be taken to avoid mistaking vessels (arrowheads) with nodules or wall thickening

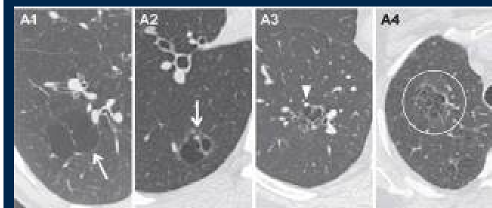
(B) Three patients with cystic lung disease: lymphangioleiomyomatosis (B1), Langerhans cell histiocytosis (B2), and lymphocytic interstitial pneumonia (B3). Multicystic lung disease is not classified or managed in Lung-RADS unless a cyst is identified with atypical features (eg, multilocular, thick-wall, associated nodularity)

Atypical pulmonary cysts: Thick walled. Lung-RADS 4A



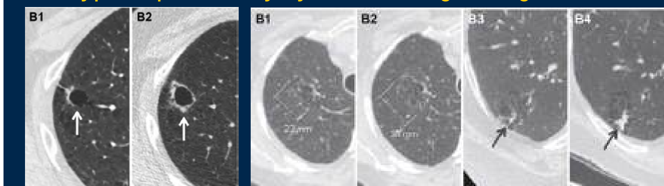
Thick-walled cysts are unilocular with a wall thickness **2 mm** or larger, which may be uniform, asymmetric, or manifest as focal wall nodularity

Atypical pulmonary cysts: Multilocular. Lung-RADS 4A



Multilocular cysts are heterogeneous in appearance, contain internal septations (A1, A2, A3, A4), and may have solid or ground glass components such as thick walls (A2, arrow), nodules (A3, arrowhead), or internal opacities

Atypical pulmonary cysts: Growing . Lung-RADS 4B



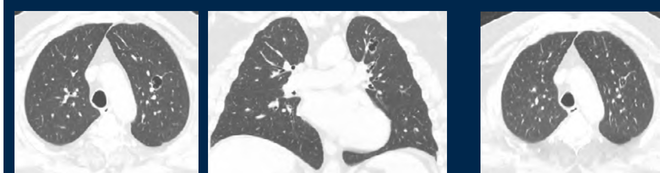
Growing wall thickness or nodularity of a thick-walled cyst, increasing loculation of a multilocular cyst, or new or increasing opacity (nodular, ground glass, or consolidation) within or adjacent to a multilocular cyst merits a 4B classification with a recommendation for appropriate diagnostic evaluation

Atypical pulmonary cysts with nodule: Lung-RADS 4A or4B

Atypical pulmonary cysts with an associated nodule that is within the cyst lumen (endophytic) or adjacent to the wall (exophytic) are classified and managed by the most suspicious finding. It can be difficult to distinguish between a cyst with nodular wall thickening (eg, a thick-walled cyst, Lung- RADS 4A) and a thin-walled cyst with an adjacent nodule (managed by nodule size and composition). When in doubt, choose the higher Lung-RADS classification

A 71-year-old with an atypical pulmonary cyst multilocular containing a 17- mm mean diameter solid component (arrow). Lung-RADS 4B

Atypical pulmonary cysts . Lung-RADS 4A/4B



70 M. Smoker. Multiloculated cyst growing at 3 months. Lung-RADS 4 B from 4A

Atypical Pulmonary Cysts

Table 2. Atypical pulmonary cysts in Lung-RADS v2022

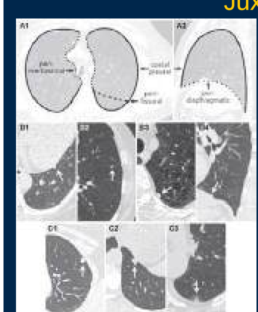
Lung-RADS	Description	Management
3	Growing cystic component (mean diameter) of a thick-walled cyst	6-month LDCT
4A	Thick-walled cyst OR Multilocular cyst at baseline OR Thin- or thick-walled cyst that becomes multilocular	3-month LDCT; PET/CT may be considered if there is a ≥8 mm (≥268 mm^3) solid nodule or solid component
4B	Thick-walled cyst with growing wall thickness/nodularity OR Growing multilocular cyst (mean diameter) OR Multilocular cyst with increased loculation or new or increased opacity (nodular, ground glass, or consolidation)	Diagnostic chest CT with or without contrast; PET/CT may be considered if there is a ≥8 mm (≥268 mm^3) solid nodule or solid component; tissue sampling; and/or referral for further clinical evaluation

Christensen J, Prosper AE, Wu CC, Chung J, Lee E, Elicker B, Hunsaker AR, Petranovic M, Sandler KL, Stiles B, Mazzone P, Yankelevitz D, Aberle D, Chiles C, Kazerooni E. ACR Lung-RADS v2022: Assessment Categories and Management Recommendations. J Am Coll Radiol. 2024 Mar;21(3):473-488. doi: 10.1016/j.jacr.2023.09.009. Epub 2023 Oct 10. PMID: 37820837.

Juxtapleural Nodules: Lung-RADS 2

- New data indicate that the size and composition criteria applied to perifissural nodules in Lung-RADS® v1.1 can safely be applied to all juxtapleural nodules (perifissural, costal pleural, peri-mediastinal, and peri-diaphragmatic)
- Classification and description: Lung- RADS 2 - Juxtapleural nodules that are solid; = 10 mm in mean diameter; smoothly marginated; and triangular, lentiform, or ovoid in shape

Juxtapleural Nodules



Juxtapleural nodules. (A) Illustration of juxtapleural nodule distribution (perimediastinal, perifissural, costal pleural, and peridiaphragmatic) in axial (A1) and sagittal (A2) planes.

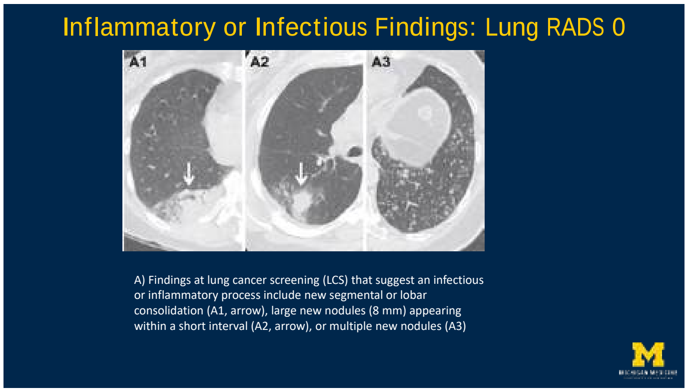
(B) Juxtapleural nodules < 10 mm in mean diameter that are solid with smooth margins and oval, lentiform, or triangular shape (arrows) are considered benign and can be classified as Lung CT Screening Reporting and Data System (Lung-RADS) 2. Examples of benign juxtapleural nodules: paramediastinal (B1), perifissural (B2), costal pleural (B3), and peridiaphragmatic (B4).

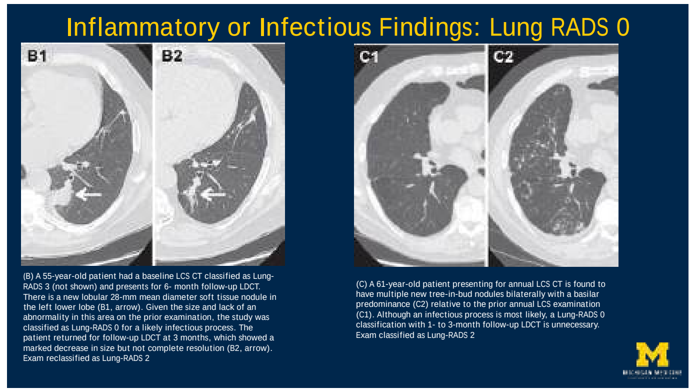
(C) Juxtapleural nodules that do not meet Lung-RADS 2 criteria (arrows) are classified based on size and composition: 9-mm solid round costal pleural nodule, Lung-RADS 4A (C1); 11-mm solid lobular peridiaphragmatic nodule, Lung-RADS 4A (C2); 15-mm part-solid costal pleural nodule with 6 mm solid component, Lung-RADS 4A

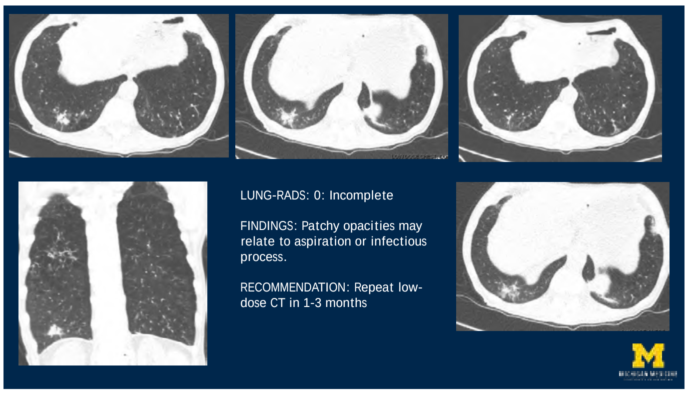
Christensen J, Prosper AE, Wu CC, Chung J, Lee E, Elicker B, Hunsaker AR, Petranovic M, Sandler KL, Stiles B, Mazzone P, Yankelevitz D, Aberle D, Chiles C, Kazerooni E. ACR Lung-RADS v2022: Assessment Categories and Management Recommendations. J Am Coll Radiol. 2024 Mar;21(3):473-488. doi: 10.1016/j.jacr.2023.09.009. Epub 2023 Oct 10. PMID: 37820837.

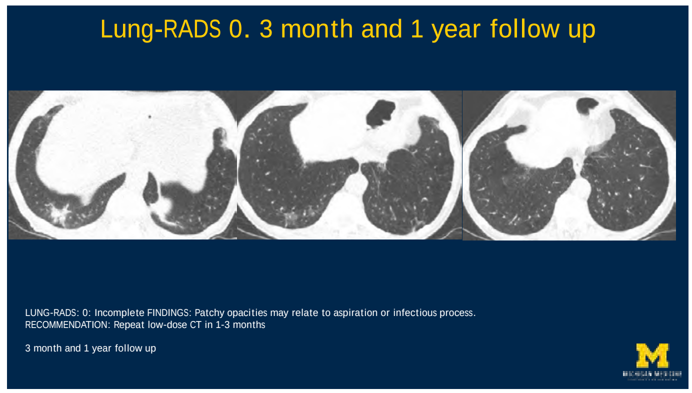
Inflammatory or Infectious Findings

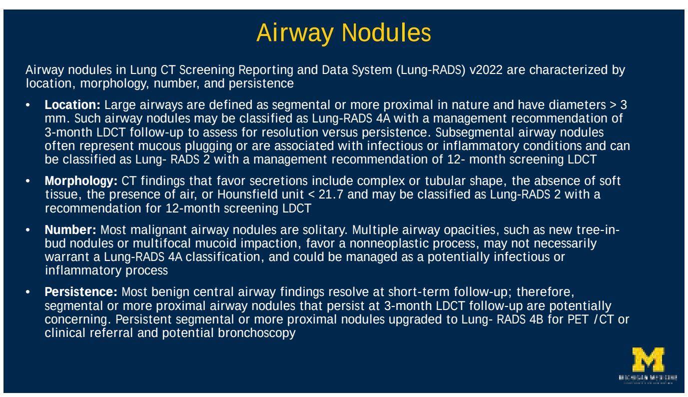
- Findings at LCS suggesting an indeterminate infectious or inflammatory process, or findings that obscure portions of the lungs, such as segmental or lobar consolidation, should be classified as Lung-RADS 0 with a recommendation for 1- to 3-month follow-up LDCT to allow time for resolution and to exclude an underlying suspicious nodule
- Some findings at LCS indicative of an infectious process may not warrant short-term follow-up (eg, tree-in-bud nodules or new <3-cm ground glass nodules). These nodules may be evaluated using existing size and composition criteria with a Lung-RADS classification and management recommendation based on the most suspicious finding, often corresponding to Lung-RADS 2 with a recommendation for 12-month LDCT

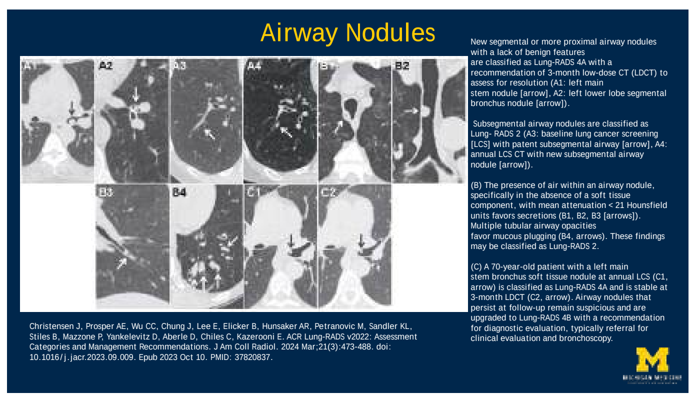

Inflammatory or Infectious Findings: Lung RADS 0
A1
A2
A3
A) Findings at lung cancer screening (LCS) that suggest an infectious or inflammatory process include new segmental or lobar consolidation (A1, arrow), large new nodules (8 mm) appearing within a short interval (A2, arrow), or multiple new nodules (A3)

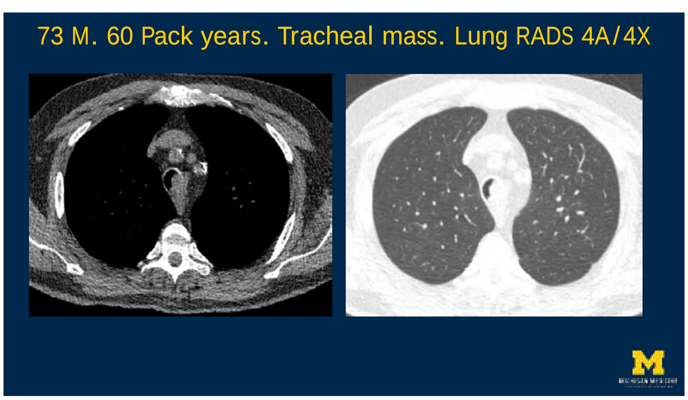

Inflammatory or Infectious Findings: Lung RADS 0
B1
B2
C1
C2
(B) A 55-year-old patient had a baseline LCS CT classified as Lung-RADS 3 (not shown) and presents for 6- month follow-up LDCT. There is a new lobular 28-mm mean diameter soft tissue nodule in the left lower lobe (B1, arrow). Given the size and lack of an abnormality in this area on the prior examination, the study was classified as Lung-RADS 0 for a likely infectious process. The patient returned for follow-up LDCT at 3 months, which showed a marked decrease in size but not complete resolution (B2, arrow). Exam reclassified as Lung-RADS 2
(C) A 61-year-old patient presenting for annual LCS CT is found to have multiple new tree-in-bud nodules bilaterally with a basilar predominance (C2) relative to the prior annual LCS examination (C1). Although an infectious process is most likely, a Lung-RADS 0 classification with 1- to 3-month follow-up LDCT is unnecessary. Exam classified as Lung-RADS 2

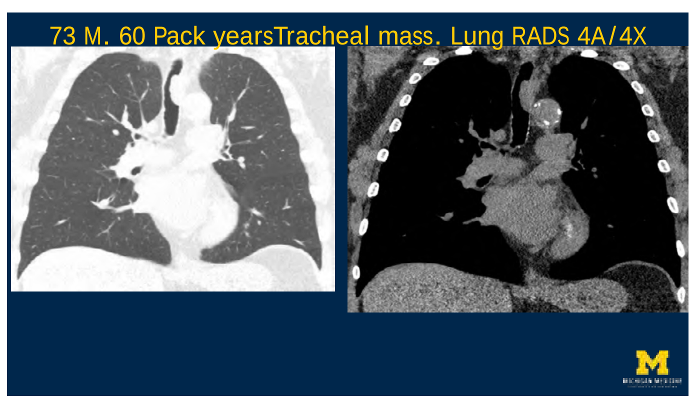

LUNG-RADS: 0: Incomplete
FINDINGS: Patchy opacities may relate to aspiration or infectious process.
RECOMMENDATION: Repeat low-dose CT in 1-3 months


Lung-RADS 0. 3 month and 1 year follow up
LUNG-RADS: 0: Incomplete FINDINGS: Patchy opacities may relate to aspiration or infectious process.
RECOMMENDATION: Repeat low-dose CT in 1-3 months
3 month and 1 year follow up

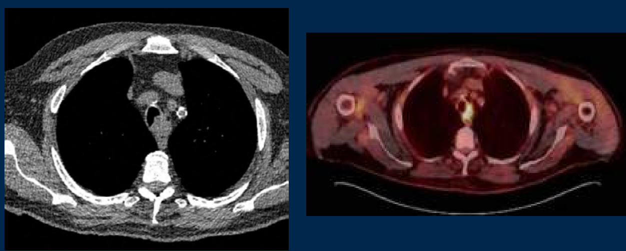

Airway Nodules
Airway nodules in Lung CT Screening Reporting and Data System (Lung-RADS) v2022 are characterized by location, morphology, number, and persistence
• Location: Large airways are defined as segmental or more proximal in nature and have diameters > 3 mm. Such airway nodules may be classified as Lung-RADS 4A with a management recommendation of 3-month LDCT follow-up to assess for resolution versus persistence. Subsegmental airway nodules often represent mucous plugging or are associated with infectious or inflammatory conditions and can be classified as Lung- RADS 2 with a management recommendation of 12- month screening LDCT
• Morphology: CT findings that favor secretions include complex or tubular shape, the absence of soft tissue, the presence of air, or Hounsfield unit < 21.7 and may be classified as Lung-RADS 2 with a recommendation for 12-month screening LDCT
• Number: Most malignant airway nodules are solitary. Multiple airway opacities, such as new tree-in-bud nodules or multifocal mucoid impaction, favor a nonneoplastic process, may not necessarily warrant a Lung-RADS 4A classification, and could be managed as a potentially infectious or inflammatory process
• Persistence: Most benign central airway findings resolve at short-term follow-up; therefore, segmental or more proximal airway nodules that persist at 3-month LDCT follow-up are potentially concerning. Persistent segmental or more proximal nodules upgraded to Lung- RADS 4B for PET /CT or clinical referral and potential bronchoscopy


Airway Nodules
A1
A2
A3
A4
B1
B2
B3
B4
C1
C2
New segmental or more proximal airway nodules with a lack of benign features are classified as Lung-RADS 4A with a recommendation of 3-month low-dose CT (LDCT) to assess for resolution (A1: left main stem nodule [arrow], A2: left lower lobe segmental bronchus nodule [arrow]).
Subsegmental airway nodules are classified as Lung- RADS 2 (A3: baseline lung cancer screening [LCS] with patent subsegmental airway [arrow], A4: annual LCS CT with new subsegmental airway nodule [arrow]).
(B) The presence of air within an airway nodule, specifically in the absence of a soft tissue component, with mean attenuation < 21 Hounsfield units favors secretions (B1, B2, B3 [arrows]). Multiple tubular airway opacities favor mucous plugging (B4, arrows). These findings may be classified as Lung-RADS 2.
(C) A 70-year-old patient with a left main stem bronchus soft tissue nodule at annual LCS (C1, arrow) is classified as Lung-RADS 4A and is stable at 3-month LDCT (C2, arrow). Airway nodules that persist at follow-up remain suspicious and are upgraded to Lung-RADS 4B with a recommendation for diagnostic evaluation, typically referral for clinical evaluation and bronchoscopy.
Christensen J, Prosper AE, Wu CC, Chung J, Lee E, Elicker B, Hunsaker AR, Petranovic M, Sandler KL, Stiles B, Mazzone P, Yankelevitz D, Aberle D, Chiles C, Kazerooni E. ACR Lung-RADS v2022: Assessment Categories and Management Recommendations. J Am Coll Radiol. 2024 Mar;21(3):473-488. doi: 10.1016/j.jacr.2023.09.009. Epub 2023 Oct 10. PMID: 37820837.

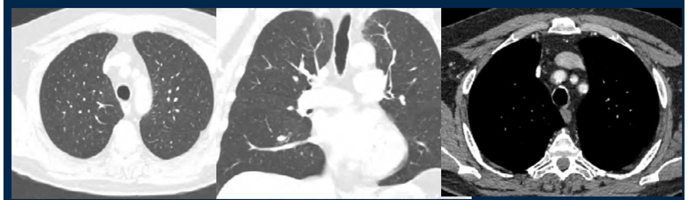

73 M. 60 Pack years. Tracheal mass. Lung RADS 4A/4X


73 M. 60 Pack yearsTracheal mass. Lung RADS 4A/4X

73 M. Tracheal mass. Lung RADS 4A/4X. Small cell Ca Trachea



73 M. Tracheal mass. Lung RADS 4A/4X. Small cell Ca Trachea. S/P Rigid bronchoscopy , debulking and definitive chemo radiation



Volumetrics

- Nodule Measurement: Nodule mean diameter, measure both the long and short axis to one decimal point in mm, and report mean nodule diameter to one decimal point
- The long and short axis measurements may be in any plane to reflect the true size of the nodule
- Volumes if obtained, should be reported to the nearest whole number in mm^3
- Potential benefits of volumetrics include automation, reproducibility and increased sensitivity, however currently no data to suggest improved outcomes over mean diameter measurements

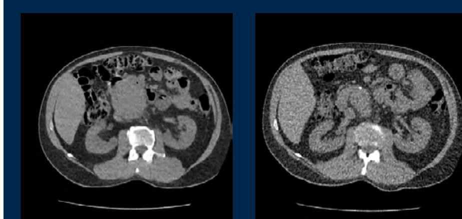
Growth Definitions

- Growth is defined as >1.5-mm mean diameter increase within a ≤12-month interval
- Radiologists are advised to always compare the current examination with the oldest available chest CT (diagnostic or screening) to determine a nodule's characteristics over time
- Nodules with ≤1.5-mm increase in size in a>12-month interval are defined as slow-growing, meaning they do not meet growth criteria from one annual screen to the next. Slow- growing nodules may be classified as stable
- Slow-Growing–Non-Solid (Ground-Glass) Nodules: A ground-glass nodule (GGN) that demonstrates growth over multiple screening exams but does not meet the > 1.5 mm threshold increase in size for any 12-month interval may be classified as Lung- RADS 2 until the nodule meets findings criteria of another category, such as developing a solid component (then manage per part-solid nodule criteria)
- Slow-Growing-Solid or Part-Solid Nodules: A solid or part-solid nodule that demonstrates growth over multiple screening exams but does not meet the > 1.5 mm threshold increase in size for any 12-month interval is suspicious and may be classified as a Lung- RADS 4B. Slow-growing nodules may not have increased metabolic activity on PET/CT; therefore, biopsy, if feasible, or surgical evaluation may be the most appropriate management recommendation

S Modifier

- Significant or potentially significant findings unrelated to lung cancer at LCS may be indicated by the addition of an S modifier to Lung-RADS categories 0 to 4
- Such findings are common with 19.6% of NLST study participants having potentially significant pathology, although other studies have reported an incidence of 10% to 45%
- Significant or potentially significant findings that are already known, treated, or in the process of clinical evaluation do not require an S modifier (for example, a patient with severe coronary artery disease who has already undergone percutaneous coronary intervention)

63 M Veteran current smoker. Lowest sections of LDCT annual screening studies



LDCT 2023 LDCT 2022

S Findings

- Moderate to severe CAC
- Aortic aneurysm
- Cancer outside the lungs- esophagus, upper abdomen
- Significant Thyroid nodule
- Interstitial lung disease
- Severe aortic valve calcification

63 M Veteran Abdominal aortic aneurysm on LDCT and subsequent CTA abdomen

Stepped Management

- The timing of follow-up imaging dictated by the Lung-RADS category is from the date of the exam being interpreted
- Lung-RADS 3, stable or decreased at 6-month follow-up: Reclassify as Lung-RADS 2, with 12-month screening LDCT from the date of the current exam (not from the baseline or annual screening exam)
- Lung-RADS 4A, stable or decreased at 3-month follow-up: Reclassify as Lung-RADS 3, with 6-month screening LDCT from the date of the current exam. At the 6-month follow-up, if the finding remains stable or decreased then reclassify as noted above to Lung- RADS 2 with a recommendation for 12-month annual screening LDCT from the date of the current exam
- Lung-RADS 3 or 4A, resolved at follow-up OR Lung-RADS 4B proven benign after appropriate diagnostic workup: Stepped management is unnecessary. The study should be reclassified based on the most suspicious nodule. If no new or growing nodules are present, then these exams can be reclassified as Lung-RADS 2 with a recommendation for 12-month annual screening LDCT from the date of the current exam

Interval Diagnostic CTs

- Patients participating in annual LCS may receive diagnostic chest CT (DCT) imaging evaluation outside of recommended LCS management
- Information from prior DCTs should be evaluated when interpreting baseline LCS and determining classification and management recommendations. For example, an 8-mm solid nodule on baseline screening CT would typically be classified as Lung-RADS 4A; however, if a prior diagnostic CT is available from 1 year ago documenting stability, then the baseline LCS examination can appropriately be classified as Lung-RADS 2. Likewise, if the 8-mm nodule is new from 1 year ago, then the appropriate classification would be Lung-RADS 4B (new 8-mm solid nodule
- A DCT may be used as a substitute for annual (not baseline) LCS if the examination is of sufficient diagnostic quality and meets technical parameters of LCS CT with the exception of dose
- If known prospectively, the DCT report should indicate that the study is also being performed as an annual LCS assessment and include a Lung-RADS classification and management recommendation

Lung Cancer Screening

What are the potential harms and challenges to implementation of Lung cancer screening?

Potential harms and challenges of LDCT Lung Ca screening

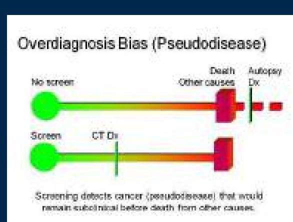
- False positive results
- Over diagnosis
- Radiation exposure
- Low screening uptake

LDCT screening Lung Ca. False Positive results

- Defined as any result leading to additional evaluation (eg, repeat LDCT scan before the next annual screening, biopsy) that did not result in a diagnosis of cancer
- Among the trials that found lung cancer screening mortality benefit and cohort studies based in the US, false-positive rates were 9.6% to 28.9% for baseline and 5.0% to 28.6% for incidence rounds
- In the NLST, false-positive results led to invasive procedures (needle biopsy, thoracotomy, thoracoscopy, mediastinoscopy, and bronchoscopy) in 1.7% of those screened (number needed to harm, 59). Complications occurred in 0.1% of those screened (number needed to harm, 1000), with major, intermediate, and minor complications occurring in 0.03%, 0.05%, and 0.01%, respectively, of those screened
- Application of Lung-RADS has been shown to reduce false positive rates in LCS

LDCT screening Lung Ca. Overdiagnosis

- Modeling study performed for the USPSTF estimated that 10-12% of screen detected cancer cases are over-diagnosed
- Many cases of overdiagnosis in lung cancer screening attributed to ground glass opacities which have a long doubling time



LDCT screening Lung Ca. Radiation exposure

Radiation exposure from 1 LDCT ranges from 0.65 to 2.36 mSv. Average natural exposure in the US is 3 mSv per year

Risk of radiation-induced lung cancer depends on the age at which screening is begun and cumulative radiation

No direct evidence that radiation at the lower levels used in screening have any detrimental effects at all

Cumulative exposure for an individual from 25 years of annual screening (ie, from age 55 to 80 years as recommended by the USPSTF in 2013) yields 20.8 mSv to 32.5 mSv.

One study estimated the lifetime risk of cancer from radiation of 10 annual LDCTs was 0.26 to 0.81 major cancers for every 1000 people screened*

*Rampinelli C, De Marco P, Origgi D, et al. Exposure to low dose computed tomography for lung cancer screening and risk of cancer: secondary analysis of trial data and risk-benefit analysis. BMJ. 2017;356:j347. doi:10.1136/bmj.j347

LDCT Screening uptake and Prevalence in the US

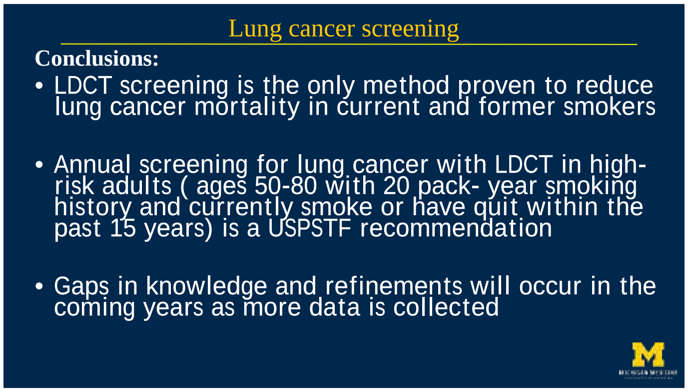
- Expanded 2021 USPSTF eligibility criteria were associated with 5,371 908 additional individuals eligible for LCS, with relative increases highest for Asian, Black, Hispanic, and female individuals, aligning with the goal of reducing race and ethnic and sex disparities in eligibility
- A major problem in LCS is low overall prevalence – 16.4% by one estimate in 2022 *
- Increasing LCS uptake nationwide is essential to realize the benefits of LDCT and reduce Lung cancer mortality

*Henderson LM, Su I, Rivera MP, et al. Prevalence of Lung Cancer Screening in the US, 2022. *JAMA Netw Open.* 2024;7(3):e243190. doi:10.1001/jamanetworkopen.2024.3190

How should LDCT screening for lung cancer be implemented at a population and institutional level?

Key points to optimize benefits of a LDCT Lung Ca screening program

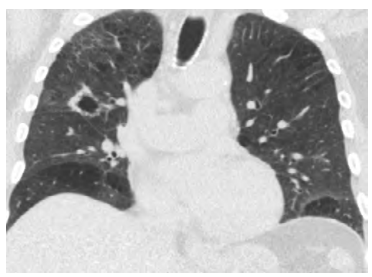
- Integrated multi disciplinary approach; Pulmonology, Thoracic surgery, Radiology. All Lung RADS 4 are discussed in the lung tumor board, which includes radiologist, oncologist, pulmonologist, pathologist, cardio-thoracic surgeon. The committee determines the follow-up scan interval and/or additional investigations
- Appropriate patient selection, education and shared decision making
- Standardized approach to CT scan protocols, reporting and follow up of screen detected findings
- Smoking cessation integral to a LDCT screening program



SELF EVALUATION

Lung Cancer Screening Review

1. For the below lesion detected on a baseline LDCT in a 60 year old smoker what would be the appropriate Lung-RADS score

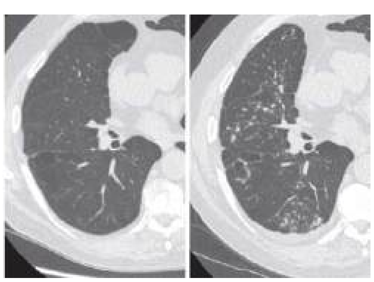


a. Lung-RADS 0
b. Lung-RADS 2
c. Lung -RADS 3
d. Lung-RADS 4A
e. Lung-RADS 4B

2. A 70 year old smoker is found to have the below finding on a baseline LDCT . What would be the appropriate Lung-RADS category ?

a. Lung-RADS 0
b. Lung-RADS 2
c. Lung -RADS 3
d. Lung-RADS 4A
e. Lung-RADS 4B

3. Baseline and 1 year annual LDCT are shown below in a 65 year old smoke. What would be the appropriate Lung RADS category for the 1 year annual LDCT?



a. Lung-RADS 0
b. Lung-RADS 2
c. Lung -RADS 3
d. Lung-RADS 1
e. Lung-RADS 4A

Lung Cancer Screening Review (cont.)

4. A 70 year old smoke has the below lesion measured at 2.5 cm on a baseline LDCT. What would be the appropriate Lung-RADS category?

a. Lung-RADS 0
b. Lung-RADS 2
c. Lung -RADS 3
d. Lung-RADS 4B
e. Lung-RADS 4X

5. A CT scan from a 56 year old smoker at base line LDCT is shown below. The lesion is measured at 3cm. What would be the appropriate Lung-RADS score?

a. Lung-RADS 0
b. Lung-RADS 2
c. Lung -RADS 3
d. Lung-RADS 4B
e. Lung-RADS 4X

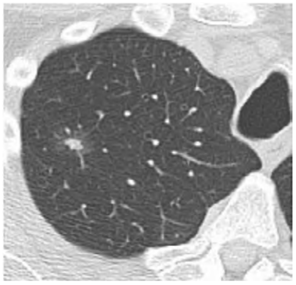
6. In which of the following patients is LDCT screening for lung cancer appropriate as per current USPSTF guidelines?

a. A 45 year old non smoker with a strong family history of lung cancer in 1st degree relatives
b. A 50 year old current smoker with a 10 pack year smoking history
c. A 60 year old current smoker with a 20 pack year smoking history
d. A 75 year old smoker with a 25 pack year smoking history and quit for 20 years
e. A 70 year old current smoker with a 20 pack year smoking history and unresectable pancreatic cancer

7. In a standard sized patient which of the following is the correct radiation dose that can be administered in a LDCT screening study?

a. CTDIvol ≤ 3 mGy
b. CTDIvol ≤ 4 mGy
c. CTDIvol ≤ 1 mGy
d. CTDIvol ≤ 5 mGy
e. CTDIvol ≤ 7 mGy

8. A 75 year old smoker is found to the have the below lesion on baseline LDCT. The overall lesion is measured at 15 mm and the solid part at 6mm. What would be the appropriate Lung-RADS category?



a. Lung-RADS 0
b. Lung-RADS 3
c. Lung -RADS 4A
d. Lung-RADS 4B
e. Lung-RADS 4X

Answer Key: 1. D, 2. D, 3. A, 4. E, 5. C, 6. C, 7. A, 8. C

Imaging of Inflammatory Bowel Disease
Robert M. Marks, MD

Disclosures

- Guerbet LLC

Objectives

- Explain the pathology of inflammatory bowel disease
- Describe the differences between CT and MR Enterography
- Review the standardized lexicon for Crohn's disease

Overview

- Crohn's Disease
- Ulcerative Colitis
- CT/MR Enterography
- Crohn's Lexicon with corresponding images

Inflammatory Bowel Disease

- Chronic abdominal disease affects ~ 3 million in the US
- Two main subtypes:
  - Crohn's Disease
    - Transmural bowel inflammation anywhere in GI tract
  - Ulcerative Colitis
    - Superficial bowel wall inflammation confined to colon and rectum

Crohn's Disease

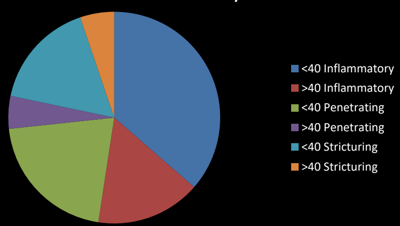
- Chronic relapsing idiopathic disorder
- Onset usually early adulthood (15-35 y/o)
- Unknown cause
  - Many causes postulated
    - Diet, smoking, stress, infection, genetic factors, and autoimmune abnormalities
    - 4x increased incidence in smokers
- More common in Caucasian and European Decent
- 5-20% of those affected have a first degree relative

Subtypes

- **Inflammatory:** bowel wall inflammation
  - Erosions, ulceration, full thickness bowel inflammation
  - Abdominal pain and diarrhea
- **Stricturing:** narrowing of the bowel caused by fibrosis (or inflammation) of the wall
  - Nausea, vomiting, constipation
- **Penetrating:** abscesses, sinus tracts, fistulas
  - Fevers, sxs secondary to fistulization

Types of Crohn's

Vienna Classification Study 2000



Inflammatory Bowel Diseases 6(1):8-15 © 2000 Crohn's & Colitis Foundation of America, Inc

Why differentiation is important

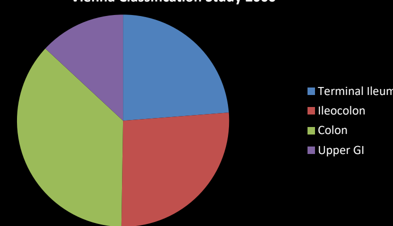
- Inflammatory - can be treated medically
  - Anti-inflammatories work better with active disease
- Penetrating and stricturing disease – may need surgery/bowel resection

Long Term Evolution

- Over 2000 patients studied over 20 years
- Most patients present with inflammatory disease
- Over 60% will develop a stricture or penetrating complication in 20 years.
  - Need to treat CD in the early inflammatory phase
    - *Cosnes "Long Term Evolution of Disease Behavior of Crohn's Disease" 2006 Inflammatory Bowel Disease*

Location of Disease

Vienna Classification Study 2000



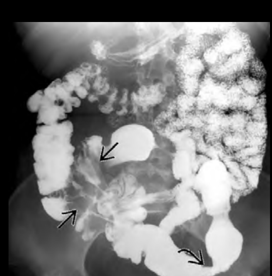
Inflammatory Bowel Diseases 6(1):8-15 © 2000 Crohn's & Colitis Foundation of America, Inc

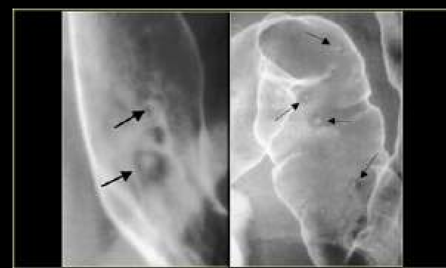
Imaging

- Fluoroscopy
  - Small Bowel Follow Through
  - Upper GI
- CT
- MR Enterography

Fluoroscopy

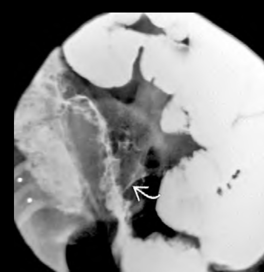
- Small Bowel Follow Through
  - Ulcers
    - Cobblestoning, aphthous ulcers
  - Mural Thickening
    - Transmural inflammation and fibrosis
  - Skip Lesion
    - Alternating normal bowel with diseased bowel
  - Sacculations on anti-mesenteric border
    - Ulcers and fibrosis typically occurs on mesenteric border
    - Increased luminal pressure
  - Post-inflammatory pseudopolyps
  - Sinus tracks, fistulas, fissures
  - Creeping Fat





Gastrointestinal: The shell sign of Crohn's disease

Journal of Gastroenterology and Hepatology
Volume 23, Issue 1, pages 163-163, 13 DEC 2007 DOI: 10.1111/j.1440-1746.2007.05257.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1440-1746.2007.05257.x/full#f1



DDx of Terminal Ileitis

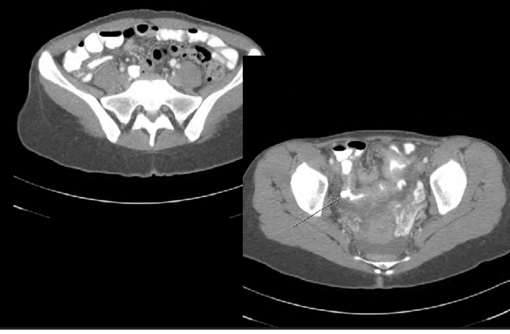
- Crohn's
- UC
- TB
- Yersinia
- MAI
- CMV

CT Findings

- In General: Discontinuous asymmetric bowel wall thickening
- Inflammatory
  - Stratified Mural Enhancement (Target Sign)
    - High density/enhancement mucosa
    - Low density submucosal edema (fat in more chronic stage)
    - Higher density outer ring (muscularis propria serosa)
  - Fibrofatty proliferation in mesentery (creeping fat)
  - "Comb Sign" → engorgement of vasa recta

CT Findings

- Stricturing
  - Increased luminal narrowing
  - No target sign or submucosal fat
  - Homogeneous attenuation of thickened wall
  - Leads to SBO
  - Can have strictures due to inflammation
    - Treatment conundrum
- Penetrating Disease
  - Abscesses, fistulas, sinus tracts



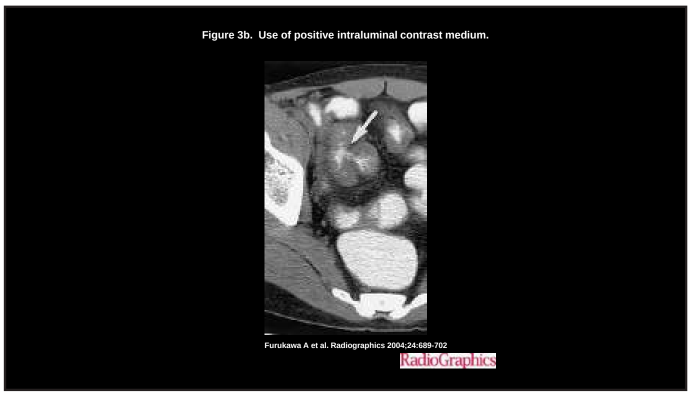


Figure 3b. Use of positive intraluminal contrast medium.
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics


Figure 11c. High-grade small bowel obstruction at the distal ileum caused by Crohn disease.
Tilt
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics

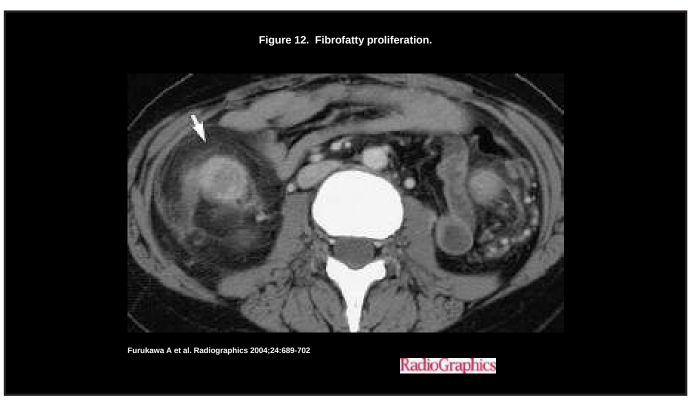


Figure 12. Fibrofatty proliferation.
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics


Figure 13. Abscess in the small bowel mesentery.
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics


Figure 15. Iliopsoas muscle abscess.
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics

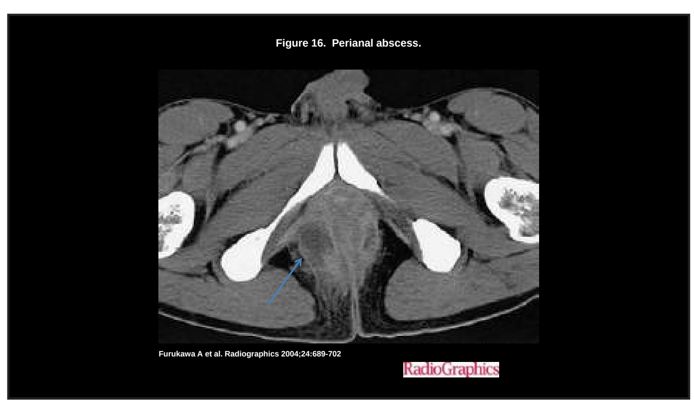


Figure 16. Perianal abscess.
Furukawa A et al. Radiographics 2004;24:689-702
RadioGraphics

Ulcerative Colitis

- Idiopathic condition of the colon causing mucosal inflammation
- Symmetric circumferential continuous confluent inflammation from rectum retrograde
- 50% increased incidence of colon carcinoma after 25 years of disease
  - Much higher risk of CA than Crohn's
- Age 15-25 (late presentation 55-65)
- More common in Caucasians and European decent
- 30-100 x greater incidence in 1st degree relatives

Ulcerative Colitis

- Superficial bowel wall inflammation confined to colon and rectum
- Begins in rectum, moves retrograde
- Backwash ileitis in 10-40% of chronic UC patients
- Associated with Primary Sclerosing Cholangitis
  - 70% of PSC patients have UC
- Toxic Megacolon
  - Acute transmural fulminant colitis, life threatening
  - Marked colonic dilatation with thumbprinting (mean 8-9 cm)

Toxic Megacolon

Fluoroscopy

- Barium Enema (acute)
  - Colorectal narrowing
  - Fine mucosal granular pattern
  - Thickened and edematous haustra
  - Flask Shaped Collar Ulcers
  - Inflammatory and Post Inflammatory Psuedopolyps

Fluoroscopy

- Barium Enema (Chronic)
  - Blunted haustra or complete haustral loss
  - "Lead Pipe" or featureless colon
  - Backwash ileitis
  - Luminal narrowing
  - Benign strictures
- Look for apple core lesions
  - Adenocarcinoma

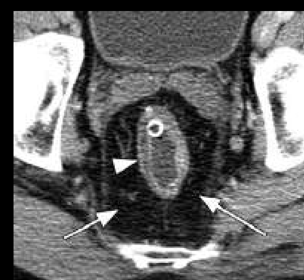
CT Findings

- Thickened bowel wall > 10mm in characteristic pattern
- Widened pre-sacral space >1.5 cm
- Stratified Mural Enhancement
  - Enhancing mucosa
  - Non-enhancing sub-mucosa
  - Enhancing outer ring (muscularis propria)
- Enhancing polyps/pseudopolyps
- Inflammatory pericolonic stranding

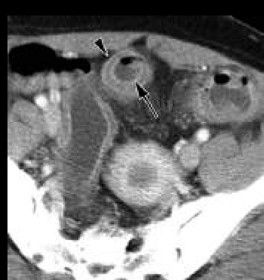
Transverse CT image in a 34-year-old woman with ulcerative colitis.

Thoeni R F , Cello J P Radiology 2006;240:623-638

Transverse CT image in a 45-year-old man with chronic ulcerative colitis.



Thoeni R F , Cello J P Radiology 2006;240:623-638



Thoeni R F , Cello J P Radiology 2006;240:623-638

Transverse CT image in a 35-year-old patient with ulcerative colitis and toxic megacolon shows markedly distended transverse colon with shaggy mucosa (arrows).

Thoeni R F , Cello J P Radiology 2006;240:623-638

CT/MR Enterography

- Noninvasive imaging method
- Utilized as biomarkers for IBD activity
- Can evaluate the entire GI tract (especially small bowel)
- Improved bowel segment resolution
- Can assess
  - Disease distribution (CD vs. UC)
  - Fistulae or strictures requiring surgery
  - Abscess (counter-indication for many medical treatments)
  - Extraintestinal disease

Comparison of MRE and CTE

Advantages of CTE

- Fast Scan (<2 sec)
- More consistent image quality (no motion or peristalsis)
- Better availability
- Lower cost
- Better spatial resolution and free air detection

Advantages of MRE

- No ionizing radiation
- Superior contrast resolution (bowel wall characterization T2, DWI, post contrast)
- Superior evaluation of perianal region and biliary tree

What is Enterography?

- CT/MR protocol tailored to evaluate the small bowel
- Enteric phase of contrast enhancement
- Large volume of nonabsorbable oral contrast (neutral on CT and low SI on T1w MRI) to visualize mural edema and mucosal hyperenhancement

Oral Contrast

- Oral contrast distends small bowel
  - Displaces intraluminal air and succus that can degrade images
- 1000-1500 mL over 45-60 minutes to give uniform distention
- Many on market: Breeza, VoLumen, MiraLax
  - Low dose Barium, with sorbitol ,which promotes distention of bowel
  - Water gets absorbed too quickly
- Some patient's have better tolerance with different oral contrast agents
  - Can benefit from multiple agents on hand

Cine Imaging MRI

Cine Imaging

- Helpful for evaluating peristalsis and discriminating underdistended from inflamed bowel
- We also use it to check if contrast made it to cecum for glucagon injection

Other technical considerations

- Survey of all members of SAR DFP Crohn's
  - Do you monitor oral contrast intake for CTE/MRE (69-75% yes)
  - Use of hypoperistaltic agent for MRE (81% yes)
  - 1.5T vs. 3T for MRE (81% had no preference)
  - MRE-predominant practice (63% yes)
  - Multiple different ways to do exams
    - Multiple pulse sequences, patient positioning
      - Gandhi NM, et al. Abdom Radiol (2020)

CTE vs. MRE Comparison

- A few studies to date
  - Comparison vs. endoscopic and histological reference standards
- Accuracy and sensitivity 80-90% for both
- What about CT vs. CTE?
  - Most CT's out of ED are without oral contrast
  - Sensitivity is comparable for inflammation
    - Not as good for subtle fistulas
      - HA Siddiki et al. AJR 2009
      - SS Lee et al. Radiology 2009
      - KB Quencer et al. Abdom Imaging 2013

When is CTE preferable?

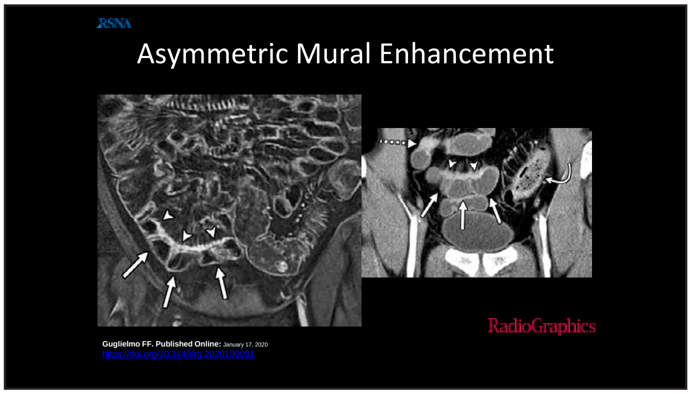
- Small bowel tumors
- Determination of precise length of diseased small bowel prior to resection
- Acutely ill patients (can't hold their breath)
- Patients with claustrophobia/can't lie still
- MR incompatible implants

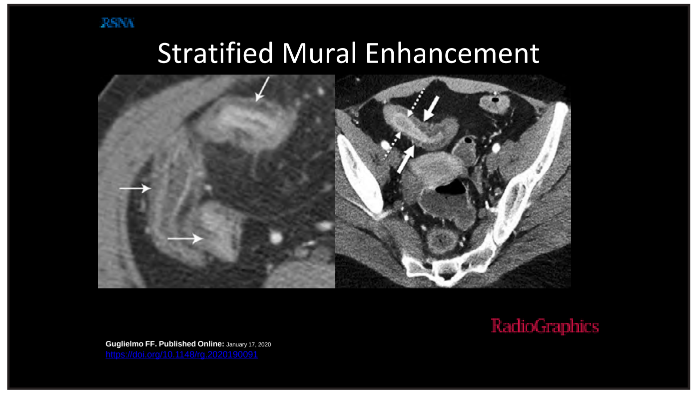
CTE Radiation

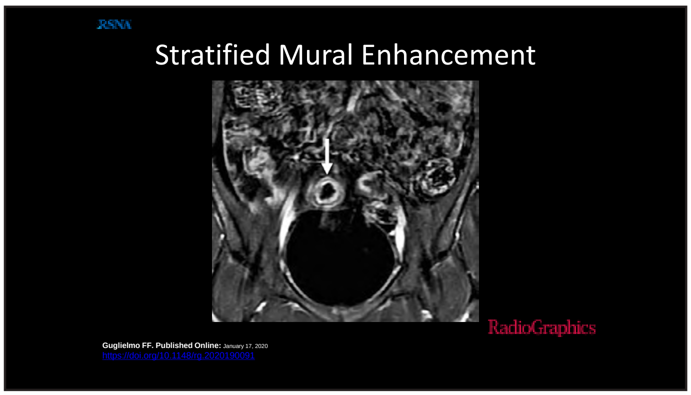
- Study has shows that Crohn's patients over 15 years can get 75mSV of radiation from CTE (study in the 90's)
- Dose reduction techniques
  - Improved software, low KV scanning, better post processing, iterative reconstruction, Proton Counting CT
  - Sub mSv CTE in children now achievable!
  - Dual Energy imaging can improve detection of bowel enhancement
    - CH McCollough, Radiology 2012
    - MJ Callahan, AJR 2015

Recommended Standardized Nomenclature

- SAR DFP Crohn's, Society of Pediatric Radiology, and American Gastroenterological Association


RSNA
Asymmetric Mural Enhancement
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020


RSNA
Stratified Mural Enhancement
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020


RSNA
Stratified Mural Enhancement
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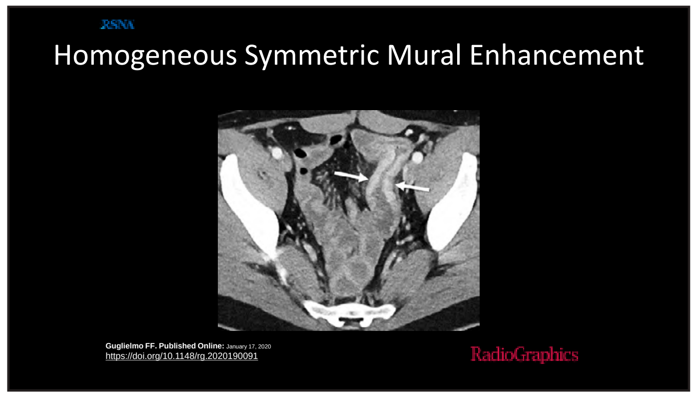
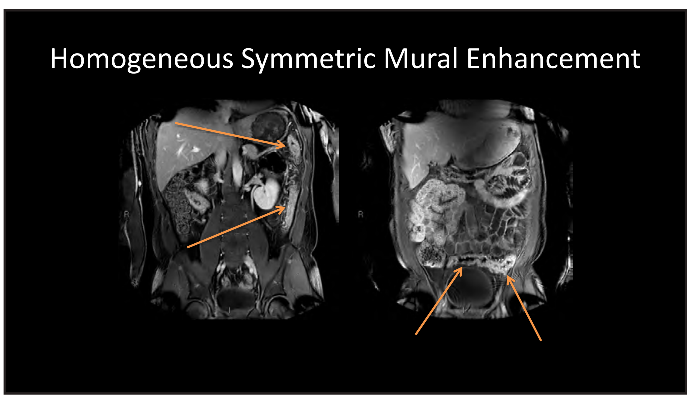
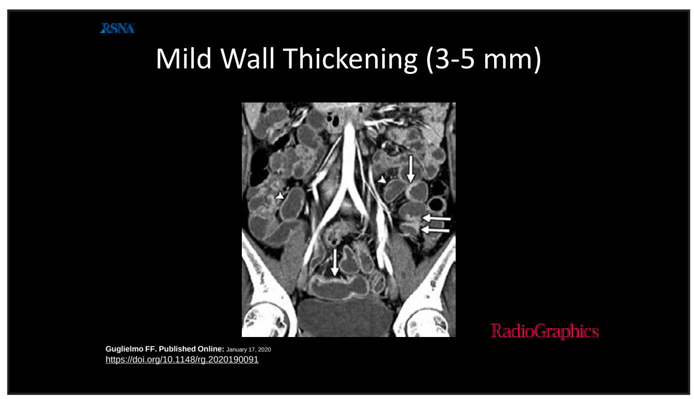
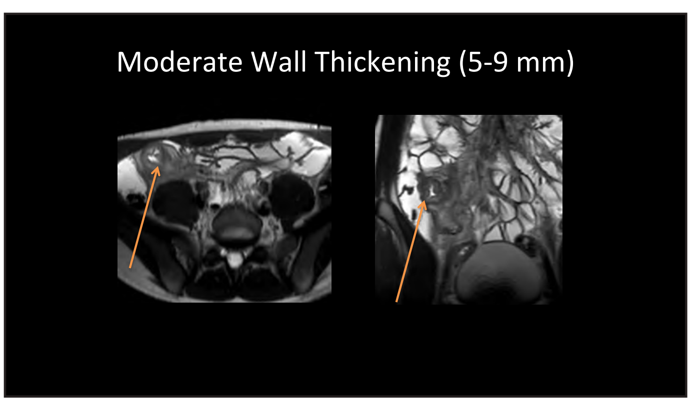
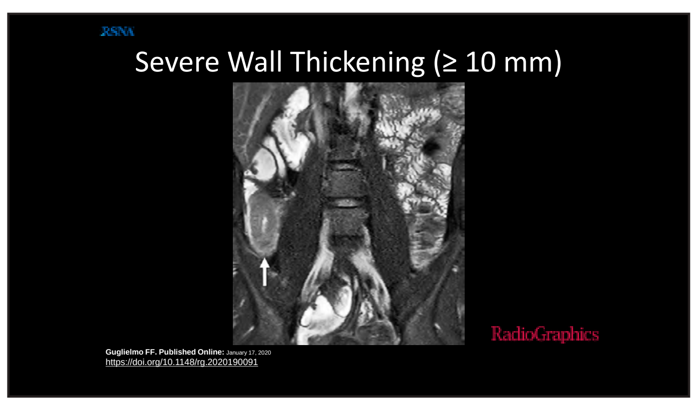
Guglielmo FF. Published Online: January 17, 2020

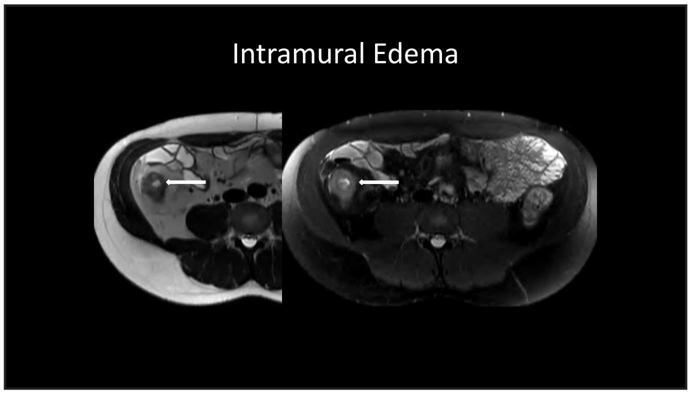

RSNA
Homogeneous Symmetric Mural Enhancement
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091
RadioGraphics

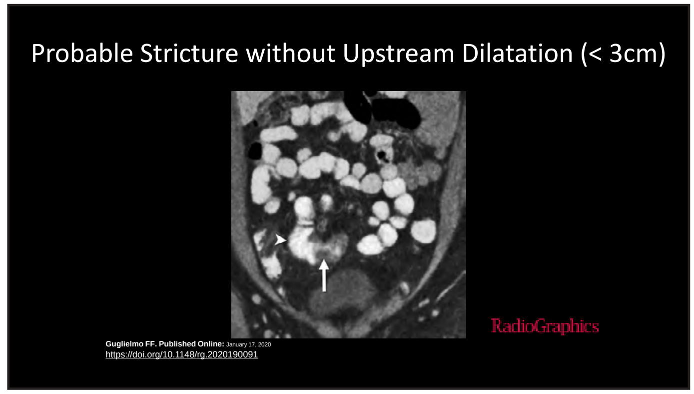

Homogeneous Symmetric Mural Enhancement

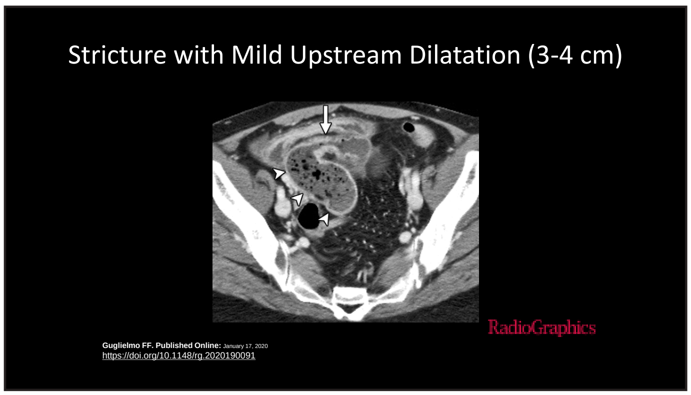

RSNA
Mild Wall Thickening (3-5 mm)
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

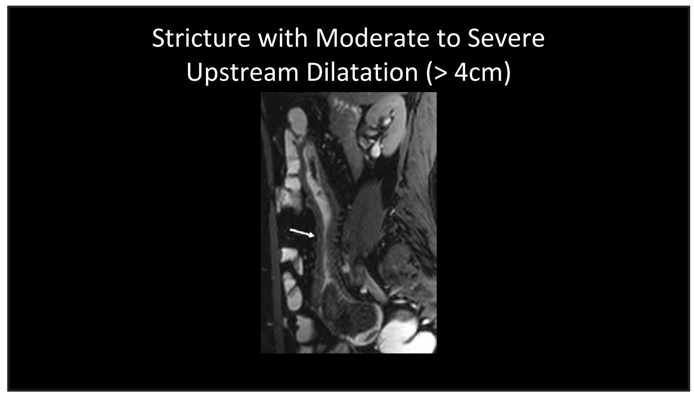

Moderate Wall Thickening (5-9 mm)

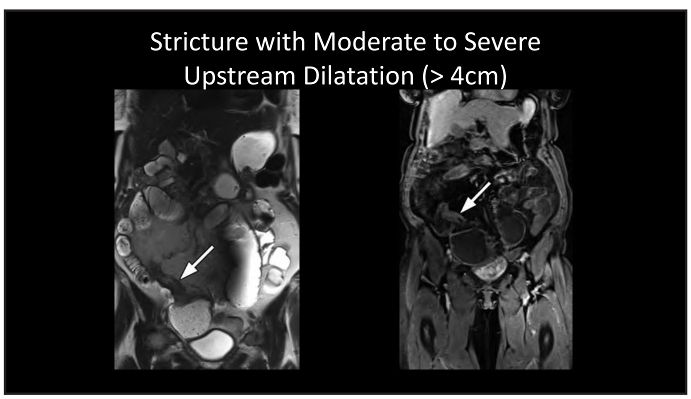

RSNA
Severe Wall Thickening (≥ 10 mm)
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

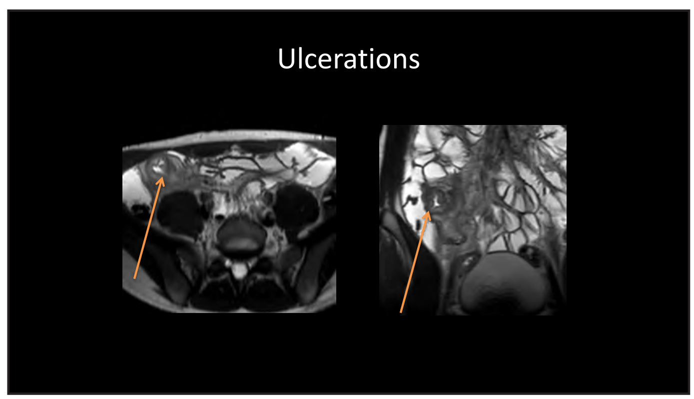

Intramural Edema

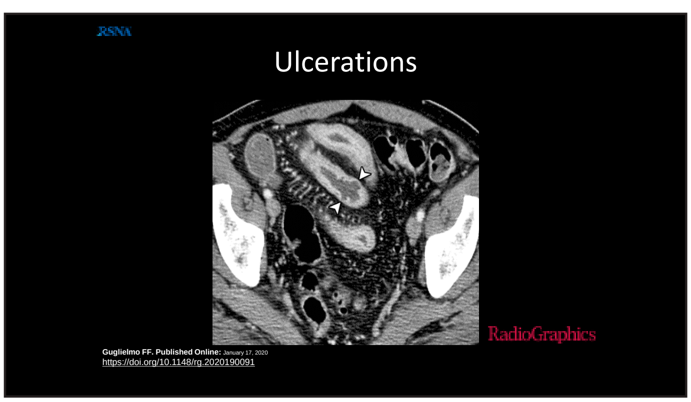

Probable Stricture without Upstream Dilatation (< 3cm)
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

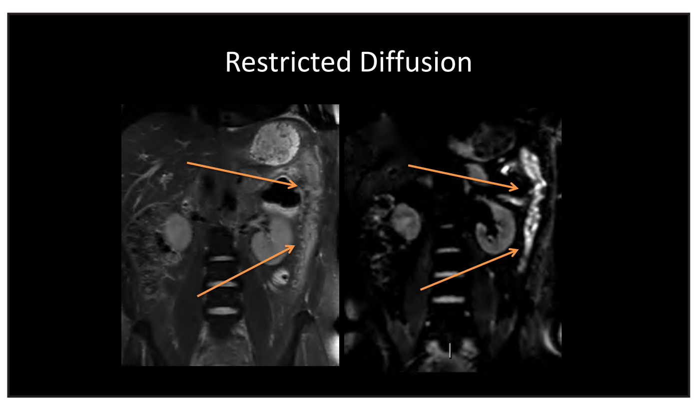

Stricture with Mild Upstream Dilatation (3-4 cm)
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

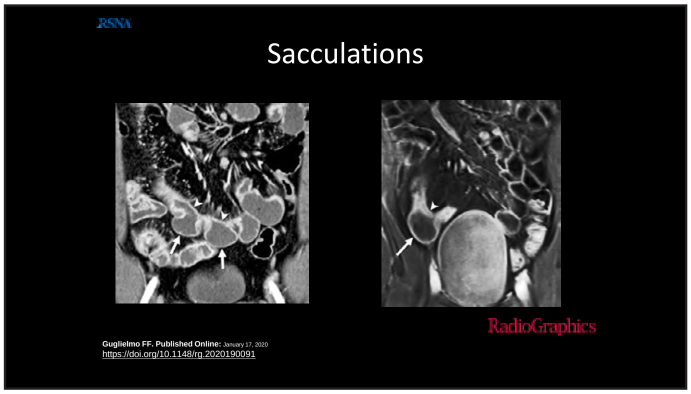

Stricture with Moderate to Severe
Upstream Dilatation (> 4cm)

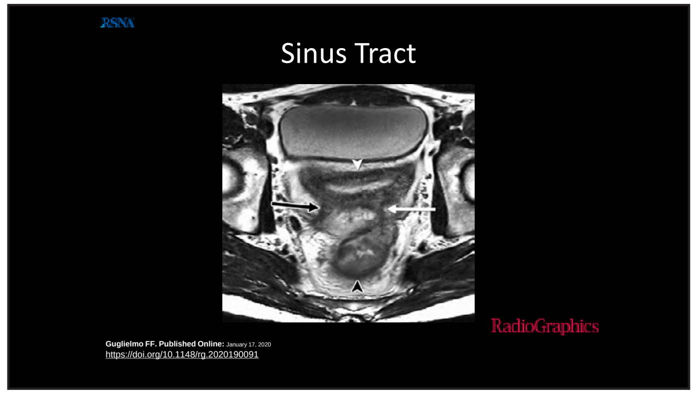

Stricture with Moderate to Severe
Upstream Dilatation (> 4cm)

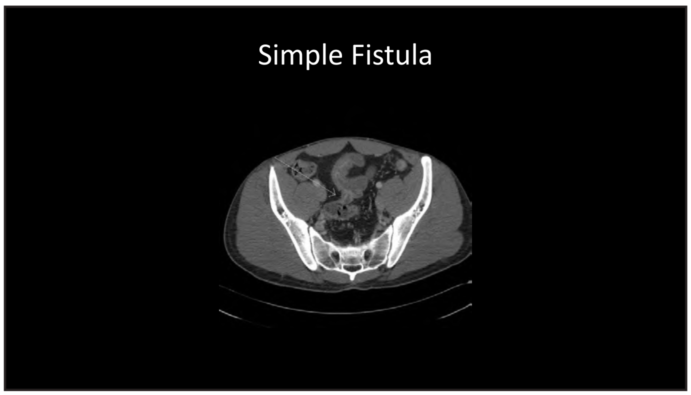

Ulcerations

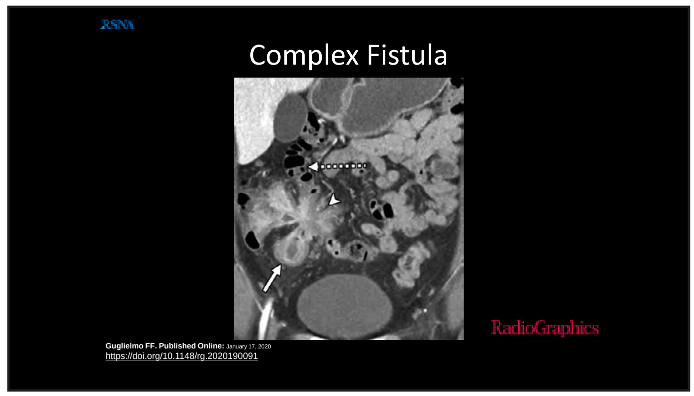

RSNA
Ulcerations
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

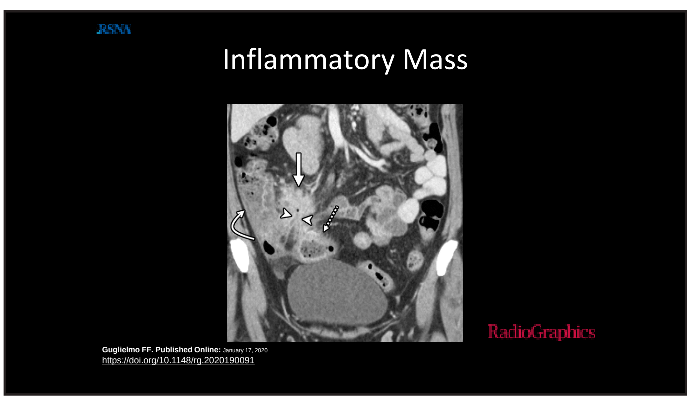

Restricted Diffusion

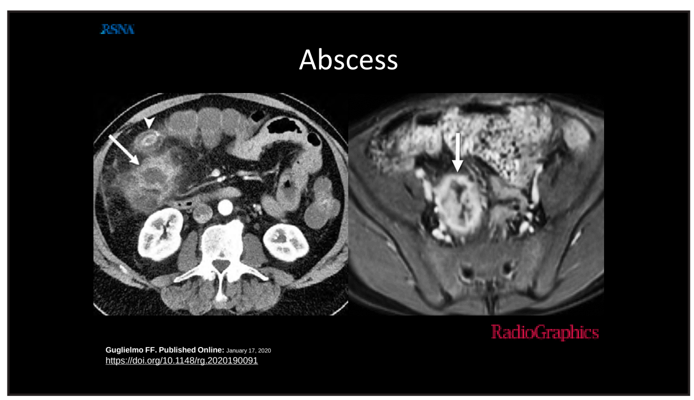

Sacculations
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

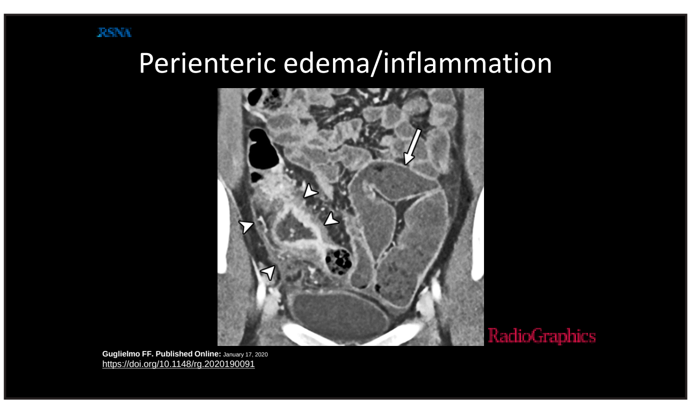

Sinus Tract
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

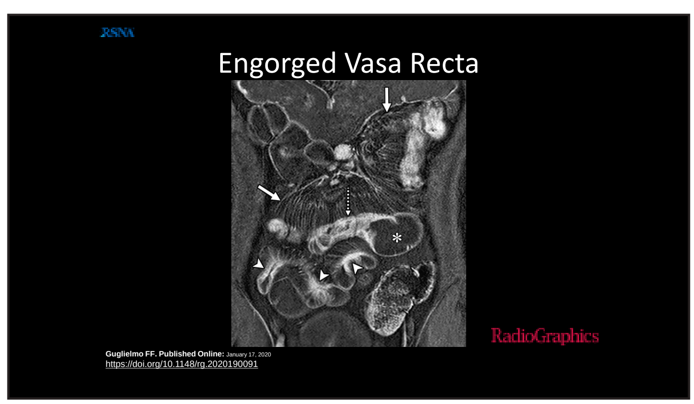

Simple Fistula


Complex Fistula
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

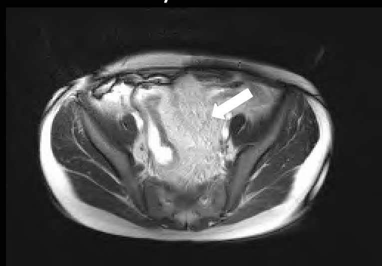

Inflammatory Mass
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091


Abscess
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091


Perienteric edema/inflammation
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091


Engorged Vasa Recta
RadioGraphics
Guglielmo FF. Published Online: January 17, 2020
https://doi.org/10.1148/rg.2020190091

Fibrofatty Proliferation



Summary

- Learned about IBD pathology
- Learned about standard imaging findings
- Learned about CTE/MRE
  - What they are used for
  - Differences between the two
- Learned the lexicon for describing findings

SELF EVALUATION

Imaging of Inflammatory Bowel Disease

1. T/F - In Crohn's disease, sacculations occur on the mesenteric side of the bowel.

2. T/F - Ulcerative colitis has a higher rate of colon cancer compared to Crohn's disease.

3. According to the Vienna classification study of 2000, what single section of bowel is the most common location of diseased bowel in Crohn's disease at time of diagnosis?

- a. Terminal ilium
- b. Ileocolon
- c. Colon
- d. Upper GI

4. According to the multi-society recommended nomenclature for Crohn's disease, what amount of bowel dilatation after a stricture is considered moderate to severe?

- a. 1-2 cm
- b. 2-3 cm
- c. 3-4 cm
- d. > 4 cm
- e. > 6 cm

5. According to the multi-society recommended nomenclature for Crohn's disease, what amount of bowel wall thickening is considered moderate?

- a. 2-3 mm
- b. 3-5 mm
- c. 5-9 mm
- d. < 10 mm

Answer Key: 1. F, 2. T, 3. C, 4. D, 5. C

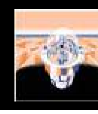
AI and the Imaging Enterprise
Lawrence Tanenbaum, MD, FACR

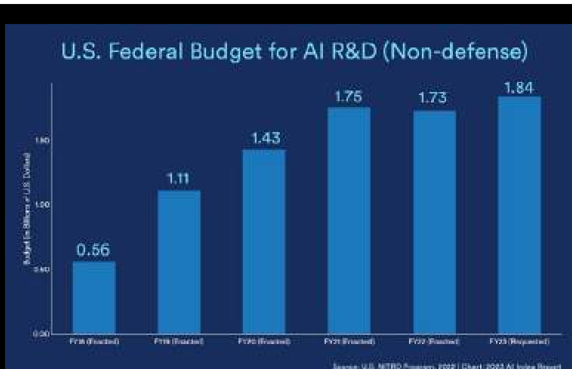
Impact of AI in Neuroimaging

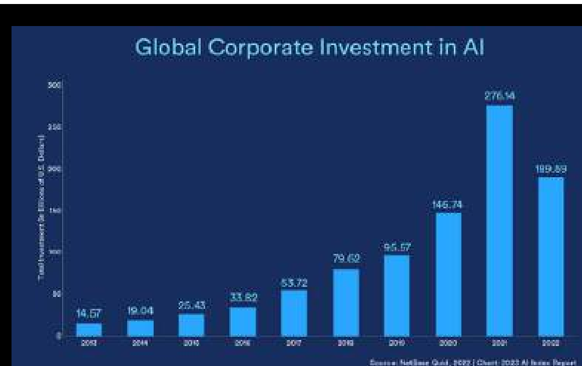
- What is AI
  - What's new?
  - Terminology and background
  - Strengths and limitations
- Impact in Imaging

What is AI?

- Branch of computer science devoted to creating systems to perform tasks that ordinarily requires human intelligence
- Broad umbrella term encompassing a wide variety of subfields and techniques



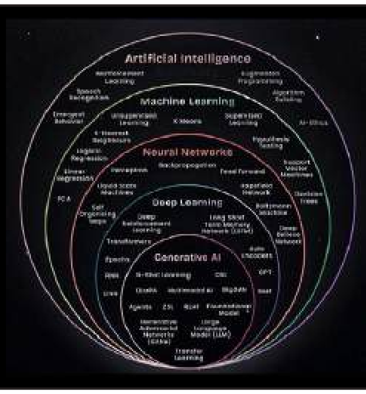




Artificial intelligence

- McKinsey 2022
  - In 2017, 1 in 5 companies used AI
  - By 2022, 50% of all companies used AI
  - 63% of all businesses say they plan to increase investment in AI over the next 3 years
- World Economic Forum 2022
  - 1 in 4 companies say AI generates at least 5% of their net earnings
  - 70% of companies reported an AI-powered revenue boost when deployed in sales, marketing, product development, & service

AI in the Healthcare Enterprise

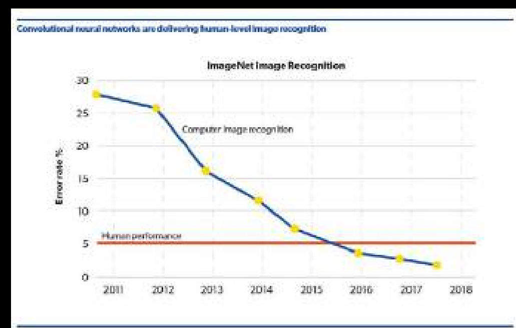


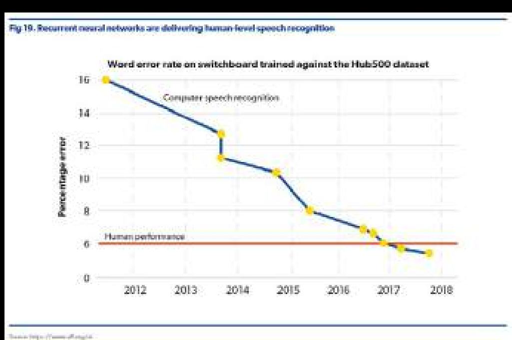
Artificial intelligence

- Term coined late 1950s
- Machine learning (ML)
  - Subset of AI in which a model gains capabilities after it is trained on, or shown, many example data points.
  - Machine learning algorithms detect patterns **and learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction**.
  - The algorithms also adapt and can become more effective in response to new data and experiences.

Artificial intelligence

- Term coined late 1950s
- Neural networks 2012
  - Mathematical system that learns skills by finding statistical patterns in enormous amounts of data.
    - By analyzing thousands of cat photos, for instance, it can learn to recognize a cat.





Artificial intelligence
Generative AI

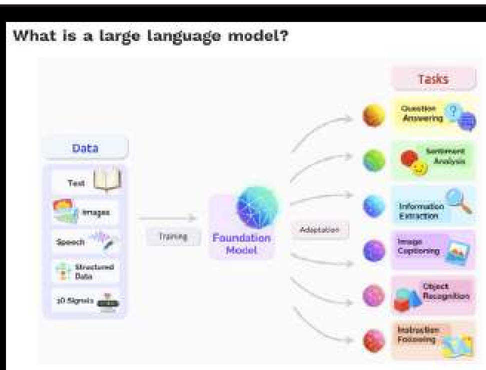
- Foundation models 2017
  - Model trained to be used for downstream tasks.
    - Effective for tasks for which it has not previously been trained.
    - Can be fine-tuned for specific applications, such as detecting lesions or segmenting anatomical structures.

Large language models
2018

- **Foundation models** that utilize DL in natural language processing (NLP) and natural language generation (NLG).
- To learn the complexity and linkages of language, large language models are pre-trained on a vast amount (billions of weights or more) of unlabeled data
- These models have the ability to understand and produce human language and also apply to images and audio

Large language models

- OpenAI - GPT 4o
  - Bing Chat -with current info available via web search
- Google – Gemini
  - Med PaLM provides high quality answers to medical questions
- Meta – LLaMa
  - Open-source research tool that can be deployed on premises
- Apple – Apple Intelligence
  - On device LLM and Private Cloud Compute

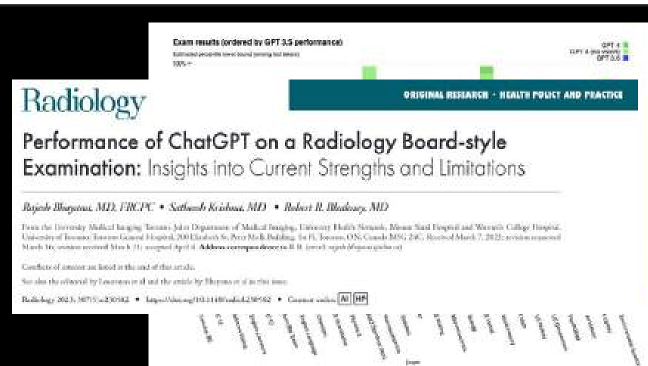


Multimodal models

- Models that can understand and combine different types of medical data, such as medical images and electronic health records.
- Multimodal models are particularly useful in medicine for tasks that require a comprehensive understanding of the patient, such as diagnosis and individualized treatment planning.

Generalist medical AI models

- Class of medical foundation models that can be used across various medical applications, replacing task-specific models.
- Three key capabilities that distinguish from conventional medical AI models.
  - Can adapt to new tasks described in plain language, without requiring retraining
  - Can accept inputs and produce outputs using various combinations of data types
  - Capable of logically analyzing unfamiliar medical content.


Exam results (ordered by GPT 3.5 performance)

Radiology

ORIGINAL RESEARCH · HEALTH POLICY AND PRACTICE

Performance of ChatGPT on a Radiology Board-style Examination: Insights into Current Strengths and Limitations

Text to Image

- Dall-E
- Midjourney
- Stable Diffusion

Midjourney

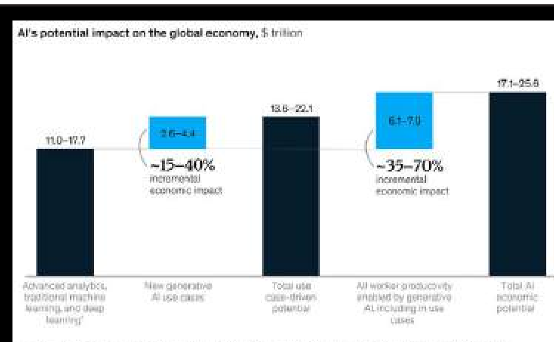
DALL-E

DALL·E: Creating Images from Text (openai.com)

Generative AI

- Funding for generative AI is significant and growing rapidly—reaching a total of $12 billion in the first five months of 2023 alone.
- Venture capital and other private external investments in generative AI increased by an average compound growth rate of 74 percent annually from 2017 to 2022.
- During the same period, investments in artificial intelligence overall rose annually by 29 percent, albeit from a higher base.

The economic potential of generative AI: The next productivity frontier Mckinsey June 2023



The economic potential of generative AI: The next productivity frontier Mckinsey June 2023

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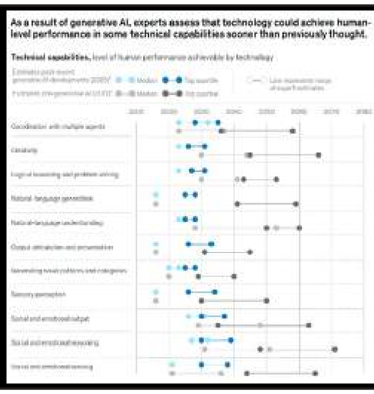
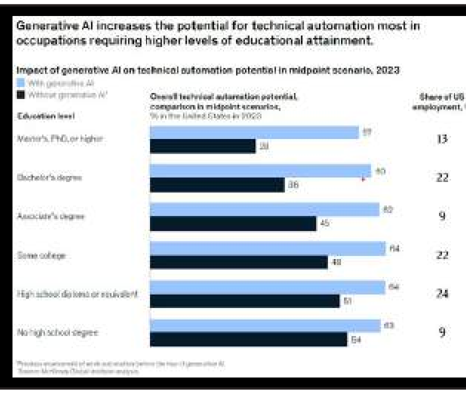
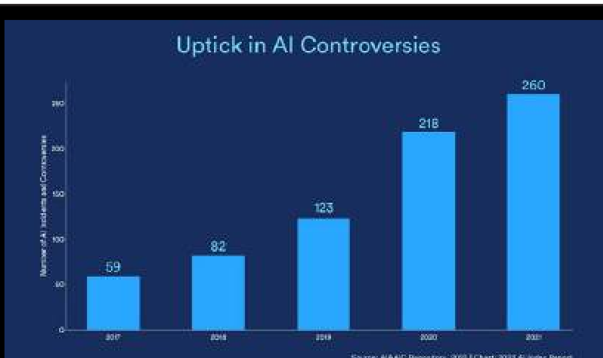
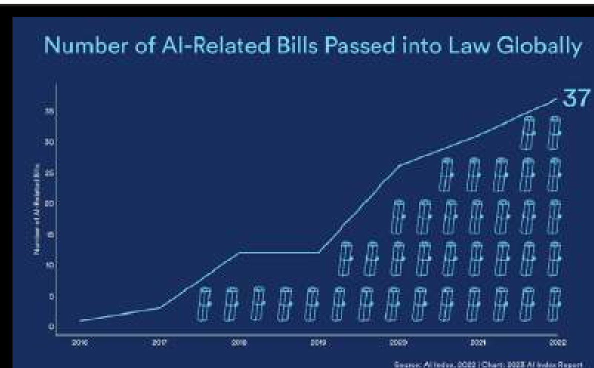


Generative AI

- Generative AI is likely to have the biggest impact on knowledge work, particularly activities involving decision making and collaboration, which previously had the lowest potential for automation.



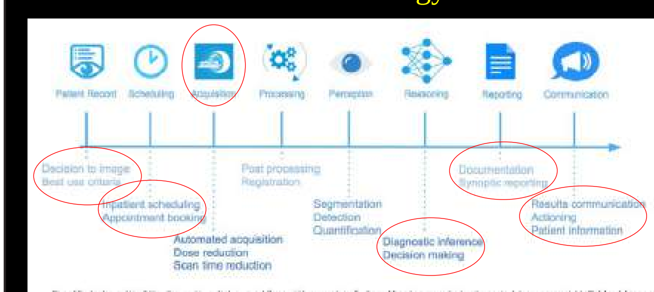




Calls for pause on AI development

- Two 3/23 open letters were signed by tech leaders and researchers calling for a pause on the development of the most powerful artificial intelligence systems.
  - The first was signed by more than 1,000 tech leaders and researchers.
  - The second was signed by more than 1,200 founders and top research scientists.
- Both letters propose delaying AI development for six months to limit the rate of growth of compute used for creating new models.

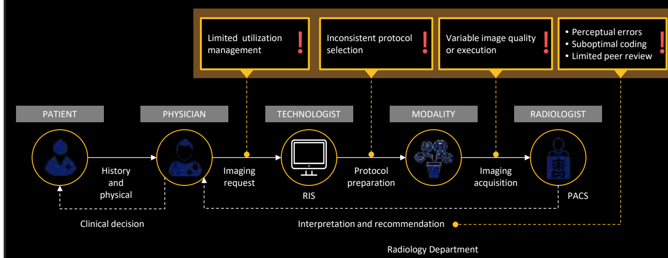
AI use cases in radiology –NLP/U



NL Processing and Understanding

- Enables computers to derive meaning from human (natural language) input.
- Used on medical records/radiology reports, NLP techniques enable automatic identification and extraction of information
- Can convert free text into a structured representation

Points of potential failure throughout the imaging enterprise

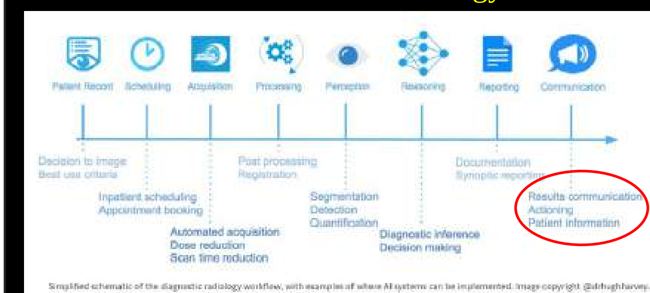


Opportunities for NLP/U

NLP/U/G Applications in Radiology Reports

- Flagging and classification of findings.
  - Highlight important/actionable findings in prior reports.
  - Improve pertinence of report in current episode of care
  - Improve and automate the coding process.
    - Reduce staffing cost
    - Improve concordance and accuracy
  - Assist in peer learning/review

AI use cases in radiology



NLP/U/G Applications in Radiology

- Extracting structured information from reports
- Flagging and classification of findings.
  - help clinicians focus on the important data in the reports.
- Identify recommendations for, automate and standardize follow-up process.

Vera Sorin, Yiftach Barash, Eli Konen, MD, Eyal Klang. Deep Learning for Natural Language Processing in Radiology—Fundamentals and a Systematic Review. J Am Coll Radiol 2020;17:639-648. 2020 American College of Radiology

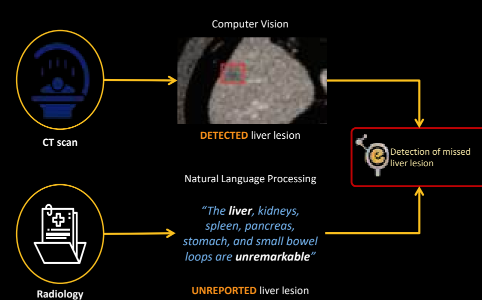
55% don't comply with follow up recommendations

Courtesy Agamon

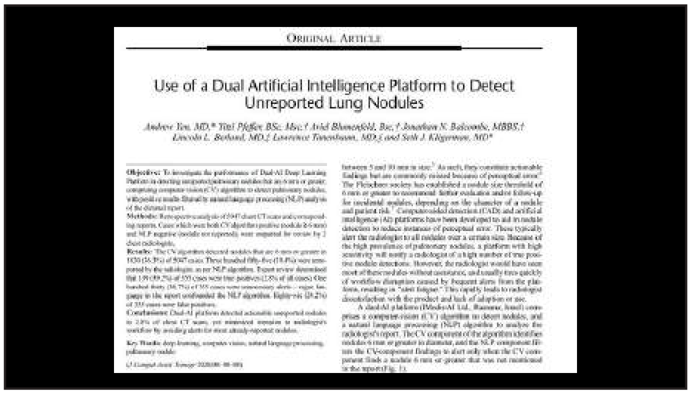
Follow up recommendations

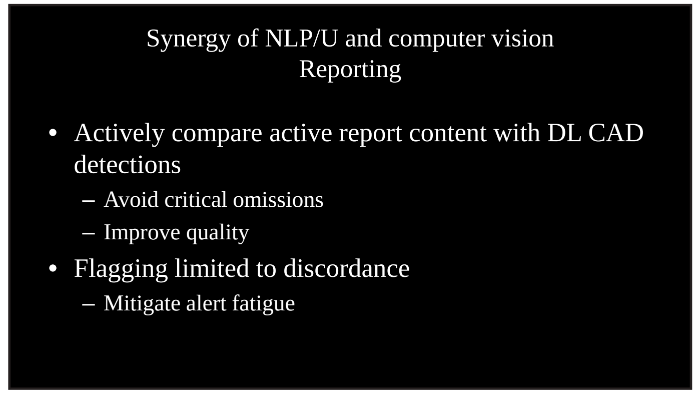
- Radiologist compliance with evidence-based follow up guidelines inconsistent within and between practices
  - Erratic quality
  - Irritant to referrers
  - Payors increasingly aware
- Improving standardization and ensuring compliance improves quality, pleases referrers and may be valued by payors

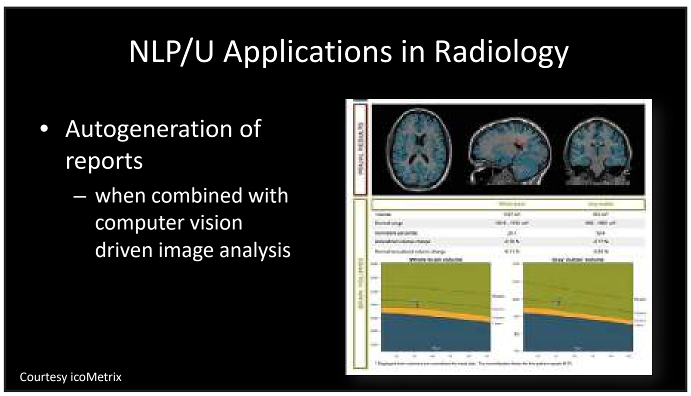
Synergy of NLP/U and computer vision

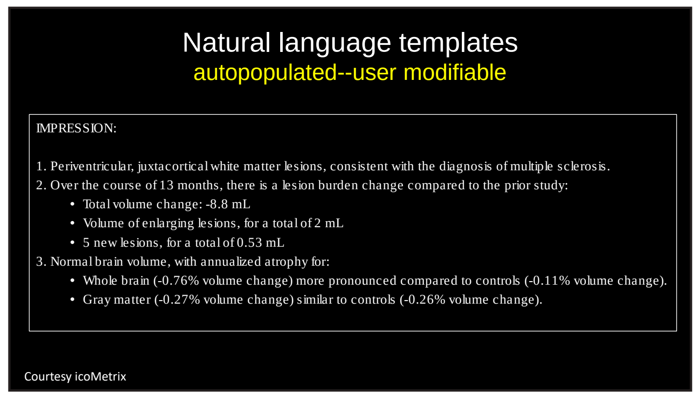


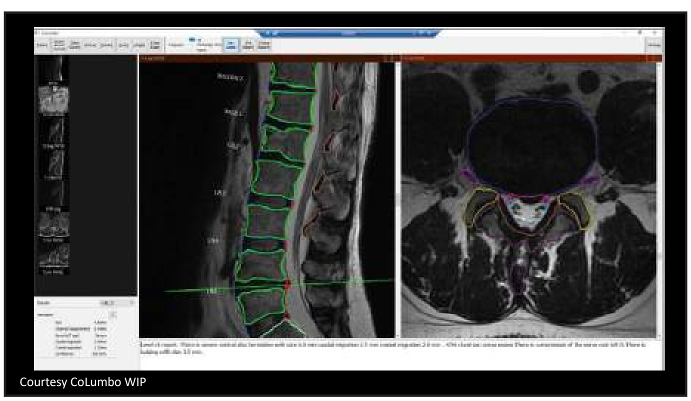
Courtesy iMedis

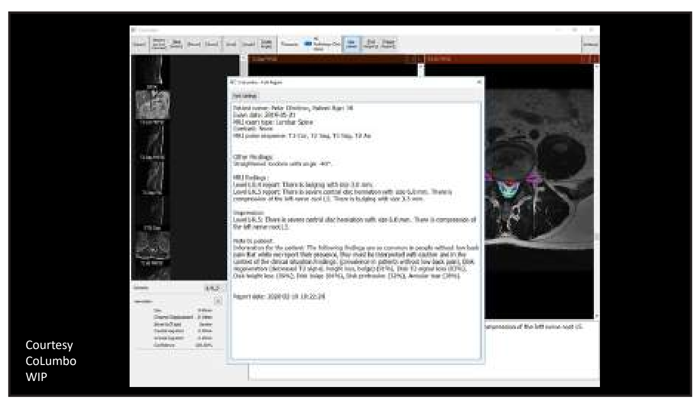

Original Article
Use of a Dual Artificial Intelligence Platform to Detect Unreported Lung Nodules

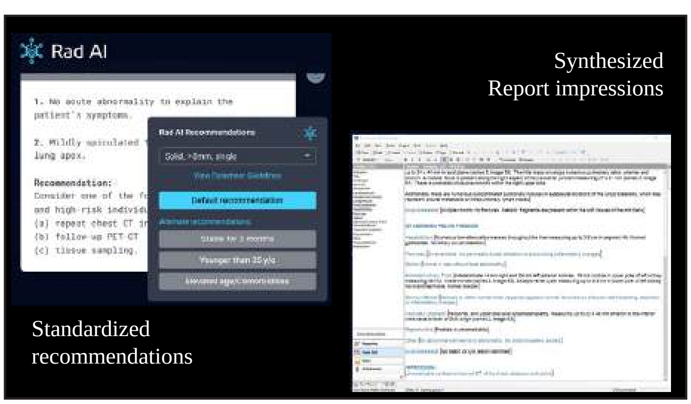

Synergy of NLP/U and computer vision
Reporting
Actively compare active report content with DL CAD detections
Avoid critical omissions
Improve quality
Flagging limited to discordance
Mitigate alert fatigue

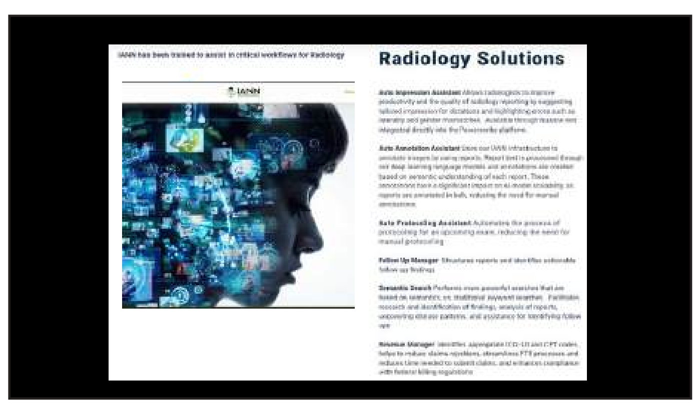

NLP/U Applications in Radiology
Autogeneration of reports
when combined with computer vision driven image analysis
Courtesy icoMetrix

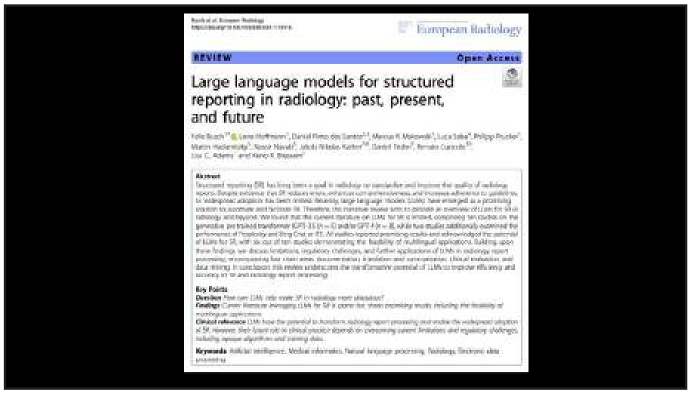

Natural language templates
autopopulated--user modifiable
IMPRESSION:
1. Periventricular, juxtacortical white matter lesions, consistent with the diagnosis of multiple sclerosis.
2. Over the course of 13 months, there is a lesion burden change compared to the prior study:
Total volume change: -8.8 mL
Volume of enlarging lesions, for a total of 2 mL
5 new lesions, for a total of 0.53 mL
3. Normal brain volume, with annualized atrophy for:
Whole brain (-0.76% volume change) more pronounced compared to controls (-0.11% volume change).
Gray matter (-0.27% volume change) similar to controls (-0.26% volume change).
Courtesy icoMetrix

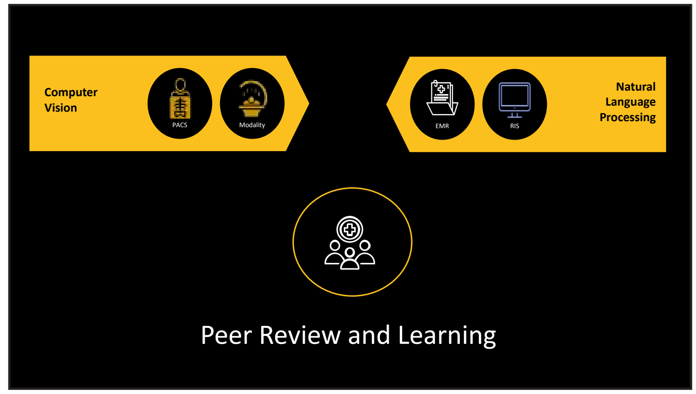

Courtesy CoLumbo WIP

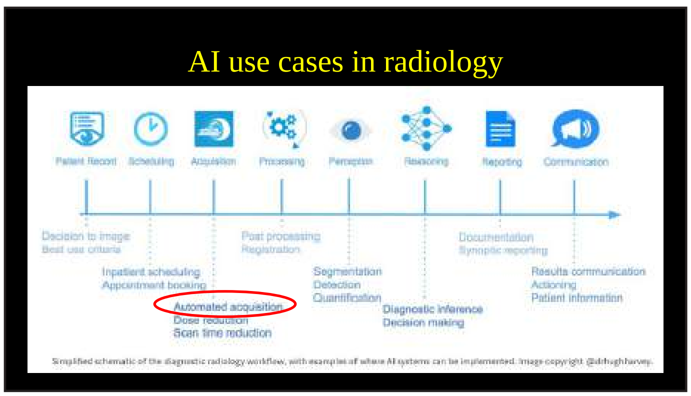

Courtesy CoLumbo WIP

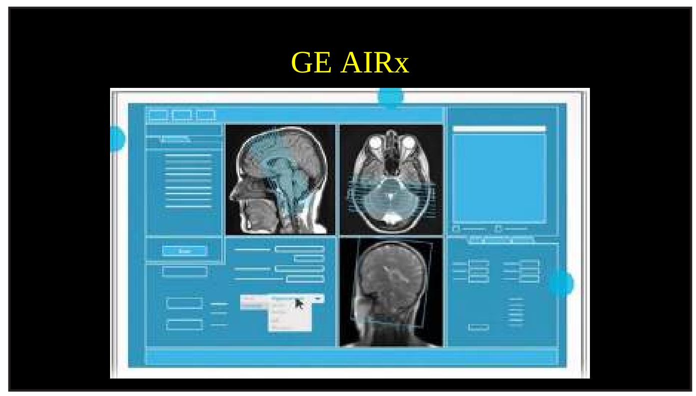

Rad AI
1. No acute abnormality to explain the patient's symptoms.
2. Mildly spiculated
lung apex.
Recommendation:
Rad AI Recommendations
Default recommendation
Synthesized Report impressions
Standardized recommendations

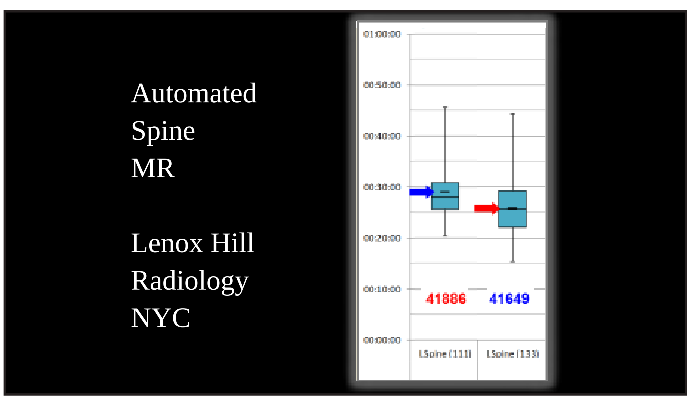

Radiology Solutions


European Radiology
REVIEW
Open Access
Large language models for structured reporting in radiology: past, present, and future

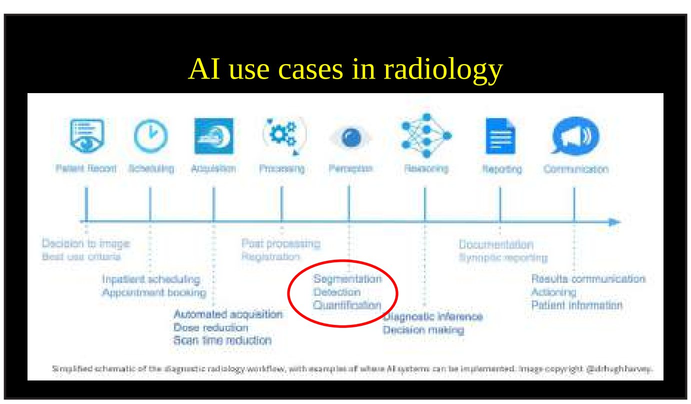

Computer Vision
PACS
Modality
EMR
RIS
Natural Language Processing
Peer Review and Learning


AI use cases in radiology
Patient Record
Scheduling
Acquisition
Processing
Perception
Reasoning
Reporting
Communication
Decision to image
Best use criteria
Post processing
Registration
Documentation
Synoptic reporting
Inpatient scheduling
Appointment booking
Segmentation
Detection
Quantification
Results communication
Actioning
Patient information
Automated acquisition
Dose reduction
Scan time reduction
Diagnostic inference
Decision making
Simplified schematic of the diagnostic radiology workflow, with examples of where AI systems can be implemented. Image copyright @drhughharvey.


GE AIRx


Automated
Spine
MR
Lenox Hill
Radiology
NYC
01:00:00
00:50:00
00:40:00
00:30:00
00:20:00
00:10:00
00:00:00
41886
41649
LSpine (111)
LSpine (133)


In-line Quality Assurance and Improvement
Pass
Fail
Detection of motion + SNR issues
SUBTLE MEDICAL


AI use cases in radiology
Patient Record
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Decision to image
Best use criteria
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Diagnostic inference
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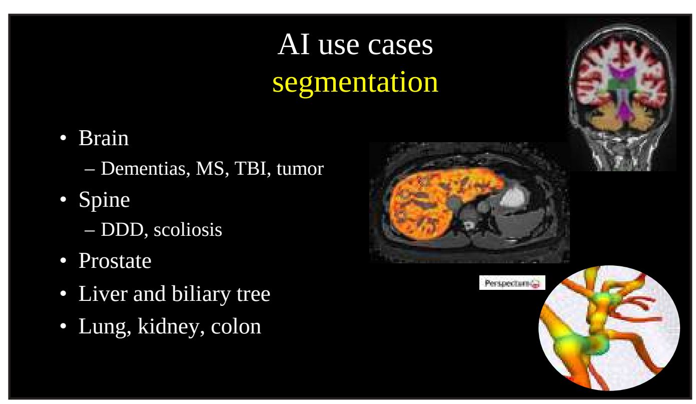
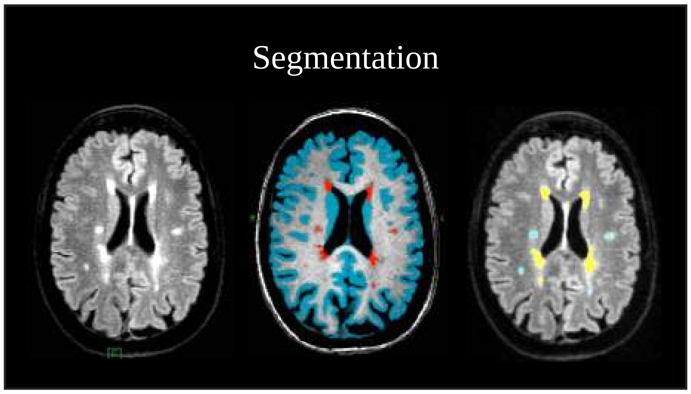
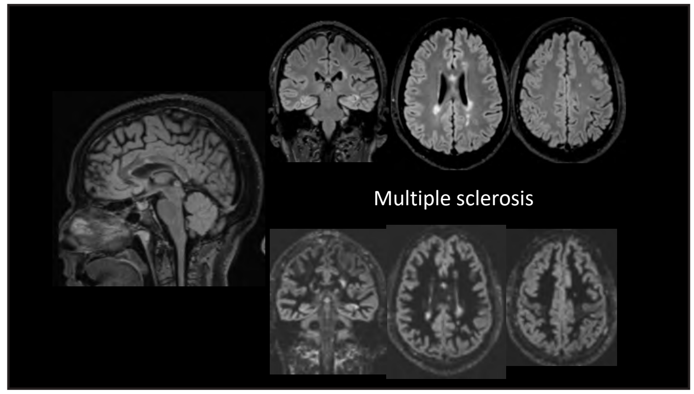
Simplified schematic of the diagnostic radiology workflow, with examples of where AI systems can be implemented. Image copyright @drhughharvey.


AI use cases
segmentation
• Brain
– Dementias, MS, TBI, tumor
• Spine
– DDD, scoliosis
• Prostate
• Liver and biliary tree
• Lung, kidney, colon
Perspectum

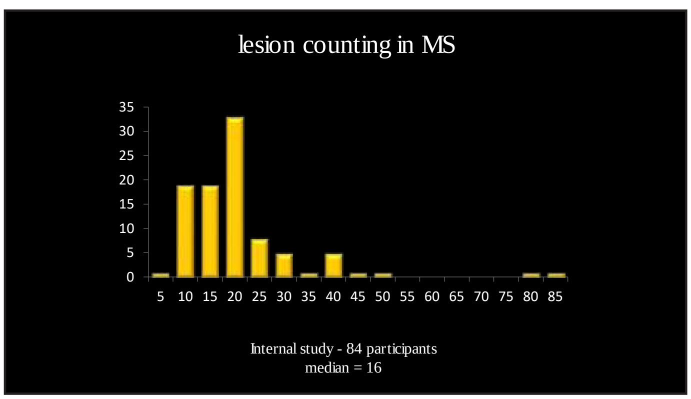


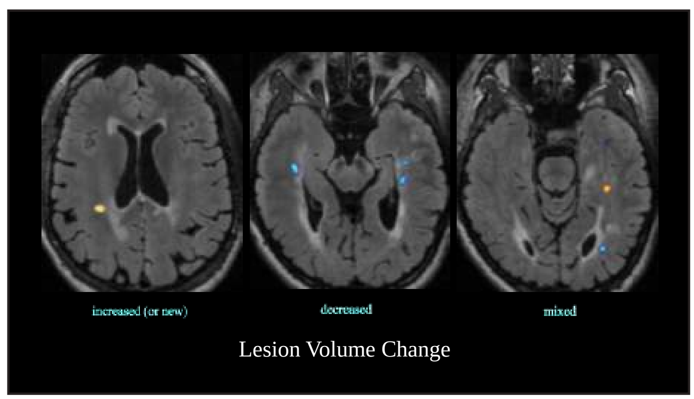


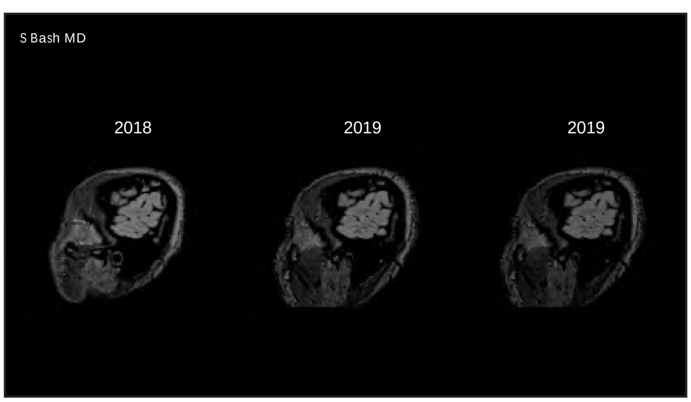
AI assist in multiple sclerosis

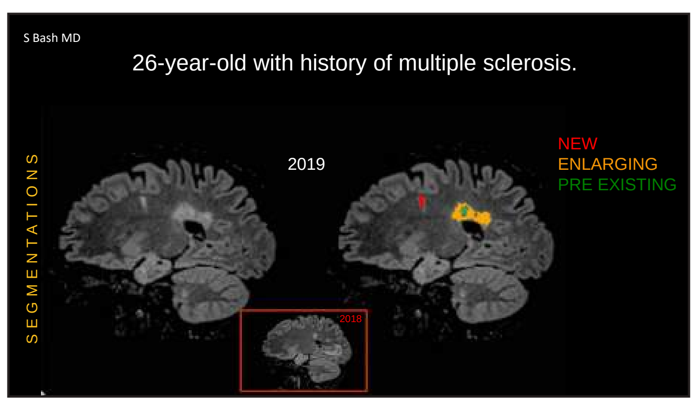
Visual side-by-side comparison of MRI scans:

- Time intensive
- Subject to reader's expertise
- Hard to quantify and detect subtle lesion changes in lesion volume and number
- Difficult to detect and quantify brain volume loss





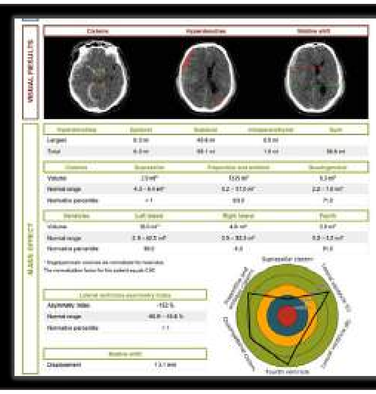




AI software-assisted MRI for QNI and MS

- Standardize and speed reporting
  - Dickerson et al. 2016
  - Lee et al. 2020
  - Alessandrino et al. 2018
- Enhance sensitivity
  - Van Heerden et al. 2015
  - Beadnall et al. 2017
  - Sima et al. 2020

Quantitative imaging of acute traumatic brain injury



Standardized outcome prediction and clinical decision-making.

NIRIS

Category	Definition	Patient Management
NIRIS 0	No abnormal finding	Discharge from the ED
NIRIS 1	Fracture +/- Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc +/- Subarachnoid hemorrhage	Follow-up neuroimaging and/ or admit for observation
NIRIS 2	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc +/- Diffuse axonal injury +/- Intraventricular hemorrhage +/- Mild hydrocephalus +/- Midline shift 0 – 5mm	Admit to a more advanced care unit
NIRIS 3	Extra- axial hematoma, parenchymal hematoma or parenchymal contusion > 5cc +/- Moderate hydrocephalus +/- Midline shift > 5mm +/- Focal herniation	Consider neurosurgical procedure (ventricular drain, burr hole, craniotomy/craniectomy, surgical drainage/ evacuation of hematoma)
NIRIS 4	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 25 cc ± Severe hydrocephalus ± Diffuse herniation/ Duret hemorrhage	High risk of TBI-related death

Raj et al., 2014, Wintermark et al,.2018

Standardized outcome prediction and clinical decision-making.

CT SCORING

Category	Definition
NIRIS 0	No abnormal finding
NIRIS 1	Fracture +/- Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc +/- Subarachnoid hemorrhage
NIRIS 2	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc +/- Diffuse axonal injury +/- Intraventricular hemorrhage +/- Mild hydrocephalus +/- Midline shift 0 – 5mm
NIRIS 3	Extra- axial hematoma, parenchymal hematoma or parenchymal contusion > 5cc +/- Moderate hydrocephalus +/- Midline shift > 5mm +/- Focal herniation
NIRIS 4	**Extra-axial hematoma**, parenchymal hematoma or parenchymal contusion **> 25 cc** ± Severe hydrocephalus ± Diffuse herniation/ Duret hemorrhage

Patient Management

- Consider neurosurgical procedure (ventricular drain, burr hole, craniotomy/craniectomy, surgical drainage/ evacuation of hematoma)
- High risk of TBI-related death

Outcome prediction

Rotterdam CT score: compressed basal cisterns +1, midline shift > 5mm +1, epidural mass lesion absent +1, *ivh or tsah +1*, sum +1 = 5 (mortality 53.65%)

Helsinki CT score: subdural hematoma +2, mass lesion size > 25 cc +2, suprasellar cisterns compressed +1 = 5

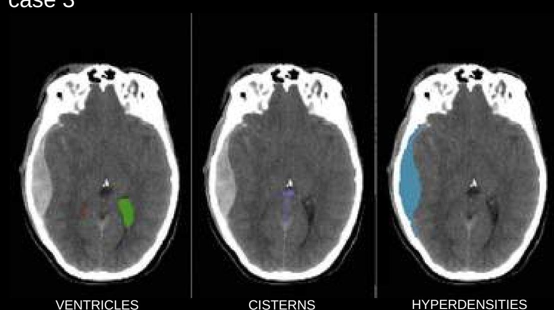
Marshall CT classification: any evacuated mass lesion = 5 (mortality 53%)

Surgical Management

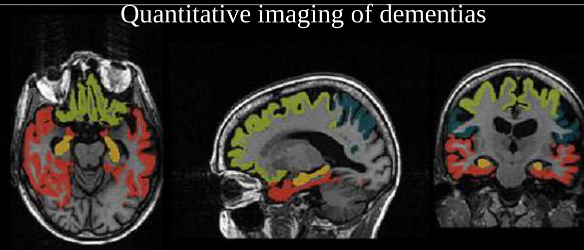
Bullock et al.,2006 Surgical Management of Acute Subdural Hematomas: Acute SDH > 10 mm OR midline shift greater than 5 mm should be surgically evacuated, regardless of GCS.

TBI case 3

SEGMENTATIONS



Quantitative imaging of dementias

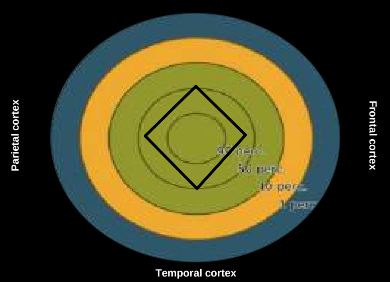


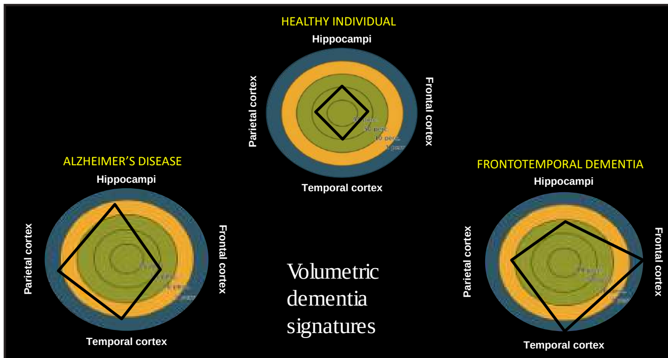
Quantitative imaging in Dementia diagnosis

- Differential diagnosis using brain volumetrics based on structure involvement
- Comparison with healthy age and sex matched population

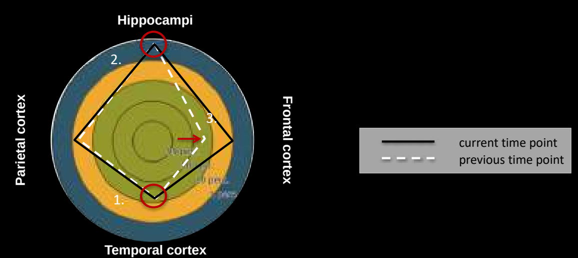
Volume loss phenotypes

	AD	VaD	FTD	DLB
Hippocampal atrophy	+++	++	++	-
Temporal atrophy	++	+	+++	-
Frontal atrophy	-	+	+++	-
Parietal atrophy	++	+	-	-
WML's	-	+++	-	-





Quantitative surveillance and progression



Alzheimer's Disease and Society

- Almost 7 million Americans suffer from Alzheimer's disease
  - 1/9 people over age 65
- Prevalence doubles every 5 years after the age of 60.
- 1 in 3 seniors will die of dementia.
- Up to 420,000 adults in the prime of life — including people as young as 30 — suffer from early-onset Alzheimer's.

Bash and Tanenbaum App Radiology 2023

Alzheimer's Disease and Society

- Major health population issue.
  - The number of new cases of dementia are expected to double by 2050
  - Since the year 2000, death from heart disease has decreased by 7%, but death from Alzheimer's disease has increased by 145%.

Bash and Tanenbaum Applied Radiology 2023

Alzheimer's Disease and Society

- 355 billion in US Cost in 2021
- Expected to climb to $1.1 trillion U.S. dollars in direct costs by the year 2050 (1)

1. Stefanacci Am J Manag Care 2011;17(suppl 13):S356–S362.

Alzheimer's Disease and Therapy

- **The first therapies are monoclonal antibodies that target, mobilize and promote clearance of Aβ.**
- Hypothesis is that Aβ aggregates trigger critical pathophysiologic events including aggregation of τ tangles, synaptic dysfunction, inflammation, and downstream neurodegeneration and cognitive decline.

WARNING: AMYLOID RELATED IMAGING ABNORMALITIES

Monoclonal antibodies directed against aggregated forms of beta amyloid, including LEQEMBI, can cause amyloid related imaging abnormalities (ARIA), characterized as ARIA with edema (ARIA-E) and ARIA with hemosiderin deposition (ARIA-H). Incidence and timing of ARIA vary among treatments. ARIA usually occurs early in treatment and is usually asymptomatic, although serious and life-threatening events rarely can occur. Serious intracerebral hemorrhages, some of which have been fatal, have been observed in patients treated with this class of medications *[see Warnings and Precautions (5.1), Adverse Reactions (6.1)]*.

ApoE ε4 Homozygotes

Patients who are apolipoprotein E ε4 (ApoE ε4) homozygotes (approximately 15% of Alzheimer's disease patients) treated with this class of medication, including LEQEMBI, have a higher incidence of ARIA, including symptomatic, serious, and severe radiographic ARIA, compared to heterozygotes and noncarriers. Testing for ApoE ε4 status should be performed prior to initiation of treatment to inform the risk of developing ARIA. Prior to testing, prescribers should discuss with patients the risk of ARIA across genotypes and the implications of genetic testing results. Prescribers should inform patients that if genotype testing is not performed they can still be treated with LEQEMBI; however, it cannot be determined if they are ApoE ε4 homozygotes and at higher risk for ARIA *[see Warnings and Precautions (5.1)]*.

Consider the benefit of LEQEMBI for the treatment of Alzheimer's disease and potential risk of serious adverse events associated with ARIA when deciding to initiate treatment with LEQEMBI *[see Warnings and Precautions (5.1) and Clinical Studies (14)]*.

ARIA

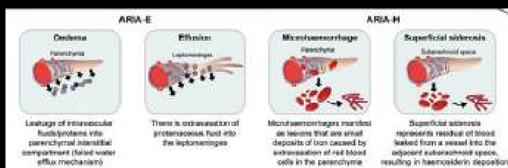
Amyloid Related Imaging Abnormalities

Leqembi PI

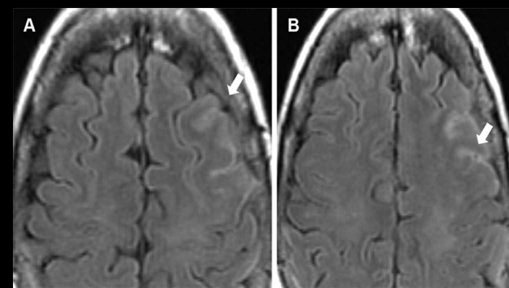
ARIA pathophysiology

pathophysiology

- Pathological **deposition** of amyloid in blood vessel walls
- Vessel wall **inflammation**.
- **Leakage** of proteinaceous fluid and blood in and around brain



Hampel et. al. BRAIN 2023: 00; 1–11 https://doi.org/10.1093/brain/awad188



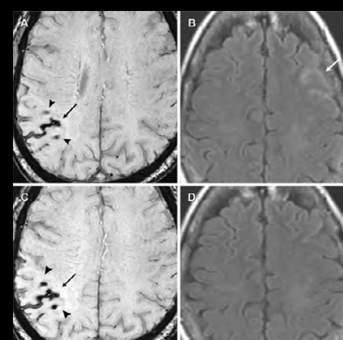
Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009

RadioGraphics

ARIA surveillance

AJNR

P.M. Cogswell et al. AJNR Am J Neuroradiol 2022;43:E19-E35



Agarwal A. Published Online: August 31, 2023 https://doi.org/10.1148/rg.230009

RadioGraphics

ARIA

- Majority of ARIA events are mild and self-limited
- Serious events have been reported
  - 2.9% of patients with ARIA-E, 0.8% for those with ARIA-H
  - 3 cases of death in the phase 3 trial of Lecanemab
  - 3 deaths deemed related to ARIA in Donanemab Phase 3 (N=853), 2 more in OLE only one deemed related to the drug.
- Risk increased in APOE-ε4 carriers (esp. homozygotes) and underlying amyloid angiopathy

Contraindications to treatment

- MRI screening for treatment exclusions
  - Amyloid angiopathy
  - Superficial siderosis
  - Microbleeds (>4)
  - Prior hemorrhage >1 cm
  - Vascular lesion (AVM, aneurysm)
  - Severe white matter disease

ARIA surveillance - Lecanemab

- MRI Safety monitoring
  - Before the **5th, 7th, and 14th biweekly doses** of lecanemab.
  - Clinical guidelines may suggest additional scanning at 6 month intervals
- More time points for certain groups such as APOE-e4 carriers (15% of AD) and those with prior episodes of ARIA.

ARIA monitoring - Donanemab

- MRI Safety monitoring
  - before **the 2nd, 3rd, 4th and 7th monthly doses**.
  - Clinical guidelines may suggest additional scanning at 6 month intervals
- More time points for certain groups such as APOE-e4 carriers (15% of AD) and those with prior episodes of ARIA.

AI tools in ARIA monitoring

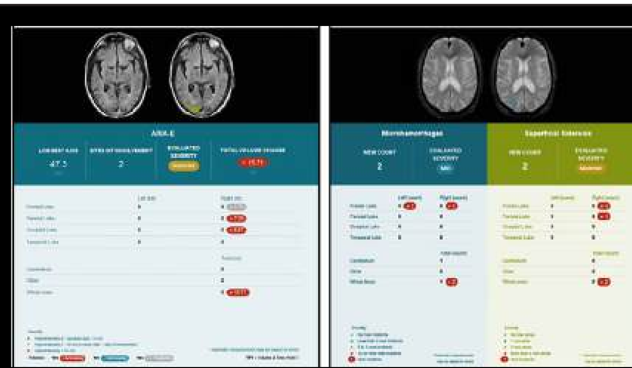
- ARIA can be subtle and unfamiliar
- ARIA quantification must be standardized and consistent
- Up to 84% of ARIA findings can be missed[1]

"It is acknowledged that **interrater variability** might be a challenge. The use of a quantitative computer-aided diagnosis (CAD), which combines computational algorithms and clinician's evaluation of the MRI images, may support the successful diagnosis of ARIA (e.g., given the difficulties of ARIA-H diagnosis). **Future clinical trials involving anti-Aβ antibodies should consider using CAD** methodology once it is validated"[4]

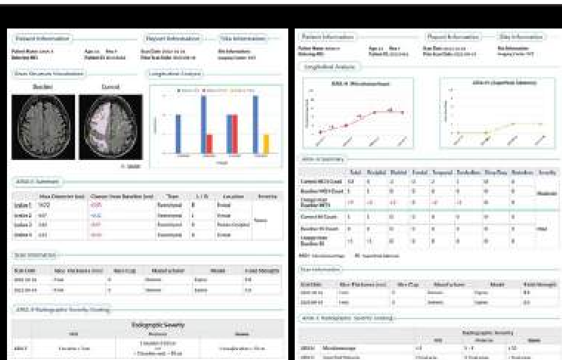
21.5% Incidence of ARIA in lecanemab group vs 9.5% in placebo group[2]

36.8% Incidence of ARIA in donanemab group vs 14.9% in placebo group[3]

Source(s): (1) Gutt et al. 2019, (2) van Dyck et al 2023, (3) Sima et al. 2023 (4) Hampel et al. 2023



Courtesy Icometrix

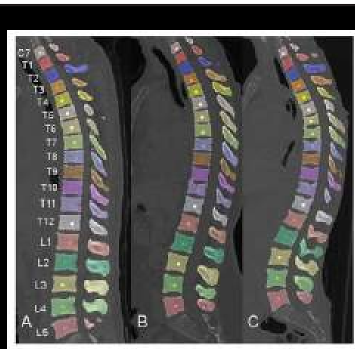


Courtesy Cortechs

AI in spine imaging

- Assisted interpretation, reporting and workflow
- Localization and labeling of spinal structures
- Segmentation
- Deformity/ scoliosis
- Degeneration / Pfirmann grading
- Spinal stenosis
- CT BMD

Segmentation And fractures



AI Rad Companion

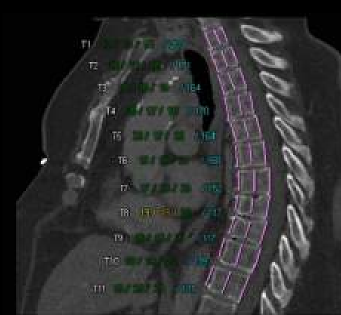
Measuring

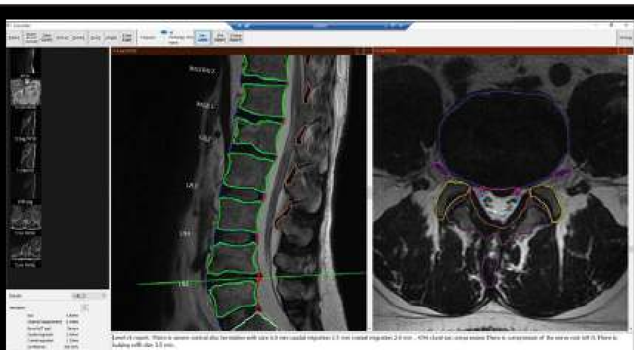
AI-Rad Companion automatically detects the thoracic vertebral bodies. After detecting they will be labelled accordingly.

At three different anatomical locations, anterior, mid and posterior the height of each vertebra is measured.

Findings based on height deviations between neighboring vertebrae are color-coded.

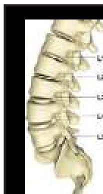
Additionally the bone density [HU] is measured and visualized.





Courtesy CoLumbo WIP

Segmentation



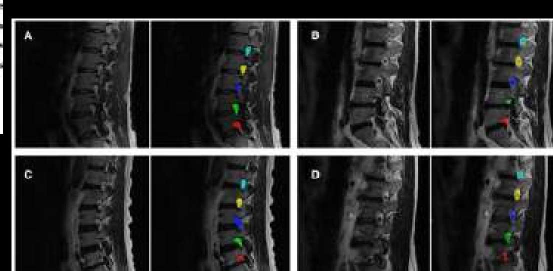
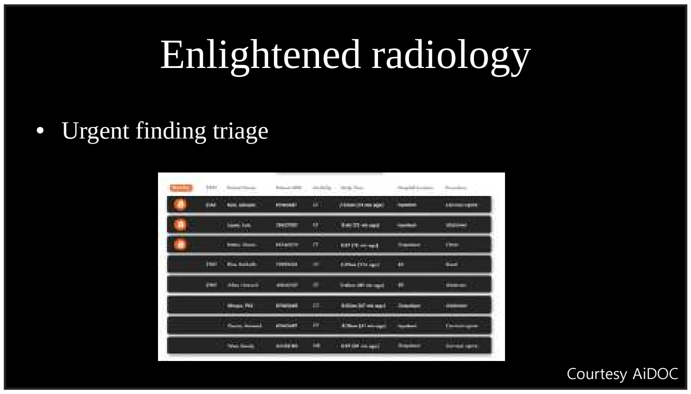
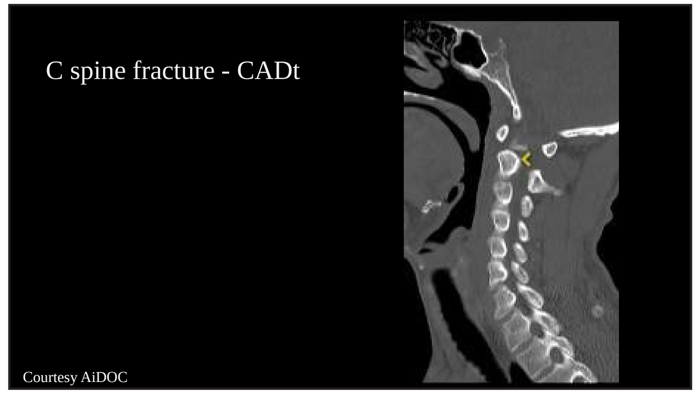
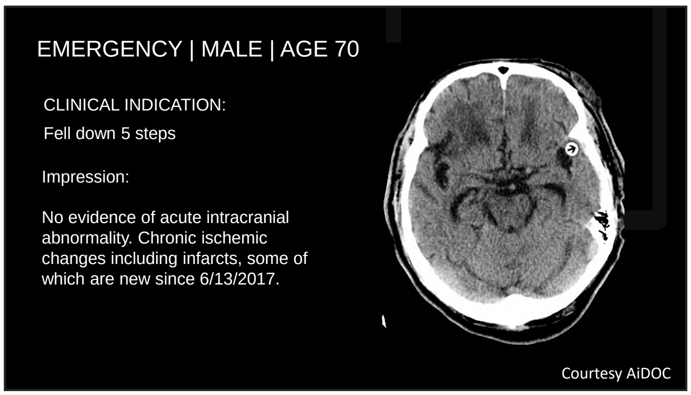
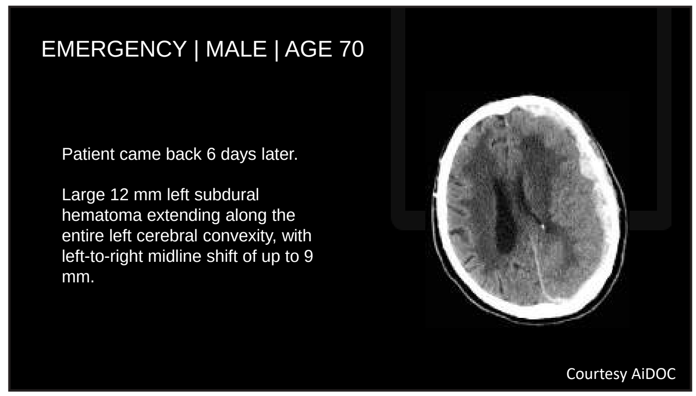


Figure 2: A–D, A random sample of automated neural foraminal segmentations used for generating measurements. Original MR images (left) and overlaid computer-generated segmentation (right).

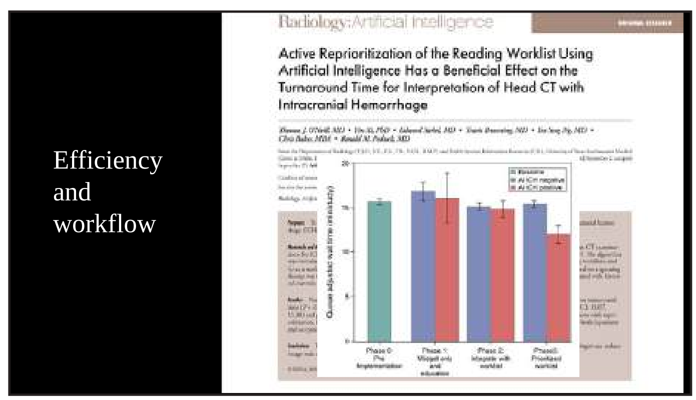

Enlightened radiology
• Urgent finding triage
Courtesy AiDOC

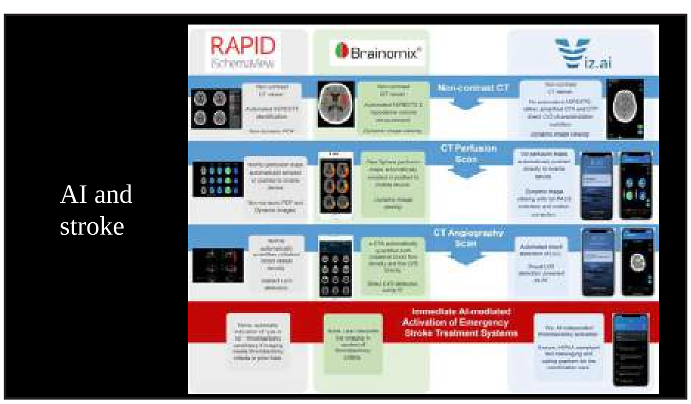

C spine fracture - CADt
Courtesy AiDOC

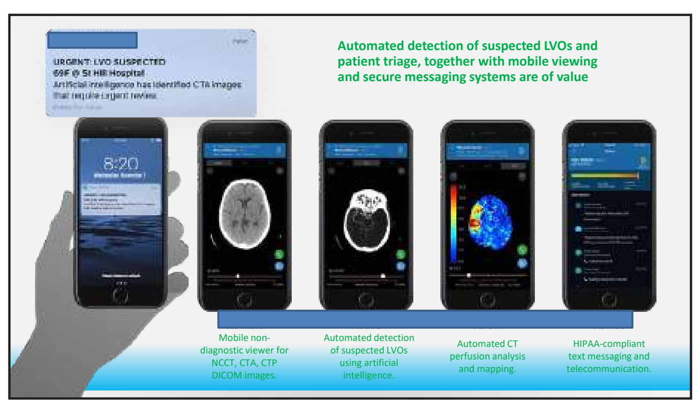

EMERGENCY | MALE | AGE 70
CLINICAL INDICATION:
Fell down 5 steps
Impression:
No evidence of acute intracranial abnormality. Chronic ischemic changes including infarcts, some of which are new since 6/13/2017.
Courtesy AiDOC

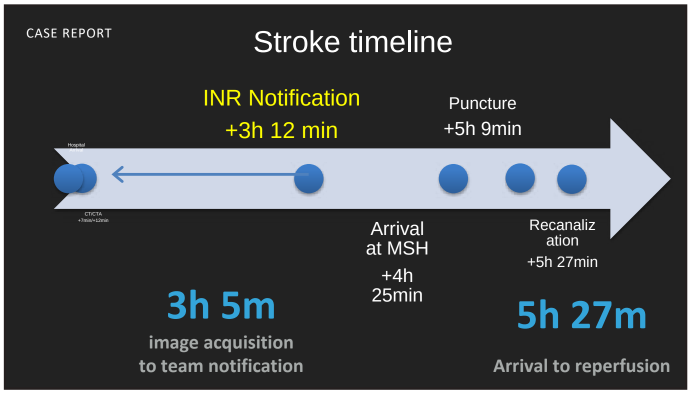

EMERGENCY | MALE | AGE 70
Patient came back 6 days later.
Large 12 mm left subdural hematoma extending along the entire left cerebral convexity, with left-to-right midline shift of up to 9 mm.
Courtesy AiDOC

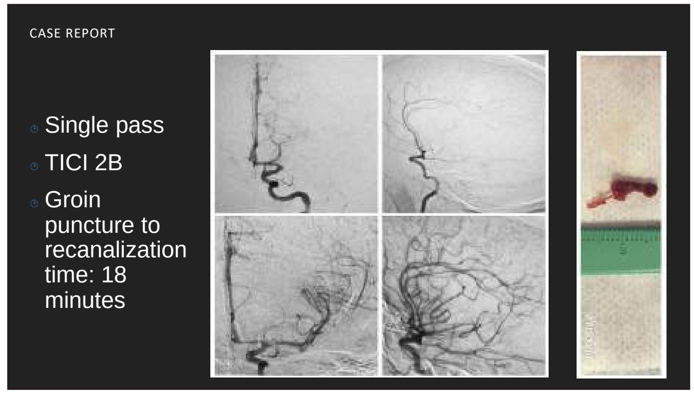

EMERGENCY | MALE | AGE 70
Patient taken for decompressive craniotomy with no change in neurological deficits and lethargy after the procedure.
Courtesy AiDOC

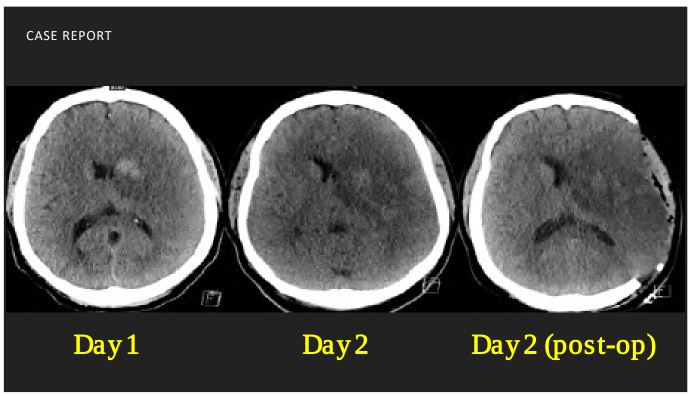

Efficiency and workflow
Radiology: Artificial Intelligence
Active Reprioritization of the Reading Worklist Using Artificial Intelligence Has a Beneficial Effect on the Turnaround Time for Interpretation of Head CT with Intracranial Hemorrhage

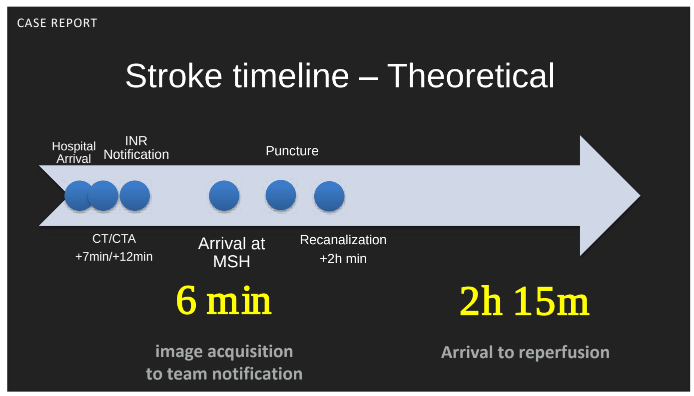

AI and stroke
RAPID
Brainomix
viz.ai
Non-contrast CT
CT Perfusion Scan
CT Angiography Scan
Immediate AI-mediated Activation of Emergency Stroke Treatment Systems

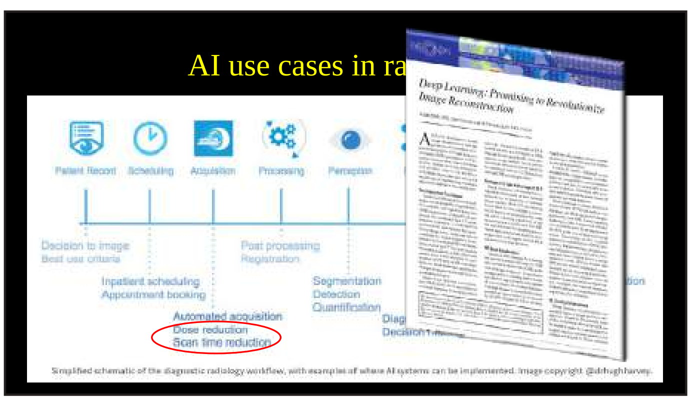

Automated detection of suspected LVOs and patient triage, together with mobile viewing and secure messaging systems are of value
Mobile non-diagnostic viewer for NCCT, CTA, CTP DICOM images.
Automated detection of suspected LVOs using artificial intelligence.
Automated CT perfusion analysis and mapping.
HIPAA-compliant text messaging and telecommunication.


CASE REPORT
Stroke timeline
INR Notification
+3h 12 min
Puncture
+5h 9min
Arrival
at MSH
+4h
25min
Recanaliz
ation
+5h 27min
3h 5m
image acquisition
to team notification
5h 27m
Arrival to reperfusion

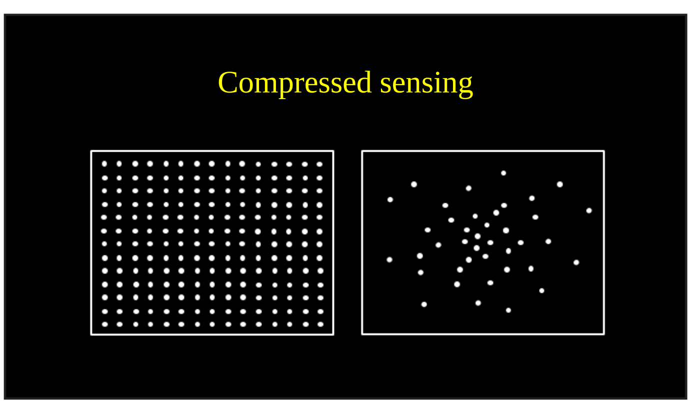

CASE REPORT
Single pass
TICI 2B
Groin
puncture to
recanalization
time: 18
minutes

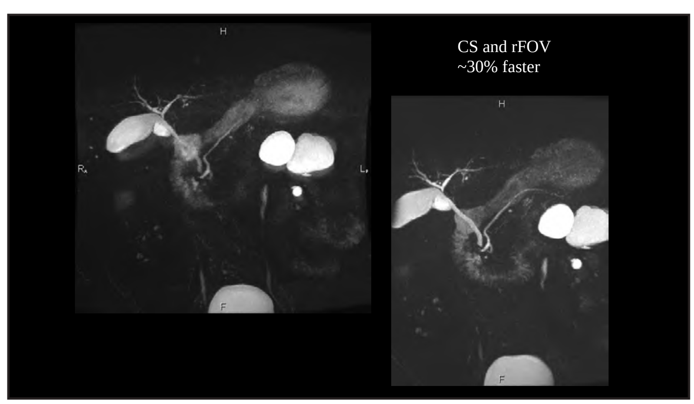

CASE REPORT
Day 1
Day 2
Day 2 (post-op)


CASE REPORT
Stroke timeline – Theoretical
Hospital
Arrival
INR
Notification
Puncture
CT/CTA
+7min/+12min
Arrival at
MSH
Recanalization
+2h min
6 min
image acquisition
to team notification
2h 15m
Arrival to reperfusion


AI use cases in ra
Deep Learning: Promising to Revolutionize
Image Reconstruction

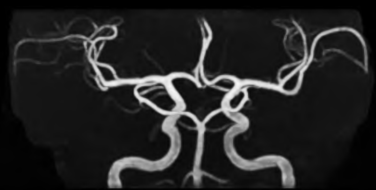

AI use cases
image reconstruction
• Compressed sensing and sparse data reconstruction
• Iterative reconstruction
• Deep learning based reconstruction


Compressed sensing


CS and rFOV
~30% faster

Sparse Data

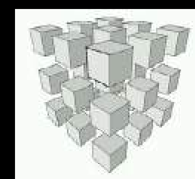
Greater Acceleration



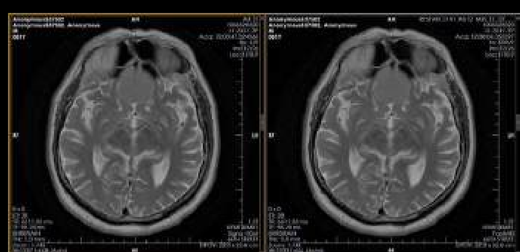
0.57 x 0.66 x 1.0 mm (CS with 3D TOF)
2:12min (50% reduction)

AI use cases
image reconstruction

- Compressed sensing and sparse data
- Iterative reconstruction
- Deep learning based reconstruction



Gold standard vs. accelerated (processed)



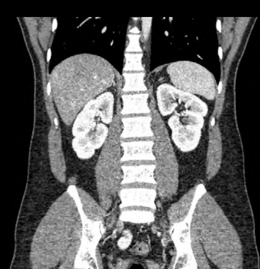
Routine protocol

Accelerated processed

33% time reduction

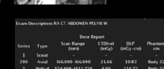
AI use cases
image reconstruction

- Compressed sensing and sparse data reconstruction
- Iterative reconstruction
- Deep learning-based reconstruction



Iterative reconstruction

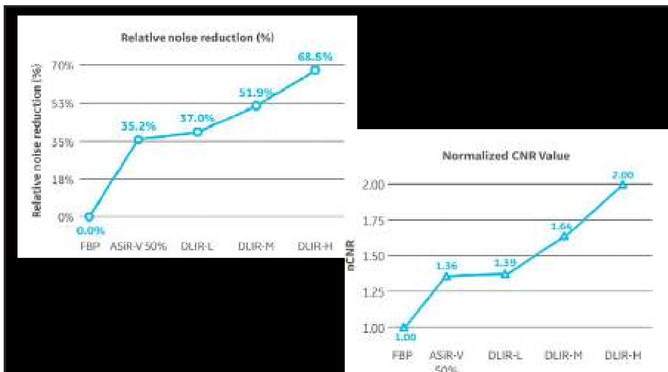
FBP



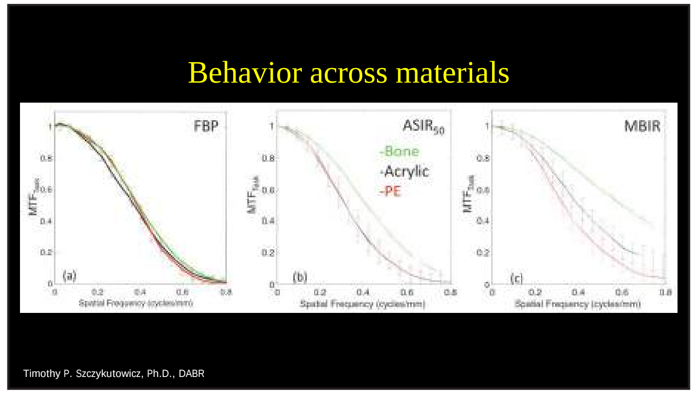
VEO

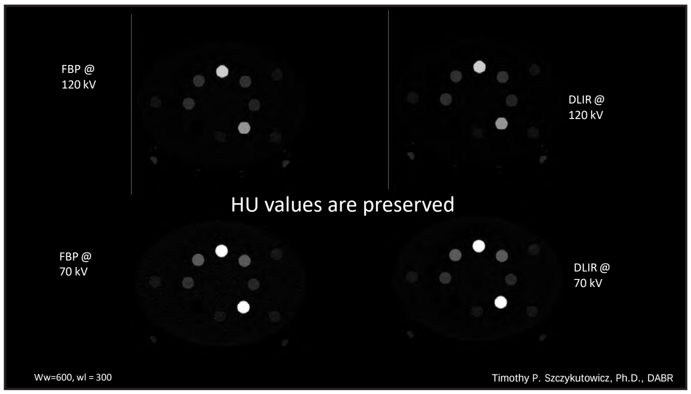
AI use cases
image reconstruction

- Deep learning CT image reconstruction
  - TrueFidelity
  - AiCE
  - PreciseImage
  - PixelShine
  - ClariPI




Improved image quality even at 1 mm slices
iDose⁴
Precise Image


Behavior across materials
FBP
ASIR50
-Bone
-Acrylic
-PE
MBIR
Spatial Frequency (cycles/mm)
Timothy P. Szczykutowicz, Ph.D., DABR


FBP @ 120 kV
DLIR @ 120 kV
HU values are preserved
FBP @ 70 kV
DLIR @ 70 kV
Ww=600, wl = 300
Timothy P. Szczykutowicz, Ph.D., DABR

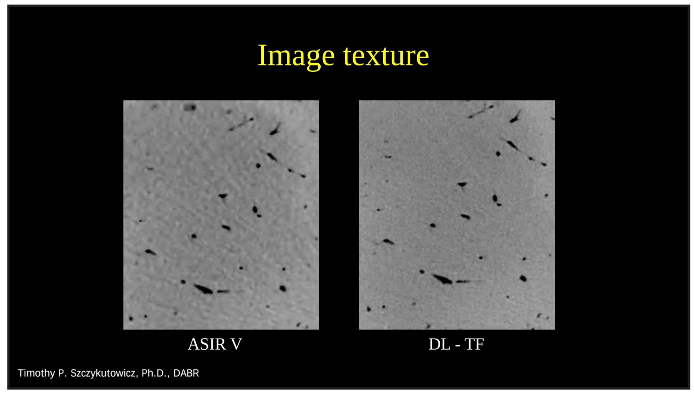
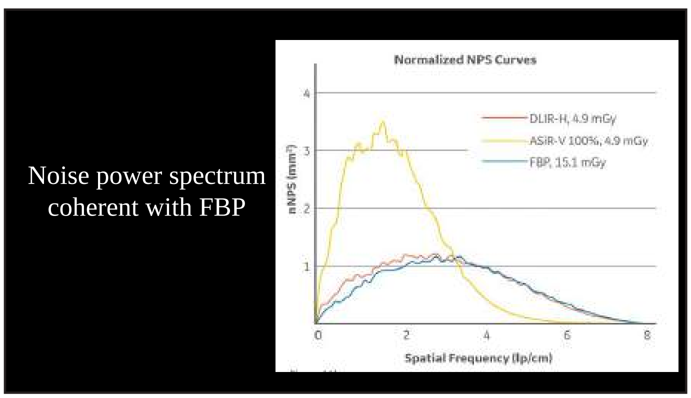
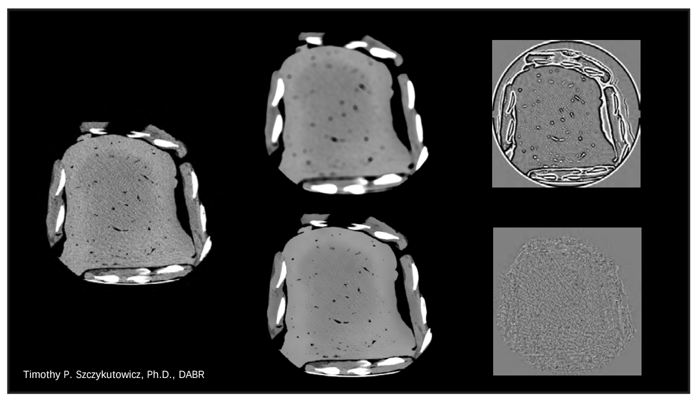
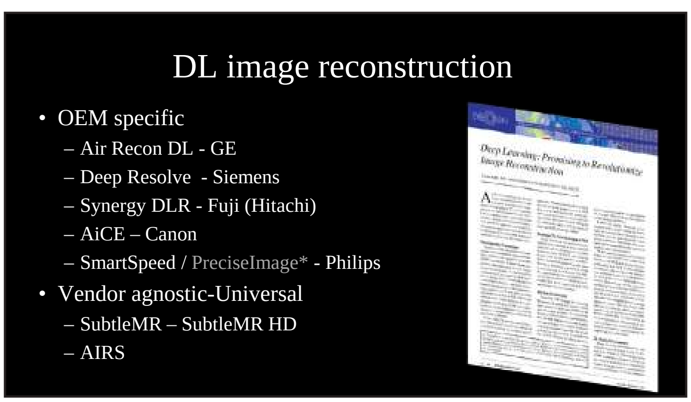
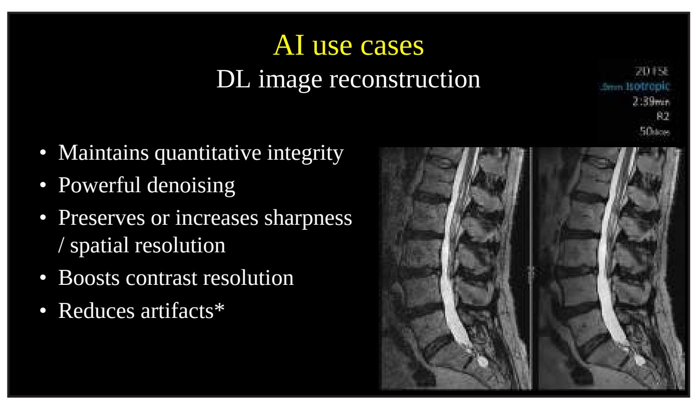


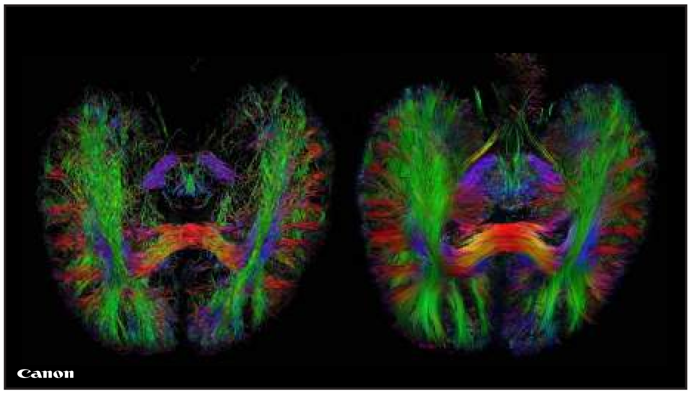
Image texture
ASIR V
DL - TF
Timothy P. Szczykutowicz, Ph.D., DABR

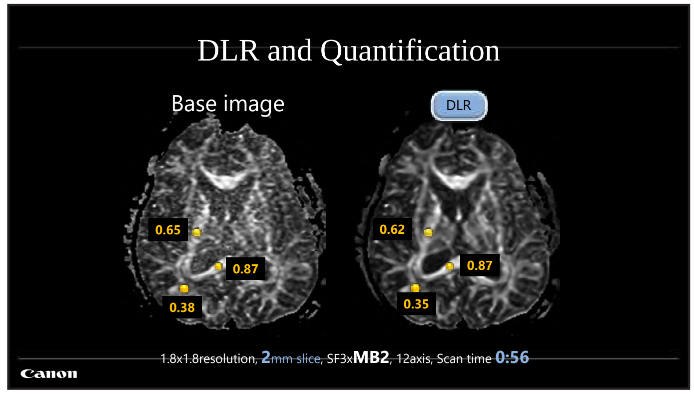

Noise power spectrum coherent with FBP
Normalized NPS Curves
DLIR-H, 4.9 mGy
ASIR-V 100%, 4.9 mGy
FBP, 15.1 mGy
nNPS (mm²)
Spatial Frequency (lp/cm)

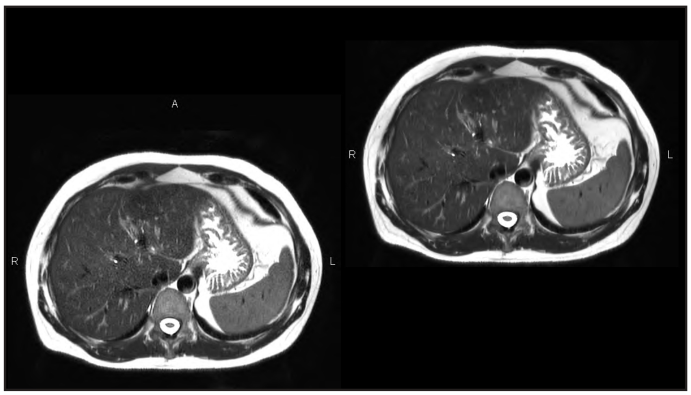

Timothy P. Szczykutowicz, Ph.D., DABR

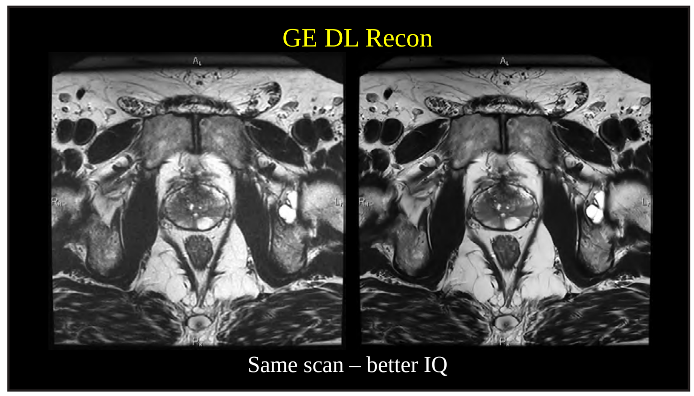

DL image reconstruction
• OEM specific
– Air Recon DL - GE
– Deep Resolve - Siemens
– Synergy DLR - Fuji (Hitachi)
– AiCE – Canon
– SmartSpeed / PreciseImage* - Philips
• Vendor agnostic-Universal
– SubtleMR – SubtleMR HD
– AIRS
Deep Learning: Promising to Revolutionize Image Reconstruction

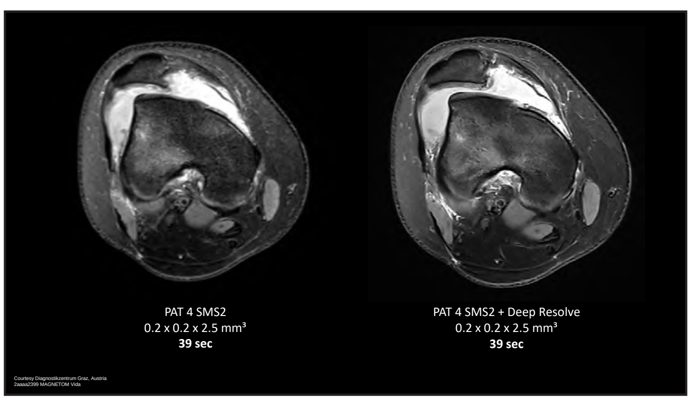

AI use cases
DL image reconstruction
• Maintains quantitative integrity
• Powerful denoising
• Preserves or increases sharpness / spatial resolution
• Boosts contrast resolution
• Reduces artifacts*

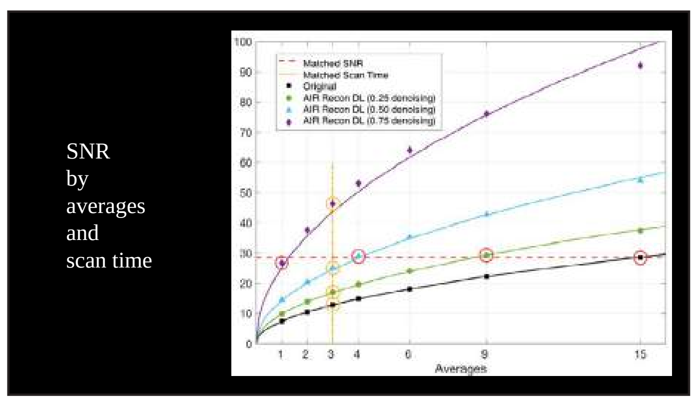

Canon

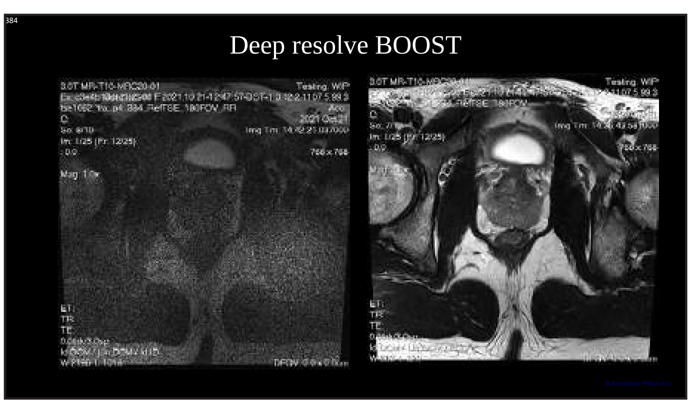

DLR and Quantification
Base image
DLR
0.65
0.87
0.38
0.62
0.87
0.35
1.8x1.8resolution, 2mm slice, SF3xMB2, 12axis, Scan time 0:56
Canon

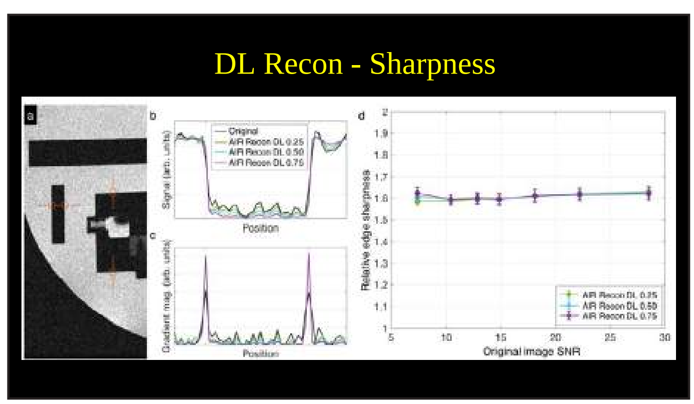

A
R
L

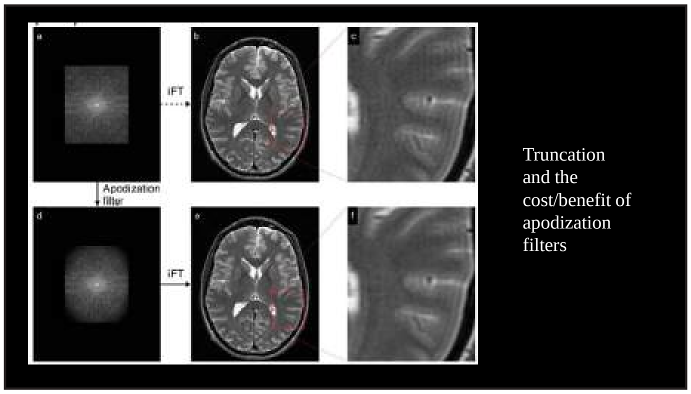

GE DL Recon
Same scan – better IQ

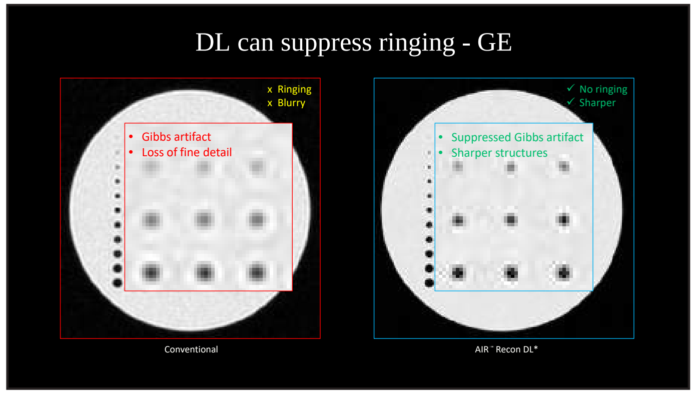

PAT 4 SMS2
0.2 x 0.2 x 2.5 mm³
39 sec
PAT 4 SMS2 + Deep Resolve
0.2 x 0.2 x 2.5 mm³
39 sec

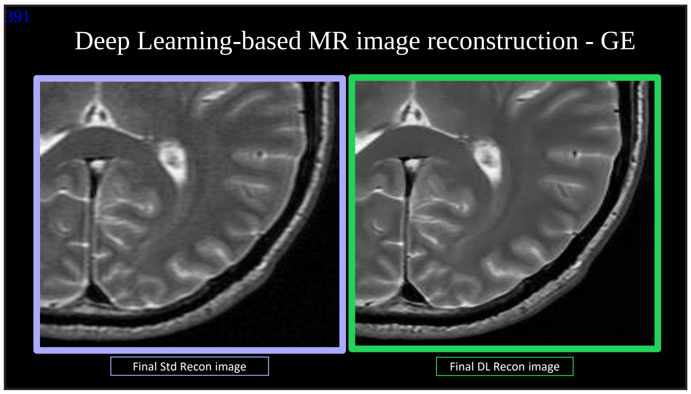

SNR
by
averages
and
scan time
Matched SNR
Matched Scan Time
Original
AIR Recon DL (0.25 denoising)
AIR Recon DL (0.50 denoising)
AIR Recon DL (0.75 denoising)
Averages

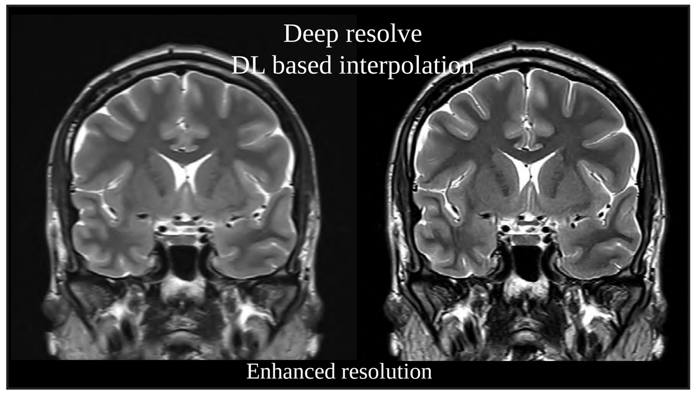

Deep resolve BOOST

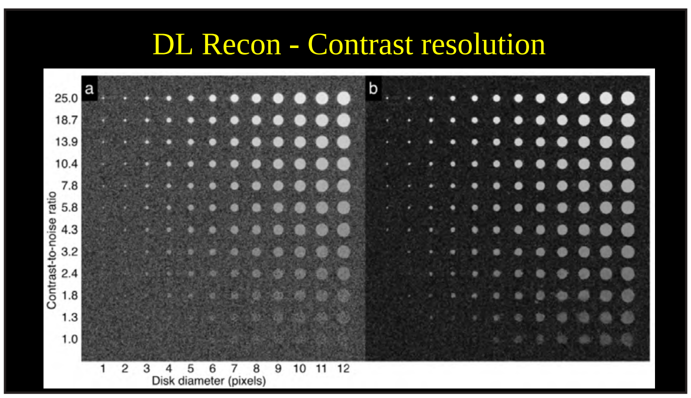

DL Recon - Sharpness
Original
AIR Recon DL 0.25
AIR Recon DL 0.50
AIR Recon DL 0.75
Position
Relative edge sharpness
Original image SNR

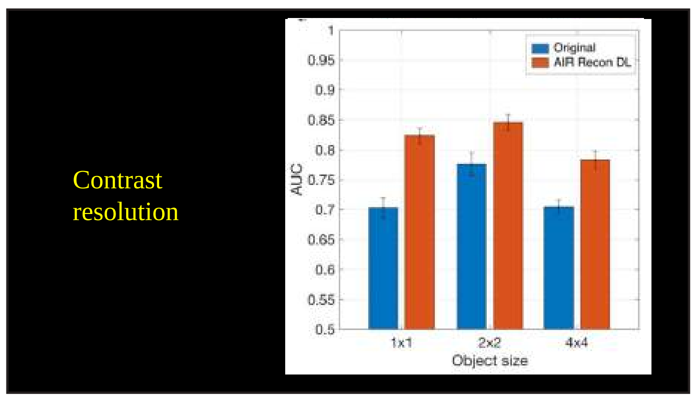

IFT
Apodization filter
IFT
Truncation and the cost/benefit of apodization filters


DL can suppress ringing - GE
x Ringing
x Blurry
Gibbs artifact
Loss of fine detail
✓ No ringing
✓ Sharper
Suppressed Gibbs artifact
Sharper structures
Conventional
AIR™ Recon DL*

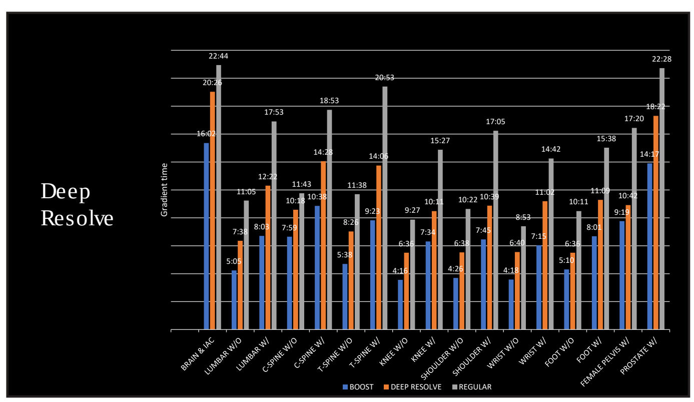

391
Deep Learning-based MR image reconstruction - GE
Final Std Recon image
Final DL Recon image

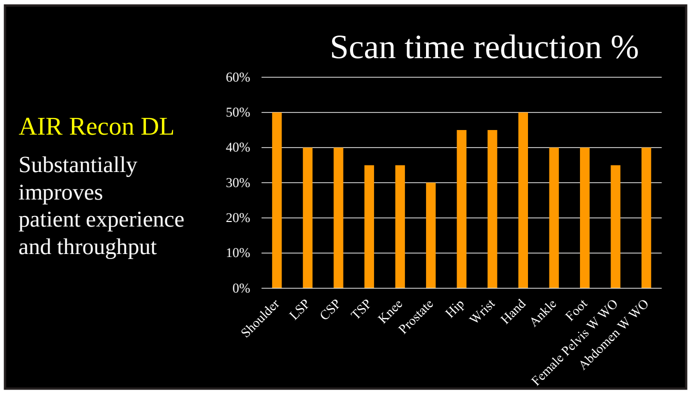

Deep resolve
DL based interpolation
Enhanced resolution

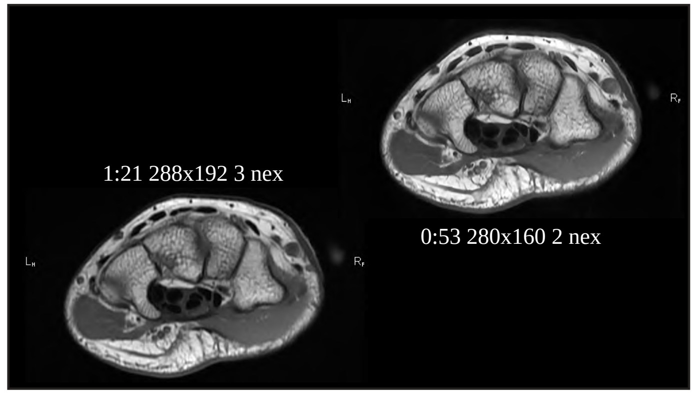

DL Recon - Contrast resolution
a
b
Contrast-to-noise ratio
25.0
18.7
13.9
10.4
7.8
5.8
4.3
3.2
2.4
1.8
1.3
1.0
1 2 3 4 5 6 7 8 9 10 11 12
Disk diameter (pixels)

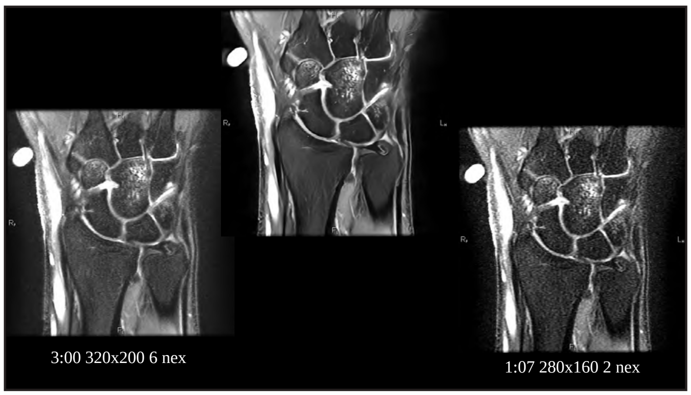

Contrast resolution
Original
AIR Recon DL
AUC
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
1x1
2x2
4x4
Object size

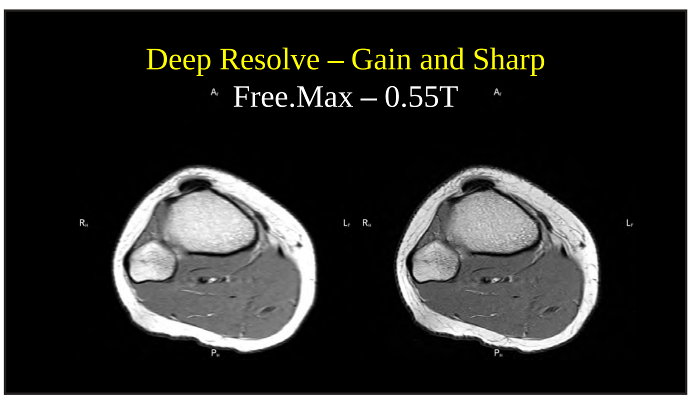

Deep Resolve
AIR Recon DL

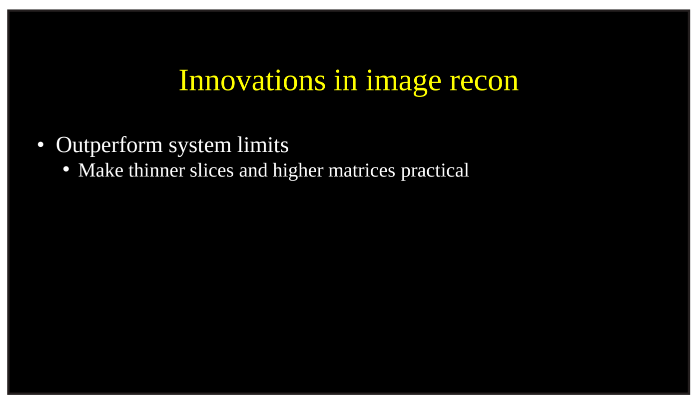

Deep Resolve
Gradient time
BOOST
DEEP RESOLVE
REGULAR

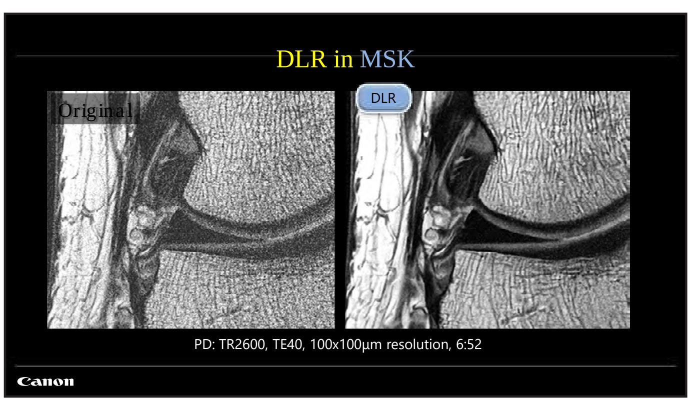

Scan time reduction %
AIR Recon DL
Substantially improves patient experience and throughput
60%
50%
40%
30%
20%
10%
0%
Shoulder
LSP
CSP
TSP
Knee
Prostate
Hip
Wrist
Hand
Ankle
Foot
Female Pelvis W WO
Abdomen W WO

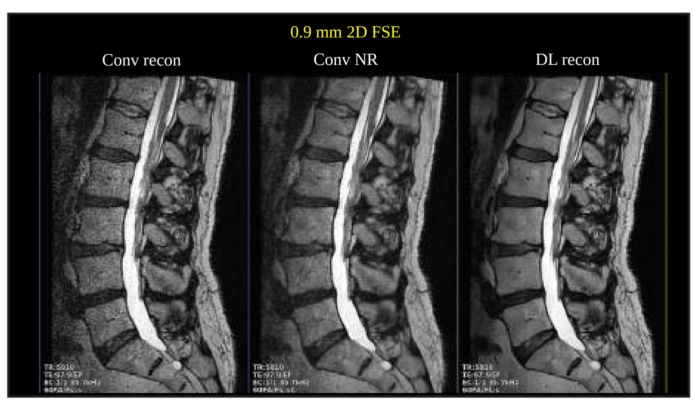

1:21 288x192 3 nex
0:53 280x160 2 nex

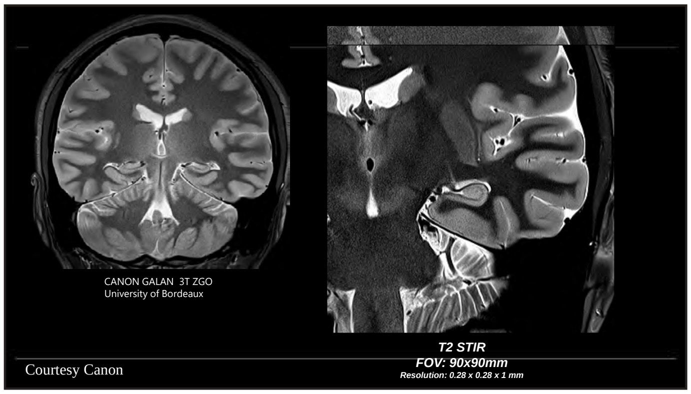

3:00 320x200 6 nex
1:07 280x160 2 nex

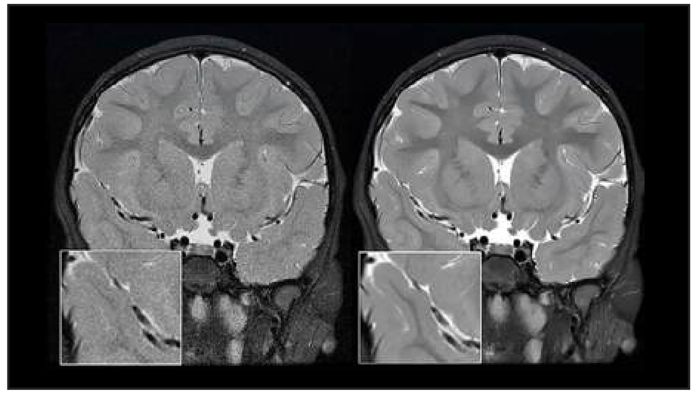

Deep Resolve – Gain and Sharp
Free.Max – 0.55T

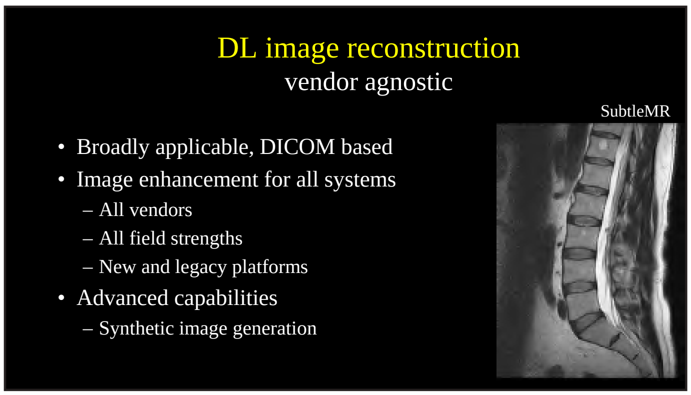

Innovations in image recon
• Outperform system limits
• Make thinner slices and higher matrices practical

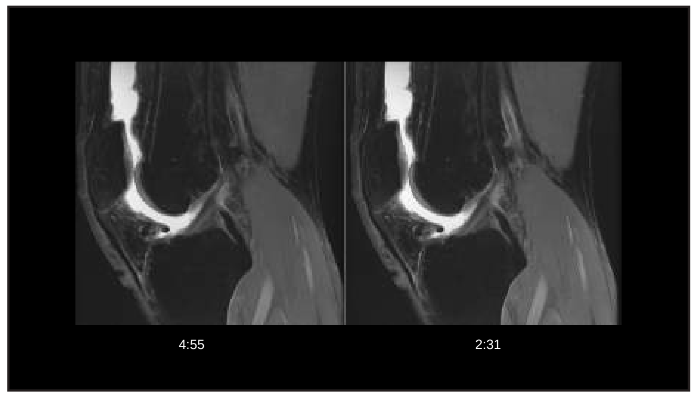

DLR in MSK
Original
DLR
PD: TR2600, TE40, 100x100µm resolution, 6:52

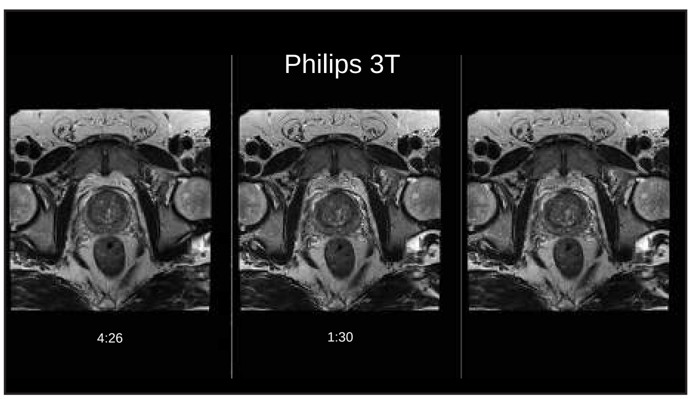

0.9 mm 2D FSE
Conv recon
Conv NR
DL recon

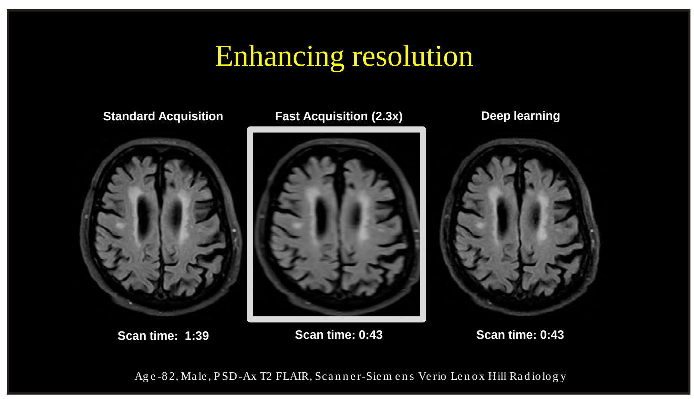

CANON GALAN 3T ZGO
University of Bordeaux
Courtesy Canon
T2 STIR
FOV: 90x90mm
Resolution: 0.28 x 0.28 x 1 mm

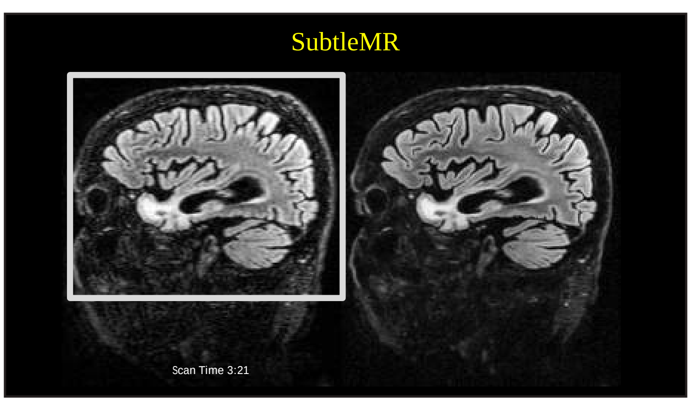


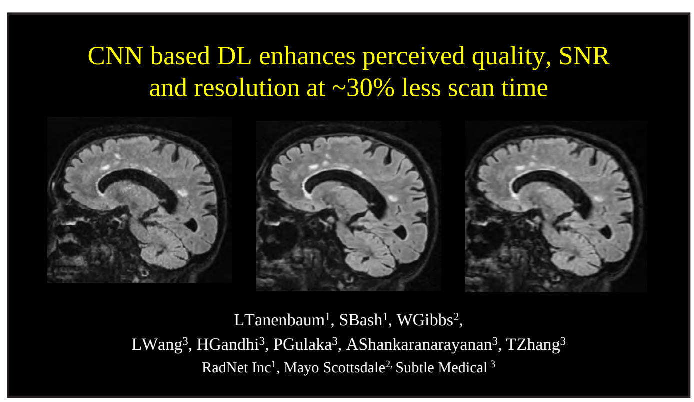

DL image reconstruction
vendor agnostic
SubtleMR
• Broadly applicable, DICOM based
• Image enhancement for all systems
– All vendors
– All field strengths
– New and legacy platforms
• Advanced capabilities
– Synthetic image generation

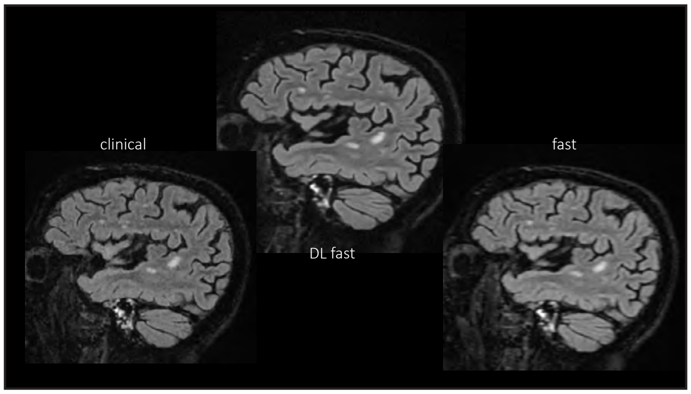

4:55
2:31

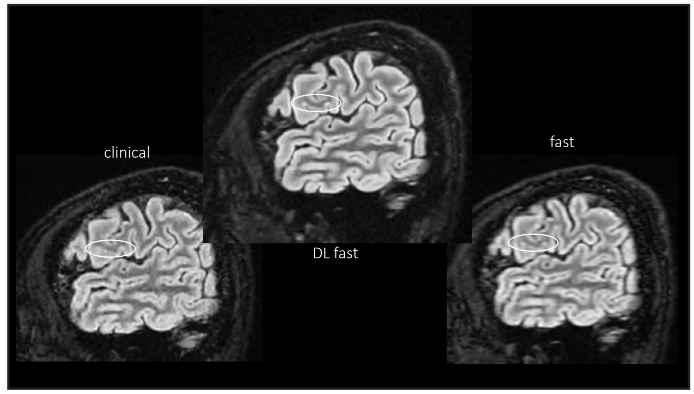

Philips 3T
4:26
1:30

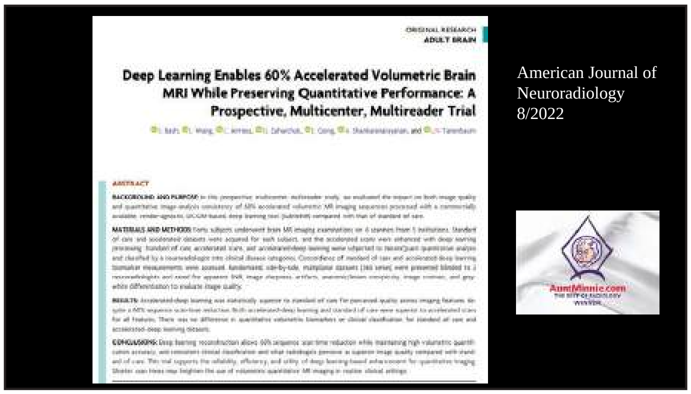

Enhancing resolution
Standard Acquisition
Fast Acquisition (2.3x)
Deep learning
Scan time: 1:39
Scan time: 0:43
Scan time: 0:43
Age-82, Male, PSD-Ax T2 FLAIR, Scanner-Siemens Verio Lenox Hill Radiology

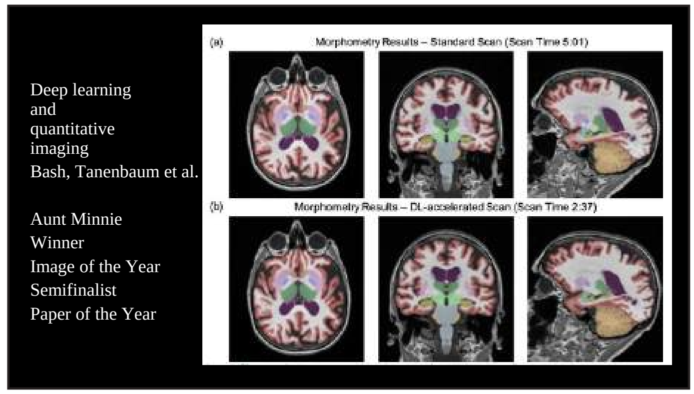

SubtleMR
Scan Time 3:21

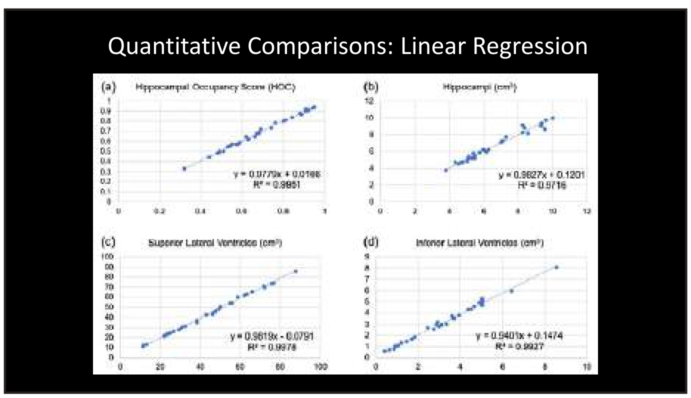

CNN based DL enhances perceived quality, SNR and resolution at ~30% less scan time
LTanenbaum[1], SBash[1], WGibbs[2],
LWang[3], HGandhi[3], PGulaka[3], AShankaranarayanan[3], TZhang[3]
RadNet Inc[1], Mayo Scottsdale[2], Subtle Medical [3]

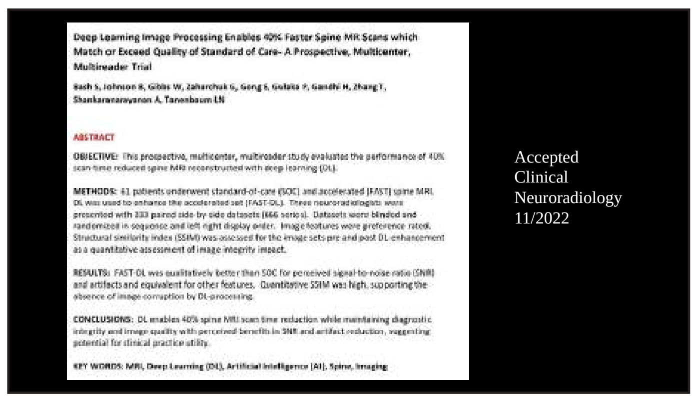

clinical
DL fast
fast


clinical
DL fast
fast

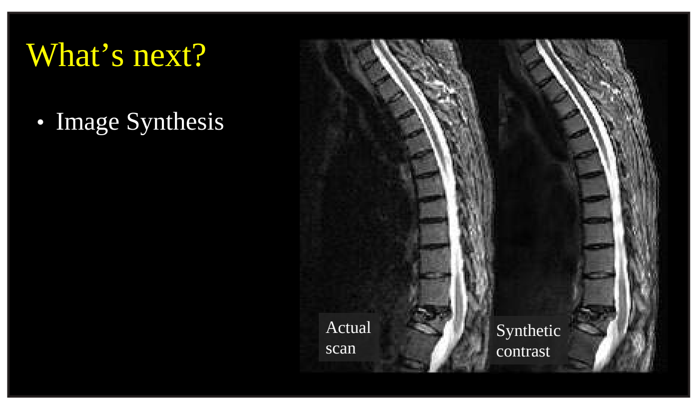

ORIGINAL RESEARCH
ADULT BRAIN
Deep Learning Enables 60% Accelerated Volumetric Brain MRI While Preserving Quantitative Performance: A Prospective, Multicenter, Multireader Trial
ABSTRACT
American Journal of Neuroradiology 8/2022


Deep learning and quantitative imaging
Bash, Tanenbaum et al.
Aunt Minnie Winner Image of the Year Semifinalist Paper of the Year
(a) Morphometry Results – Standard Scan (Scan Time 5:01)
(b) Morphometry Results – DL-accelerated Scan (Scan Time 2:37)


Quantitative Comparisons: Linear Regression
(a) Hippocampal Occupancy Score (HOC)
y = 0.9779x + 0.0166
R² = 0.9851
(b) Hippocampi (cm³)
y = 0.9827x + 0.1201
R² = 0.9716
(c) Superior Lateral Ventricles (cm³)
y = 0.9819x - 0.0791
R² = 0.9978
(d) Inferior Lateral Ventricles (cm³)
y = 0.9401x + 0.1474
R² = 0.9927


Deep Learning Image Processing Enables 40% Faster Spine MR Scans which Match or Exceed Quality of Standard of Care- A Prospective, Multicenter, Multireader Trial
Bash S, Johnson B, Gibbs W, Zaharchuk G, Gong E, Gulaka P, Gandhi H, Zhang T, Shankaranarayanan A, Tanenbaum LN
ABSTRACT
OBJECTIVE: This prospective, multicenter, multireader study evaluates the performance of 40% scan-time reduced spine MRI reconstructed with deep learning (DL).
METHODS: 41 patients underwent standard-of-care (SOC) and accelerated (FAST) spine MRI. DL was used to enhance the accelerated set (FAST-DL). Three neuroradiologists were presented with 333 paired side-by-side datasets (666 series). Datasets were blinded and randomized in sequence and left-right display order. Image features were preference rated. Structural similarity index (SSIM) was assessed for the image sets pre and post DL-enhancement as a quantitative assessment of image integrity impact.
RESULTS: FAST-DL was qualitatively better than SOC for perceived signal-to-noise ratio (SNR) and artifacts and equivalent for other features. Quantitative SSIM was high, supporting the absence of image corruption by DL-processing.
CONCLUSIONS: DL enables 40% spine MRI scan time reduction while maintaining diagnostic integrity and image quality with perceived benefits in SNR and artifact reduction, suggesting potential for clinical practice utility.
KEY WORDS: MRI, Deep Learning (DL), Artificial Intelligence (AI), Spine, Imaging
Accepted Clinical Neuroradiology 11/2022


SOC
SubtleMR
fast


What's next?
Image Synthesis
Actual scan
Synthetic contrast

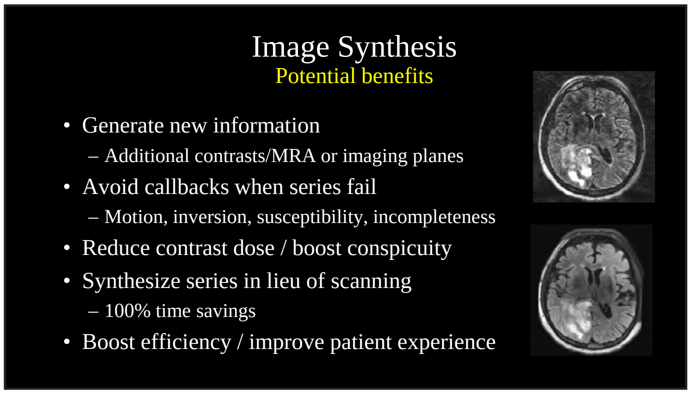


Image Synthesis
Potential benefits
• Generate new information
– Additional contrasts/MRA or imaging planes
• Avoid callbacks when series fail
– Motion, inversion, susceptibility, incompleteness
• Reduce contrast dose / boost conspicuity
• Synthesize series in lieu of scanning
– 100% time savings
• Boost efficiency / improve patient experience

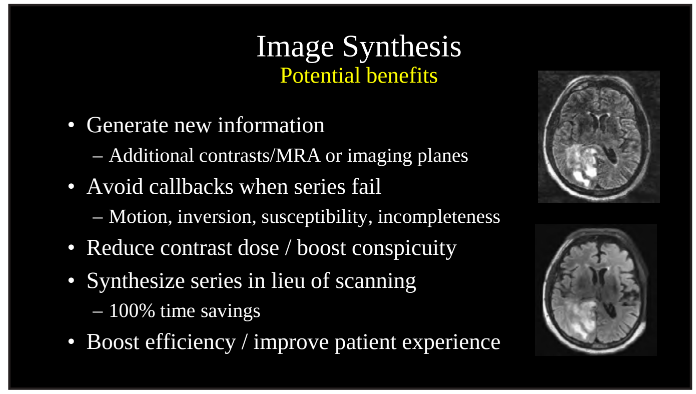


Image Synthesis
Potential benefits
• Generate new information
– Additional contrasts/MRA or imaging planes
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– Motion, inversion, susceptibility, incompleteness
• Reduce contrast dose / boost conspicuity
• Synthesize series in lieu of scanning
– 100% time savings
• Boost efficiency / improve patient experience

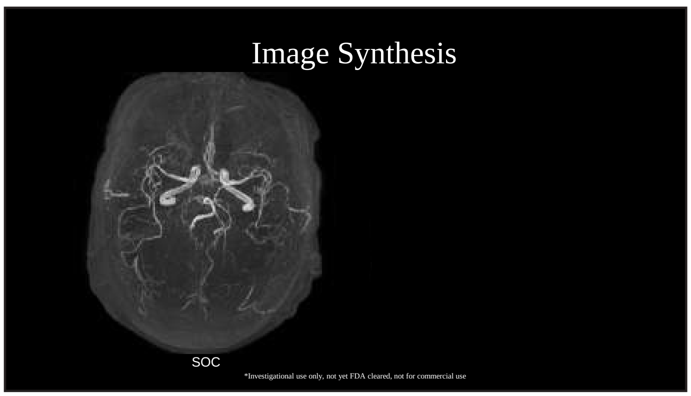
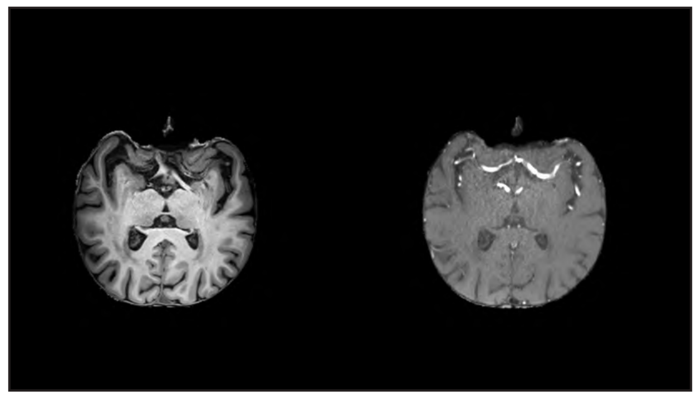
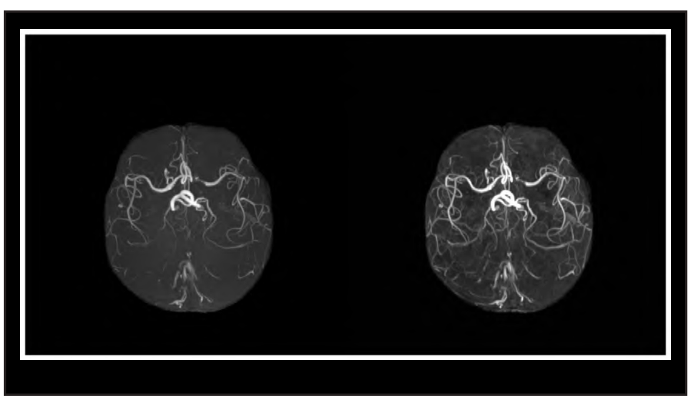


Image Synthesis
SOC
*Investigational use only, not yet FDA cleared, not for commercial use






Environmental Sustainability and MRI: Challenges, Opportunities, and a Call for Action
Environmental gadolinium concerns
Radiology
Contrast Media–driven Anthropogenic Gadolinium: Knowns and Unknowns

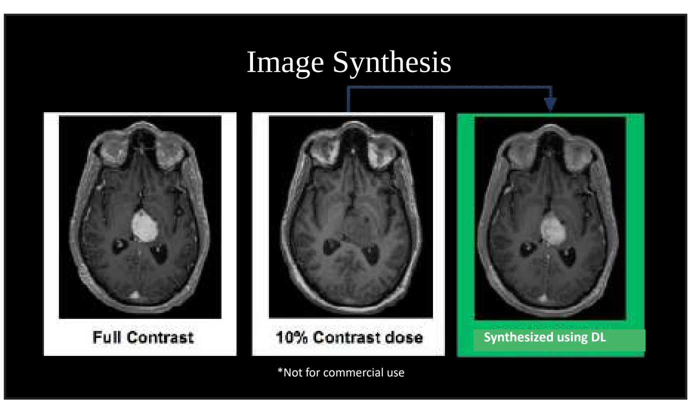
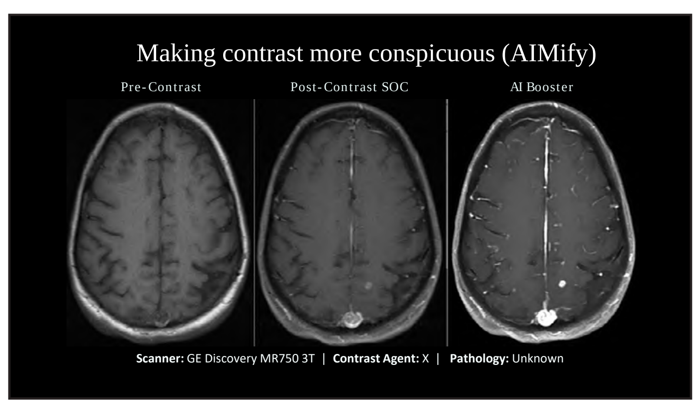
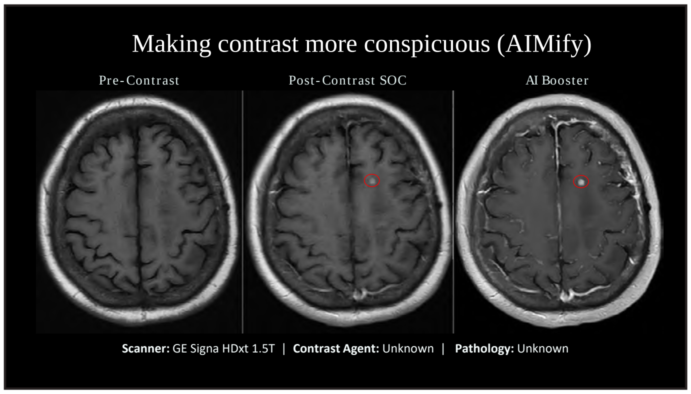
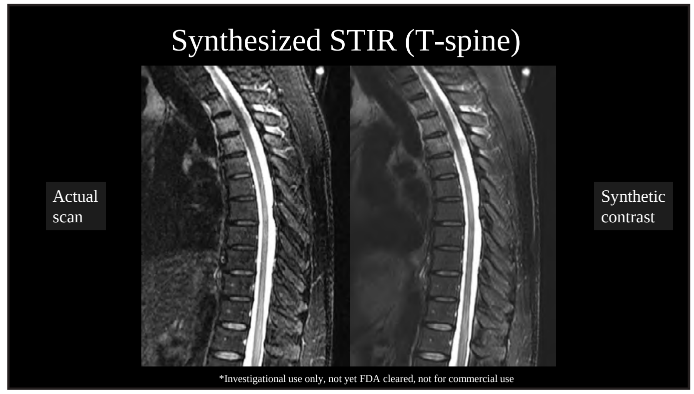


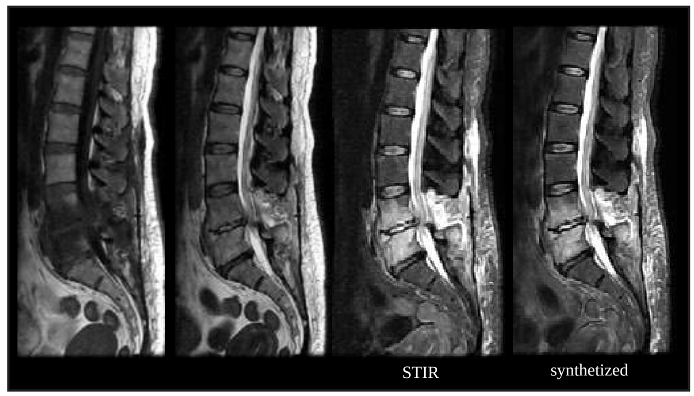
Image Synthesis
Full Contrast
10% Contrast dose
Synthesized using DL
*Not for commercial use


Making contrast more conspicuous (AIMify)
Pre-Contrast
Post-Contrast SOC
AI Booster
Scanner: GE Discovery MR750 3T | Contrast Agent: X | Pathology: Unknown


Making contrast more conspicuous (AIMify)
Pre-Contrast
Post-Contrast SOC
AI Booster
Scanner: GE Signa HDxt 1.5T | **Contrast Agent:** Unknown | **Pathology:** Unknown


Synthesized STIR (T-spine)
Actual scan
Synthetic contrast
*Investigational use only, not yet FDA cleared, not for commercial use


STIR
synthetized


STIR
synthetized


acq-STIR
synthetic-STIR


Tumor
STIR
SubtleSTIR
STIR
SubtleSTIR
*Investigational use only, not yet FDA cleared, not for commercial use


STIR
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Trauma
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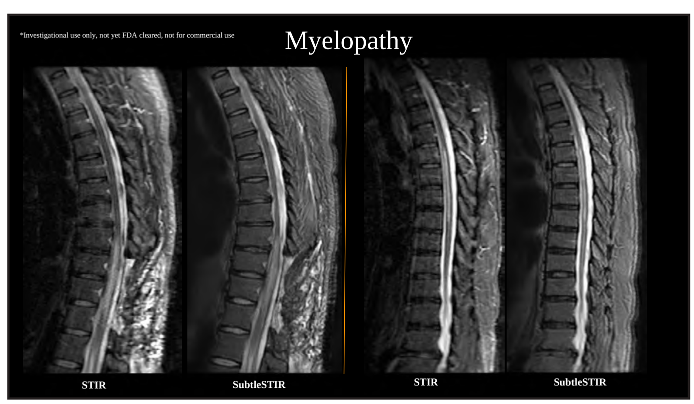
*Investigational use only, not yet FDA cleared, not for commercial use
Myelopathy
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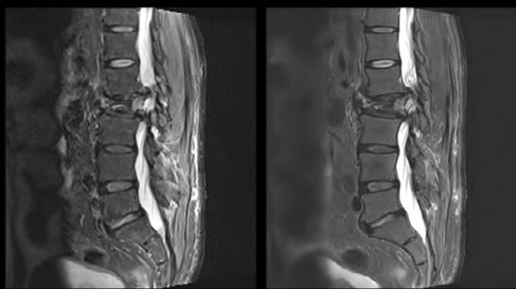
Artifact



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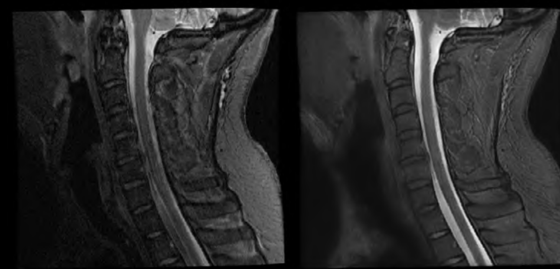
Artifact



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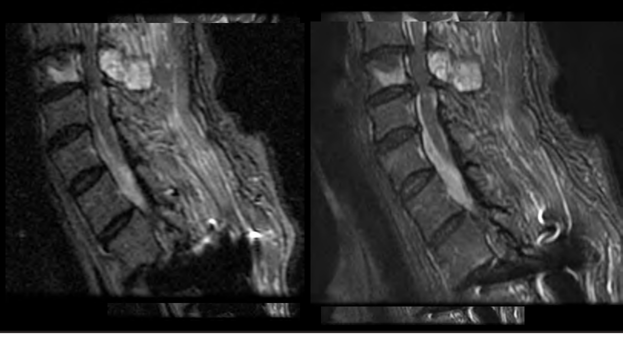
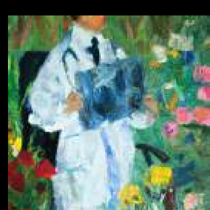
Artifact - Susceptibility



Impact of AI in Neuroimaging

- What is AI
  - What's new?
  - Terminology and background
  - Strengths and limitations
- Impact in Imaging

AI and the Imaging Enterprise



Lawrence N Tanenbaum, MD FACR
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SELF EVALUATION

AI and the Imaging Enterprise

1. Place these technologies in chronological order of their development:

a. Machine learning
b. Agents
c. Neural networks
d. Foundational models
e. Large language models

2. Current or potential benefits of AI in the imaging enterprise. Which is least correct?

a. Utilization and no-show management
b. Medical record review
c. Protocol selection
d. Independent image review and reporting
e. On device triage
f. Enhanced Image reconstruction
g. Assisted report generation

3. Back office applications of AI

a. Synoptic reporting
b. Report summarization
c. Improved procedure coding
d. Improved follow up compliance
e. All of the above

4. AI for image reconstruction. Which is false?

a. Improve accuracy of image reporting
b. Improve the SNR or reduce the scan times of spine MR
c. Reduce the dose necessary for spine CT
d. Enhance the spatial resolution of spine MR/CT
e. Maintain the quantitative accuracy of traditional reconstruction

5. AI based image recon

a. Maintains identical quantitative values to traditional reconstruction techniques
b. Can be done in a virtually universal and vendor agnostic way using DICOM data
c. Can leverage both machine learning and/or deep learning techniques
d. Can reduce noise and artifacts
e. Eliminate the need for a human interpretation

Answer Key: 1. a, c, e, d, b, 2. D, 3. E, 4. A, 5. E

Neonatal Emergencies
Summer L. Kaplan, MD

Objectives

After this presentation, the participant will be able to:

1. Discuss appearances of neonatal hemorrhage and infarct on ultrasound
2. Describe an approach to neonatal cyanosis
3. Explain features of neonatal bowel obstruction

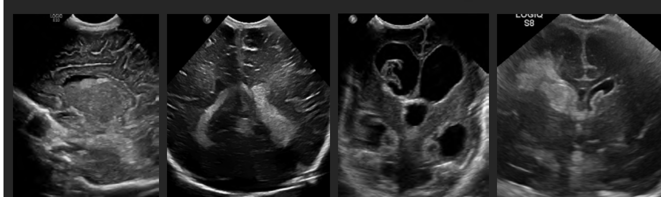
Neonatal Emergencies

- Seizure
- Respiratory distress
- Cyanosis
- Vomiting/Abdominal distention

Neonatal Seizure

- Intracranial bleed
- Mass effect
- Sinus thrombosis
- Global ischemia

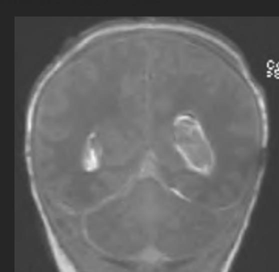
Intracranial Hemorrhage Grades

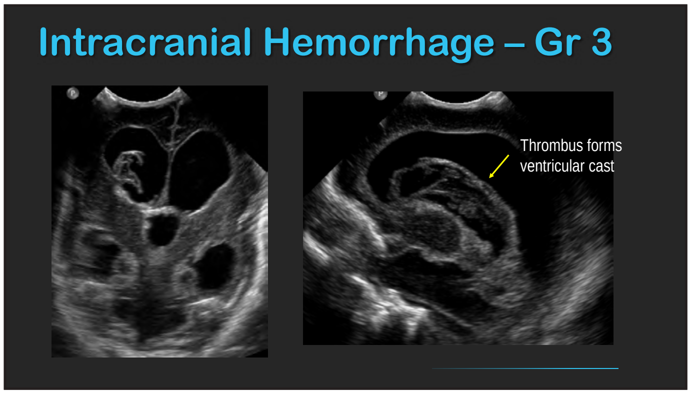


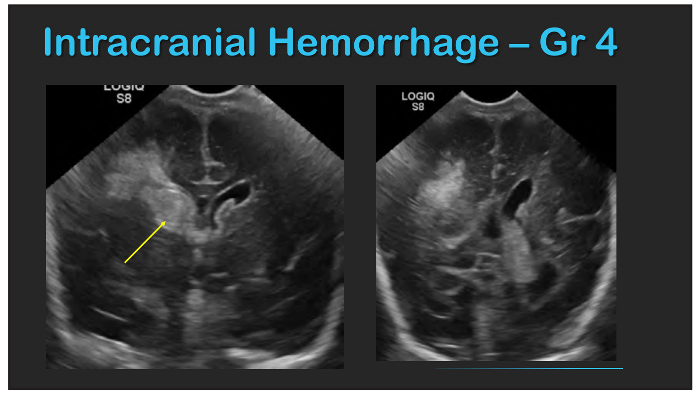
Grade 1 Grade 2 Grade 3 Grade 4

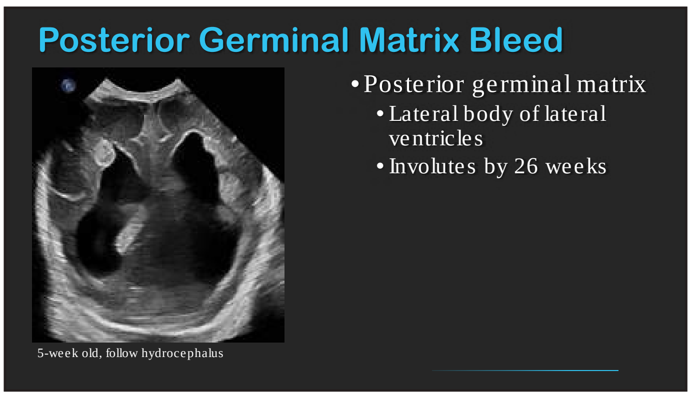
Intracranial Hemorrhage – Gr 1

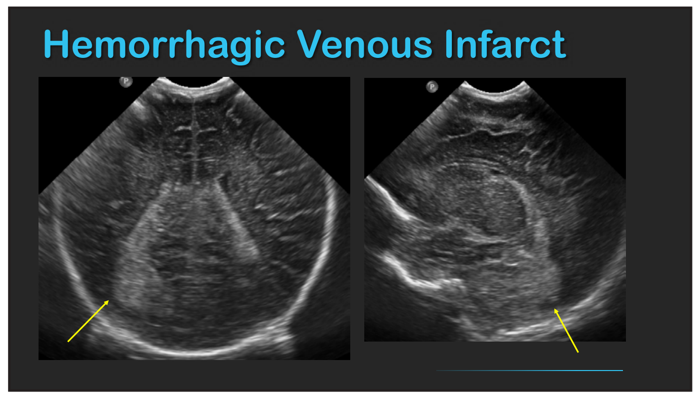
Grade 2 / Choroid Plexus

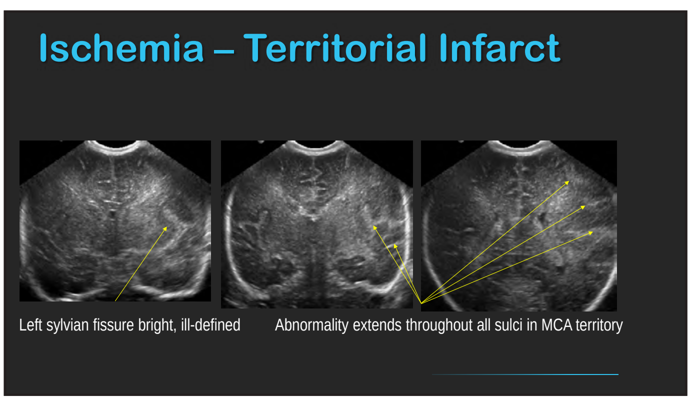


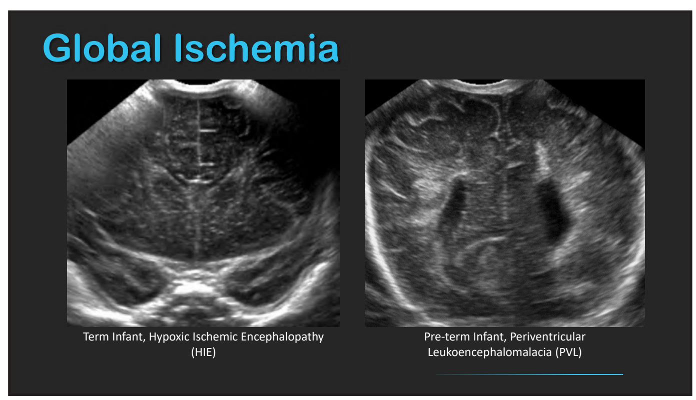

Intracranial Hemorrhage – Gr 3
Thrombus forms ventricular cast

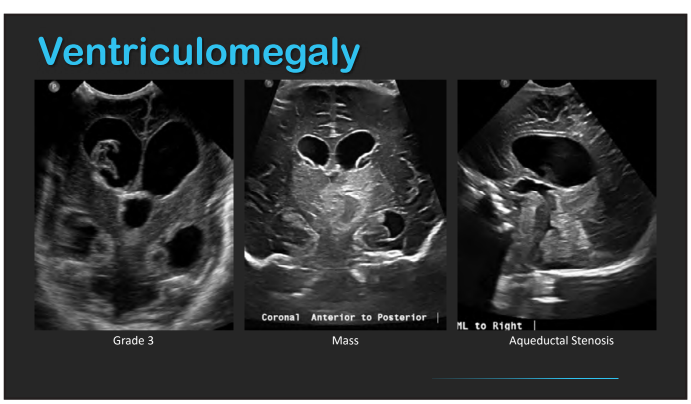

Intracranial Hemorrhage – Gr 4
LOGIQ S8
LOGIQ S8

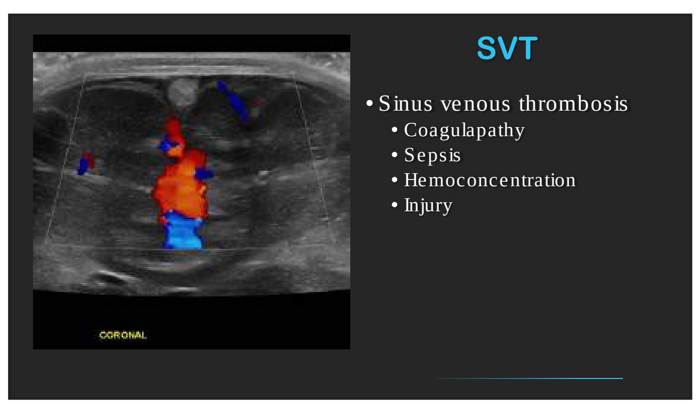

Posterior Germinal Matrix Bleed
• Posterior germinal matrix
• Lateral body of lateral ventricles
• Involutes by 26 weeks
5-week old, follow hydrocephalus


Hemorrhagic Venous Infarct


Ischemia – Territorial Infarct
Left sylvian fissure bright, ill-defined
Abnormality extends throughout all sulci in MCA territory


Global Ischemia
Term Infant, Hypoxic Ischemic Encephalopathy (HIE)
Pre-term Infant, Periventricular Leukoencephalomalacia (PVL)


Ventriculomegaly
Coronal Anterior to Posterior
ML to Right
Grade 3
Mass
Aqueductal Stenosis


SVT
CORONAL
• Sinus venous thrombosis
• Coagulapathy
• Sepsis
• Hemoconcentration
• Injury

Neonatal Respiratory Distress

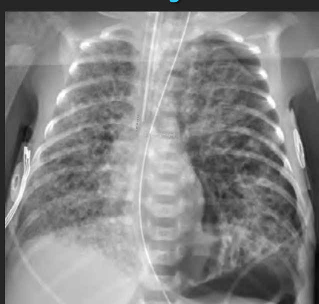
- Interstitial emphysema
- Meconium aspiration
- Pneumonia
- CDH
- CPAM

Premature Lung Disease


0-day old, respiratory distress

- "Neonatal respiratory distress syndrome"
- < 36 weeks gestation
  - Earlier gestation is more severe
- Immaturity of Type II pneumocytes
  - Surfactant deficiency
  - Genetic deficiency in term infants
- Treated with surfactant, high-flow oscillatory ventilation

Pulmonary Interstitial Emphysema




10 days later, mostly gone

Chronic Lung Disease of Prematurity


6-week old 26-week gestation

- "Bronchopulmonary Dysplasia"
- Barotrauma and oxygen-related injury
  - Develops in weeks to months
  - Susceptible lung
- Prevention
  - Nutrition
  - Fluid restriction
  - Vent settings
  - SpO2 84 – 94%
  - Steroids, bronchodilators, diuretics

Meconium Aspiration


0-day old, tachypnea

- Term infants
- Often intubated
- Opacities:
  - Bilateral
  - Diffuse
  - Patchy reticular
- Hyperinflation (may be due to intubation)
- Changes with time

Meconium Aspiration


Appearance depends on when you see it: 19 days later

Neonatal Pneumonia


0-day old, respiratory distress

- Term infants
- Opacity pattern is variable:
  - Bilateral, scattered
  - Patchy, reticular
- Common organisms
  - Group B streptococcus
  - E. coli
  - Staphylococcus aureus
  - Sexually transmitted

Mass effect

Congenital Pulmonary Airway Malformation

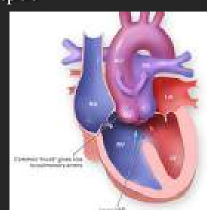
- Microcystic, macrocystic, mixed
- Lower lobes more typical
- May present as hybrid lesion with sequestration
  - Systemic arterial supply

Neonatal Cyanosis

1. Truncus arteriosus
2. Transposition of the great arteries
3. Tricuspid atresia
4. Tetralogy of Fallot
5. Total anomalous pulmonary venous return

Truncus arteriosus

Affects pulmonary arterial output

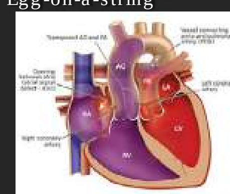


https://www.chop.edu/conditions-diseases/truncus-arteriosus

Transposition

Arterial output disease

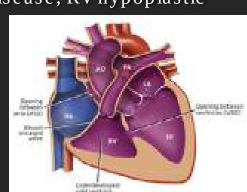
"Egg-on-a-string"



https://www.chop.edu/conditions-diseases/transposition-great-arteries

Tricuspid Atresia

Systemic venous return disease, RV hypoplastic

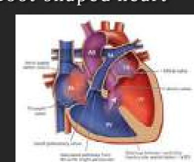


https://www.chop.edu/conditions-diseases/tricuspid-atresia

Tetralogy of Fallot

Pulmonary arterial output disease

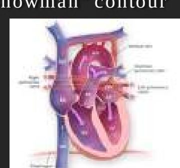
"Boot-shaped heart"



https://www.chop.edu/conditions-diseases/tetralogy-fallot

TAPVR

- Total anomalous pulmonary venous return
- "snowman" contour



https://www.chop.edu/conditions-diseases/total-anomalous-pulmonary-venous-ret

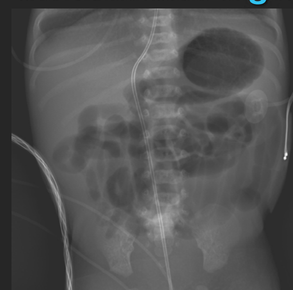
TAPVR

- Total anomalous pulmonary venous return
- "snowman" contour
- Pulmonary venous return disease infradiaphragmatic
  - Pulmonary edema

Vomiting/Abdominal Distention

- Obstruction
- Midgut volvulus
- NEC

Meconium Plug Syndrome



1-day old w/ no meconium

- 1:500 births
  - 24-48 hours life
- Risk factors:
  - Low-birth weight infants
  - Maternal diabetes
    - Glucagon secretion limits peristalsis in left colon
  - Maternal Mg++, pre-eclampsia
- May need water-soluble enema
- No long-term sequelae

2-day old w/ no meconium

Hirschsprung Disease

2-day old w/ no meconium

- 1:5000 births
  - 95% diagnosed < 1-year old
  - Sporadic or familial
- Absent ganglion cells colon
  - Short segment 80%
    - Rectum + distal sigmoid
  - Long segment 15 – 20%
    - Rectum + entire sigmoid
  - Total colonic aganglionosis 5%
- Surgical treatment, pull-through procedure

Obstruction, Inguinal Hernia

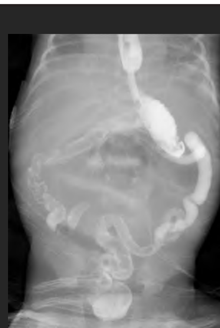
3-week old w/ vomiting

- Tubular, stacked bowel loops
- Obstruction and ileus may look similar
  - Degree of distention
  - Degree of stacked loops
  - Rectal gas not reliable in infants – fluid filled rectum
- Assess support devices

Duodenal Atresia

0-day old w/ prenatal abnormality

- Failure of duodenal recanalization
  - 2nd portion duodenum
  - Vomiting bilious or non-bilious
- Associated with
  - Trisomy 21
  - Cardiac malformations
  - VACTERL
  - Other bowel atresias
- US may exclude other etiologies
- Surgical duodeno-duodenostomy



3-day old 32-week gestation w/ bilious vomiting, no meconium

3-day old 32-week gestation w/ bilious vomiting, no meconium

Jejuno-Ileal Atresia

- In utero intestinal ischemia
  - Jejunal > ileal
  - Sporadic
- Types
  - I: Internal membrane, no discontinuity
  - II: Blind pouches connected by fibrous cord
  - IIIa: no connection + mesenteric defect
  - IIIb: ileal segment coiled around jejunal segment
  - IV: multiple atresias
- US, Water-soluble enema

3-day old 32-week gestation w/ bilious vomiting, no meconium

Necrotizing Enterocolitis

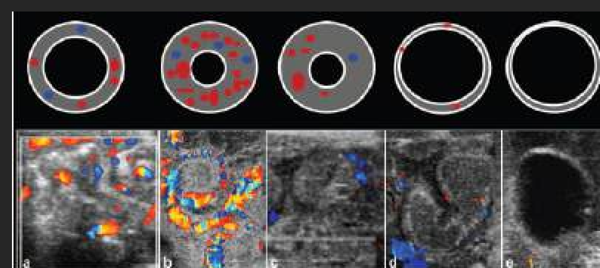
- Pneumatosis
  - "Bubbly lucencies"
  - Intestinalis
  - Coli
- Ileus
  - Tubular loops
  - Mild dilation
- Portal venous gas
  - US more sensitive
- Pneumoperitoneum

4-wo, 30-week gestation w/ abdominal distention, discoloration

Necrotizing Enterocolitis

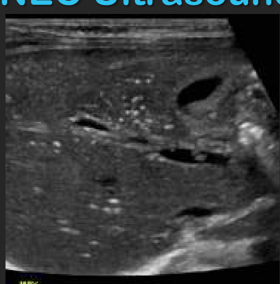
0-day old, 30-week gestation | 4-weeks old, abdominal distention | 1 hour later | 5 hours later

NEC Ultrasound



Epelman et al, Radiographics 2007

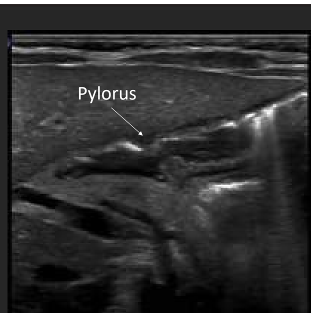
NEC Ultrasound



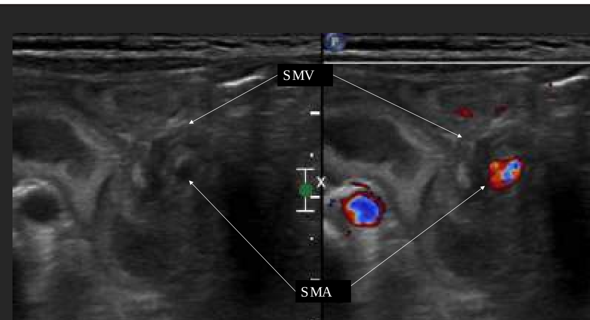
Spontaneous Intestinal Perforation

- Affects very low birth weight infants
- Typically perforates at terminal ileum >> jejunum, colon
  - Infection, ischemia
- Risk factor: early post-natal steroids, indomethacin
- Medical and surgical treatment options

14-day old 26-weeks GA w/abdominal distention

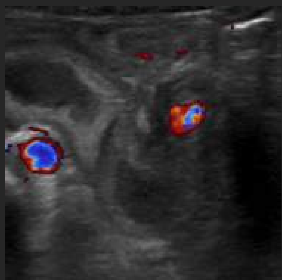


6-month old w/ bilious vomiting



6-month old w/ bilious vomiting

Midgut Volvulus



6-month old w/ bilious vomiting

- SMA should be left of SMV
- Ultrasound diagnosis
  - Linear probe, baby head probe
  - Sensitivity 83 – 96%
  - Specificity 89 – 100%
  - Clockwise whirlpool sign
  - Obstructed duodenum
- Fluoroscopy may confirm atypical cases

Midgut Volvulus

FLUOROSCOPY

Duodenojejunal junction should be:

- Left upper quadrant
- Level of pylorus

Fluoroscopic signs

- "Bird beak"
- "Corkscrew"

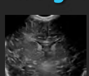
8-day old w/ prenatal abnormality

Osteogenesis Imperfecta

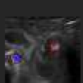
8-day old w/ prenatal abnormality

- Type I collagen deficiency
  - Many genetic variants
  - Inheritance patterns heterogeneous
- Brittle bones, blue sclerae, dental defects
- Type 1 OI most common
  - Autosomal dominant

Key Points



- Neonatal intracranial hemorrhage and infarct can be differentiated in part by location
  - Intracranial hemorrhage grading scale
- Appearance of lung disease may change over hours
  - PIE and chronic lung disease both due to barotrauma



- Ultrasound should be secondary tool in evaluating neonatal bowel, after radiographs
  - Ultrasound performed well may substitute for fluoroscopy in volvulus

Neonatal Emergencies

Summer L. Kaplan, MD MS

SELF EVALUATION

Neonatal Emergencies

1. The features of a Papile grade 3 intracranial hemorrhage are:

a. intraventricular hemorrhage and enlarged ventricles
b. intraventricular hemorrhage and midline shift
c. periventricular hemorrhge extending from the germinal matrix
d. subdural hemorrhage

2. Chronic lung disease of prematurity is caused by

a. autosomal dominant inheritance
b. surfactant
c. barotrauma
d. infection

3. Neonatal cyanosis associated with primary deficiency affecting venous return to the heart includes (check all that apply):

a. Truncus Arteriosus
b. Transposition of the Great Arteries
c. Tricuspid Atresia
d. Tetralogy of Fallot
e. Total Anomalous Pulmonary Venous Return

4. Duodenal atresia is associated with

a. Total anomalous pulmonary venous return
b. Trisomy 21
c. Hirschsprung disease
d. Autosomal dominant inheritance

5. Hirschsprung disease is characterized by:

a. Abormally low rectosigmoid ratio
b. Abnormally high rectosigmoid ratio
c. Microcolon
d. Hypertrophy of the anal sphincter muscle

Answer Key: 1. A, 2. C, 3. C & E, 4. B, 5. A

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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HRCT Evaluation of Interstitial Lung Disease

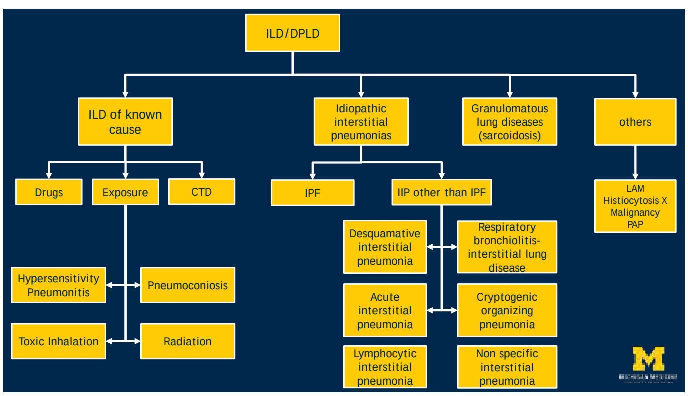
HRCT evaluation of Interstitial Lung Disease (ILD)

Learning Objectives:

- To understand the HRCT technique and key definitions seen in patients with ILD
- To describe the imaging manifestations of the major ILD encountered in clinical practice
- To review the current classification of Idiopathic Interstitial Pneumonias (IIP) and the role of imaging in the diagnosis of Idiopathic Pulmonary Fibrosis (IPF)

Key Terms and Definitions

- **Interstitial Lung Disease (ILD)/Diffuse Parenchymal Lung Disease (DPLD)**- A broad group of disease of known or unknown etiology causing inflammation and fibrosis in the lung interstitium
- **Idiopathic Interstitial pneumonias (IIP)-** ILD of unknown cause
- **Idiopathic pulmonary Fibrosis/IPF (IPF)-** Corresponds histologically with usual interstitial pneumonia (UIP) and represents the most common IIP. Chronic progressive fibrotic ILD of unknown cause



Role of HRCT in ILD

- **Detection of diffuse lung disease**
  - detect abnormalities before other tests become abnormal
  - exclude certain diseases as cause of symptoms
- **Characterization of diffuse lung disease**
  - identify specific abnormalities
  - formulate differential diagnosis
  - determine if reversible or irreversible abnormalities are present
  - help determine prognosis
- **Differential diagnosis and guidance for further testing**
  - HRCT findings may be sufficiently diagnostic
  - HRCT findings may suggest the next appropriate study

    Tree in bud- sputum analysis

    Perilymphatic nodules or possible infection- transbronchial biopsy

    Nonspecific diffuse lung disease- VATS
- **Sequential evaluation of abnormalities over time**
  - response to treatment
  - disease behavior over time

HRCT Technique and possible protocols

HRCT basic technique

- Non contrast axial imaging at full inspiration in supine position
- 0.625-1.25 mm thick sections
- Sharp (edge-enhancing) algorithm
- Axial (non helical) vs Volumetric protocol

Optional image acquisition

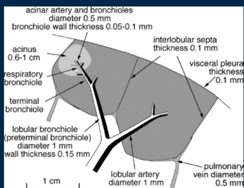
- Prone imaging
- Expiratory imaging
- Low dose technique (mAs 40-100) and prone only imaging : long term follow up of established diagnosis with multiple repeat studies

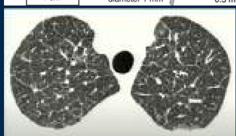
Axial (non helical) vs Volumetric protocol

- Axial 1mm/10 mm skip and shoot method
- Volumetric helical technique- Current recommendation

- Evaluation of the entire lung parenchyma
- Reformats in coronal and sagittal planes and image manipulation such as MIP and Minip possible
- Better diagnosis and characterization of bronchiectasis and nodules

Normal anatomy on HRCT: Secondary pulmonary lobule





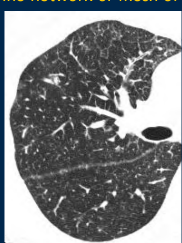
- Key anatomic structure in understanding HRCT abnormalities
- Smallest unit of lung delineated by connective tissue septa
- Many pathological processes occur in relationship to specific components of the secondary pulmonary lobule

HRCT Findings in ILD

- Reticular Opacities
- Nodules
- Increased lung Attenuation: Ground Glass Opacity and Consolidation
- Decreased lung attenuation: Cysts, Mosaic perfusion and Emphysema

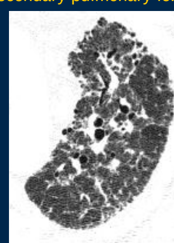
HRCT abnormalities: Reticular opacities

Fine network or mesh of overlapping lines within the secondary pulmonary lobule



Nodular and smooth septal thickening. Lymphangitis carcinomatosa

Smooth septal thickening. Edema

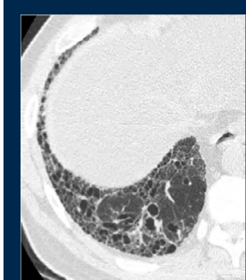


Irregular reticulation. Fibrosis

HRCT findings of Fibrosis

- Reticular abnormalities
- Lobular distortion
- Traction bronchiectasis
- Honeycombing

Reticular pattern and Traction Bronchiectasis and Bronchiolectasis



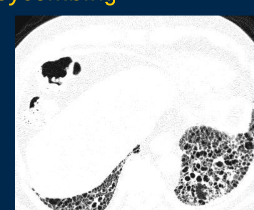
Traction bronchiectasis and bronchiolectasis both refer to irreversible dilatation of an airway related to surrounding or adjacent lung fibrosis

Traction bronchiectasis and/ or bronchiolectasis, when detected in the setting of chronic fibrosis, is generally considered evidence of irreversible disease, and progression predicts worsening mortality risk

HRCT findings of honeycombing

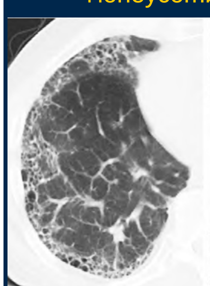
Most specific HRCT sign of fibrosis- subpleural clustered cystic spaces

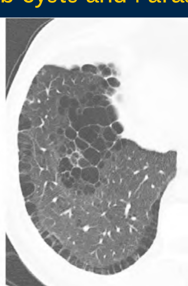
- Always involves the subpleural lung
- Most cysts are 3-10mm in diameter
- Cysts have thick walls
- A layer or cluster of cysts should be visible
- The cysts of honeycombing should be of air attenuation
- There should be no anatomy within the cysts
- Cysts do not branch
- Associated signs of fibrosis are present in the same lung regions



Honeycombing on HRCT in an appropriate distribution has a positive predictive value for a histologic pattern of UIP ranging from 90-100%

Honeycomb cysts and Paraseptal Emphysema





The cysts of paraseptal emphysema are typically more than 1.0 cm in diameter, larger than honeycomb cysts, and have thinner walls

Interobserver variability for presence or absence of honeycombing is borderline

Presence of honeycombing is no longer considered a required feature in many cases of IPF in the appropriate clinical context

HRCT Findings in ILD

- Reticular Opacities
- **Nodules**
- Increased lung Attenuation: Ground Glass Opacity and Consolidation
- Decreased lung attenuation: Cysts, Mosaic perfusion and Emphysema

HRCT findings: Nodules
Differential diagnosis of nodules relative to lung structures

- **Primary Perilymphatic distribution**

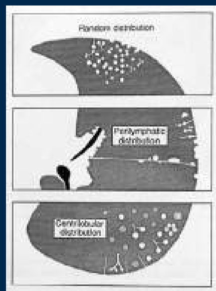
-Sarcoidosis
-CWP/Silicosis
-Lymphangitis carcinomatosa

- **Primary Random distribution**

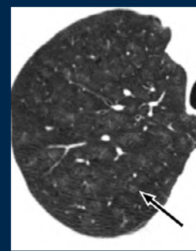
-Hematogenous metastases
-Miliary disease

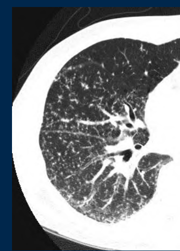
- **Primary Centrilobular distribution**

-Subacute HP
-RB-ILD



HRCT Nodule distribution


Centrilobular nodules. RB-ILD


Perilymphatic nodules. Sarcoidosis

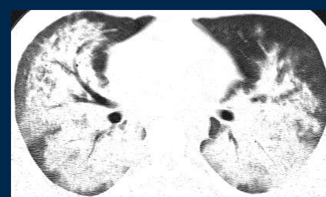

Random nodules. Miliary TB

HRCT Findings in ILD

- Reticular Opacities
- Nodules
- **Increased lung Attenuation: Ground Glass Opacity and Consolidation**
- Decreased lung attenuation: Cysts, Mosaic perfusion and Emphysema

HRCT Findings: Increased lung attenuation: Ground glass opacity and consolidation

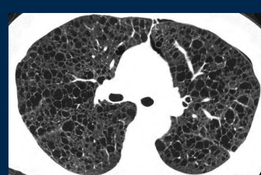

GGO

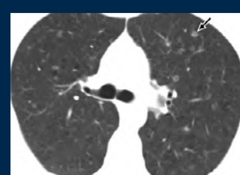

Consolidation

HRCT Findings in ILD

- Reticular Opacities
- Nodules
- Increased lung Attenuation: Ground Glass Opacity and Consolidation
- **Decreased lung attenuation: Cysts, Mosaic perfusion and Emphysema**

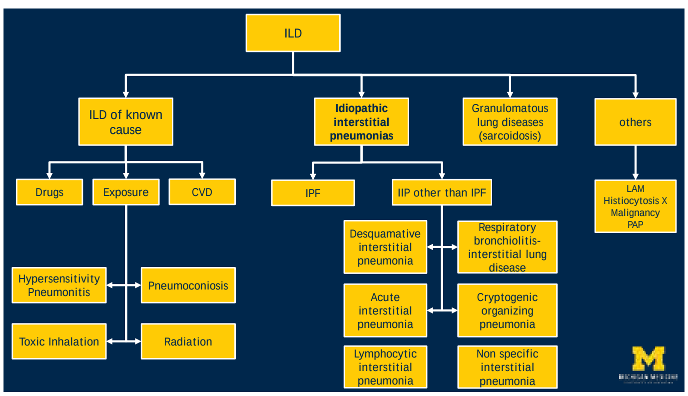
HRCT Finding: Cystic lung disease
Cysts- round air density structures greater than 1cm in size with a thin but recognizable wall


LAM – Female, diffuse uniform thin-walled cysts, effusions, ptx


PLCH- Smoker, upper lung, nodules, irregular cysts

Differential diagnosis of primary cystic lung disease

- **Langerhans cell histiocytosis**
- **Lymphangioleiomyomatosis**
- **Lymphoid interstitial pneumonia**
- **Birt-Hogg-Dube disease**
- Pneumatoceles from prior infection
- Treated cystic metastases
- Benign metastasizing leiomyoma
- Papillomatosis
- Neurofibromatosis



Revised ATS/ERS classification of IIP: Multidisciplinary Diagnoses

Major idiopathic interstitial pneumonias

- Idiopathic pulmonary fibrosis
- Idiopathic nonspecific interstitial pneumonia
- Respiratory bronchiolitis-interstitial lung disease
- Desquamative interstitial pneumonia
- Cryptogenic organizing pneumonia
- Acute interstitial pneumonia

Rare idiopathic interstitial pneumonias

- Idiopathic lymphoid interstitial pneumonia
- Idiopathic pleuroparenchymal fibroelastosis

Unclassifiable idiopathic interstitial pneumonias

Am J Respir Crit Care Med Vol 188, Iss. 6, pp 733-748, Sep 15, 2013

Idiopathic Interstitial Pneumonias Revised ATS/ERS IIP classification

Category	Clinical-Radiological-Pathological diagnosis	Associated Radiologic and/or pathologic-morphologic pattern
Chronic Fibrosing IP	Idiopathic pulmonary fibrosis Idiopathic nonspecific interstitial pneumonia	Usual interstitial pneumonia Nonspecific interstitial pneumonia
Smoking related IP	Respiratory bronchiolitis-interstitial lung disease Desquamative interstitial pneumonia	Respiratory bronchiolitis Desquamative interstitial pneumonia
Acute/subacute IP	Cryptogenic organizing pneumonia Acute interstitial pneumonia	Organizing pneumonia Diffuse alveolar damage

Am J Respir Crit Care Med Vol 188, Iss. 6, pp 733-748, Sep 15, 2013

ILD. Practical issues for Image interpretation

- UIP refers specifically to the imaging or histologic pattern, while IPF refers to the clinical syndrome
- ILD can manifest with various imaging and histologic patterns and sometimes even multiple patterns in the same patient. For example, an imaging and histologic pattern of UIP may be ultimately diagnosed as CTD-related ILD rather than IPF due to the presence of systemic rheumatologic disease
- Identify the predominant HRCT pattern

Practical Imaging Interpretation in Patients Suspected of Having IPF

Imaging serves a key role in the diagnosis of patients suspected of having idiopathic pulmonary fibrosis (IPF)

Accurate pattern classification at thin-section chest CT is a key step in multidisciplinary discussions, guiding the need for surgical lung biopsy and determining available pharmacologic therapies

The recent approval of new treatments for fibrosing lung disease has made it more critical than ever for radiologists to facilitate accurate and early diagnosis of IPF

Fibrotic Lung Diseases: Common Etiologies

Idiopathic

- Usual interstitial pneumonitis (UIP)/Idiopathic pulmonary fibrosis (IPF)
- Nonspecific interstitial pneumonitis (cellular and fibrotic NSIP)

Known causes

- Connective Tissue Disease (UIP/NSIP)
- Chronic hypersensitivity pneumonitis (HP)
- Asbestosis/Pneumoconiosis
- Sarcoidosis (Stage III-IV upper lobes)

ATS/ERS/JRS/ALAT Criteria for HRCT diagnosis of a UIP pattern

UIP pattern (all 4)

- Sub pleural, basal predominance
- Reticular abnormality
- **Honeycombing**
- Absence of inconsistent features

Probable UIP

- Sub pleural, basal predominance
- Reticular abnormality
- **No honeycombing**
- Absence of inconsistent features

Indeterminate UIP

- Diffuse distribution without subpleural predominance
- CT features of lung fibrosis that do not suggest any specific etiology

Findings inconsistent with a UIP pattern (anyone)

- Upper mid lung or peribronchovascular predominance
- Extensive GGO (> reticulation)
- Profuse micronodules
- Discrete cysts (bilateral, away from honey combing)
- Mosaic perfusion, air trapping (bilateral, >3 lobes)
- Lobular or segmental consolidation

Raghu, G et al. Am J Respir Crit Care Med 2011; 183: 788-824. Updated evidence based guidelines for the diagnosis and management of IPF

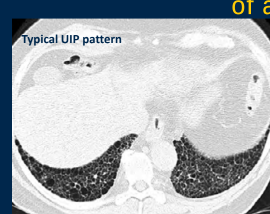
Two international multidisciplinary groups have published recent statements (2018) on the diagnosis of IPF

The Fleischner Society and a joint working group formed by the American Thoracic Society, European Respiratory Society, Japanese Respiratory Society, and Latin American Thoracic Society (ATS/ERS/JRS/ALAT)

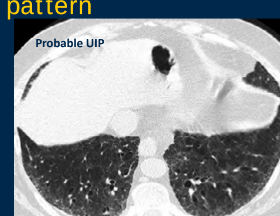
Each group defined four diagnostic categories of pulmonary fibrosis at thin-section CT in patients suspected of having UIP or IPF

Hobbs S, Chung JH, Leb J, Kaproth-Joslin K, Lynch DA. Practical Imaging Interpretation in Patients Suspected of Having Idiopathic Pulmonary Fibrosis: Official Recommendations from the Radiology Working Group of the Pulmonary Fibrosis Foundation. Radiol Cardiothorac Imaging. 2021 Feb 25;3(1):e200279. doi: 10.1148/ryct.2021200279. PMID: 33778653; PMCID: PMC7977697.

ATS/ERS/JRS/ALAT Criteria for HRCT diagnosis of a UIP pattern

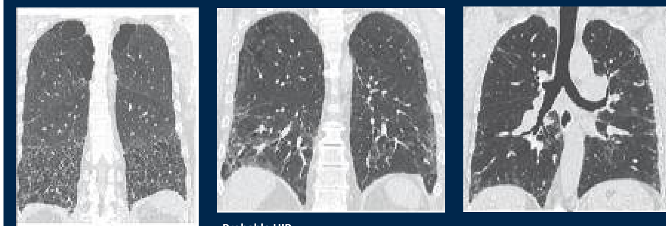


- Sub pleural, basal predominance
- Reticulation with traction bronchiectasis or bronchiolectasis
- Honeycombing
- Absence of inconsistent features



- Sub pleural, basal predominance
- Reticulation with traction bronchiectasis or bronchiolectasis
- No honeycombing
- Absence of inconsistent features

HRCT Patterns of UIP



UIP Pattern

Sub pleural, basal predominance

Honeycombing

Probable UIP

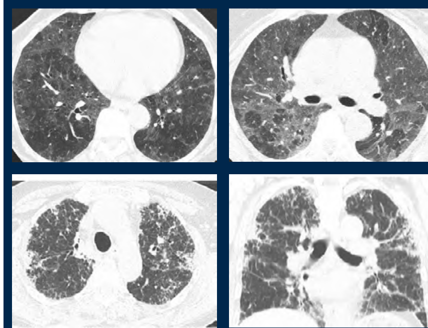
Sub pleural, basal predominance

Reticulation with traction bronchiectasis or bronchiolectasis

No honeycombing

Indeterminate UIP

Peribronchovascular and subpleural ground-glass opacities, intermingled with fine reticulation but no honeycombing or traction bronchiectasis)



Findings inconsistent with a UIP pattern (anyone)

- upper mid lung or peribronchovascular predominance
- Extensive GGO (> reticulation)
- profuse micronodules (bilateral, upper lobes)
- discrete cysts (bilateral, away from honey combing)
- mosaic perfusion, air trapping (bilateral, > 3 lobes)
- lobular or segmental consolidation

Fibrosing Hypersensitivity Pneumonitis

Idiopathic Interstitial Pneumonias
Revised ATS/ERS IIP classification

Category	Clinical-Radiological-Pathological diagnosis	Associated Radiologic and/or pathologic-morphologic pattern
Chronic fibrosing IP	Idiopathic pulmonary fibrosis Idiopathic nonspecific interstitial pneumonia	Usual interstitial pneumonia Nonspecific interstitial pneumonia
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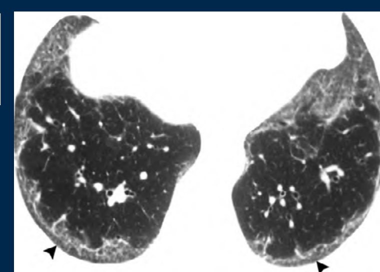
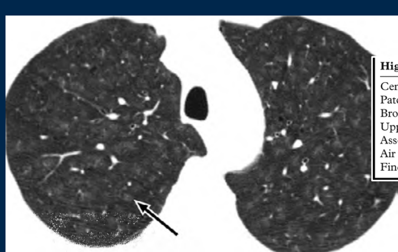
Am J Respir Crit Care Med Vol 188, Iss. 6, pp 733-748, Sep 15, 2013

Nonspecific interstitial pneumonia

Ground glass opacity
Reticulation
Little or no honeycombing
Peripheral and basal distribution
Relative subpleural sparing



Smoking related IIP- RB ILD



High-Resolution CT Findings of RB-ILD

Centrilobular nodular opacities
Patchy ground-glass opacity
Bronchial wall thickening
Upper lobe predominance
Associated centrilobular emphysema
Air trapping at expiration
Findings of fibrosis absent

Smoking related IIP- DIP

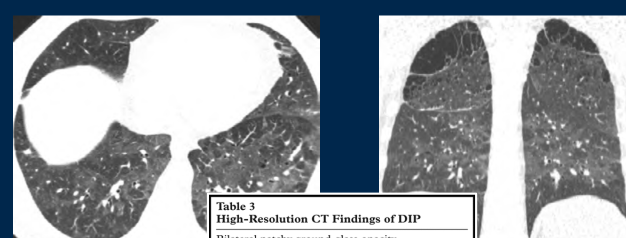
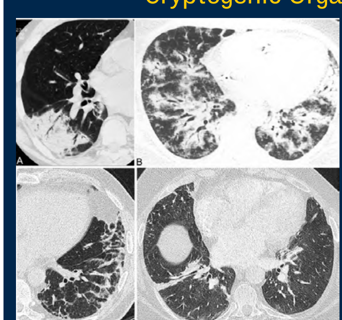


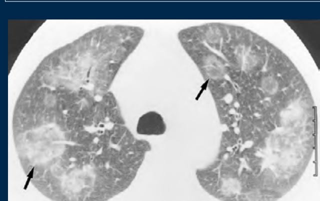
Table 3
High-Resolution CT Findings of DIP

Bilateral patchy ground-glass opacity
Reticular opacities
Subpleural and basal predominance
Honeycombing uncommon
Associated centrilobular emphysema

Cryptogenic Organizing Pneumonia

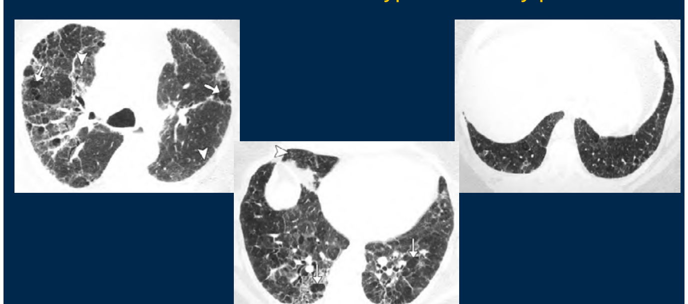


Consolidation
Peribronchovascular or peripheral distribution
GGO
Atoll or reversed halo sign



American Journal of Roentgenology. 2003;180: 1251-1254.

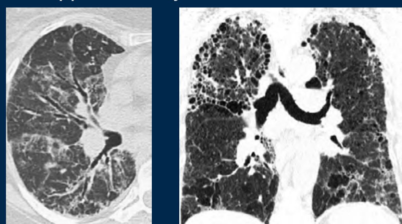
Differential considerations in IIP: Hypersensitivity pneumonitis



Silva et al. Radiology Vol. 246, No. 1: 288-297 Chronic Hypersensitivity Pneumonitis: Differentiation from Idiopathic Pulmonary Fibrosis and Nonspecific Interstitial Pneumonia by Using thin section CT

Differential considerations in IIP: Hypersensitivity pneumonitis

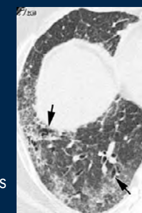
Thin-section CT findings allow confident distinction of chronic HP from IPF and NSIP approximately 50% of the time.



Chronic HP

Silva et al. Radiology Vol. 246, No. 1: 288-297

Differential considerations in IIP: CTD- ILD



- CTD is a frequent cause of IIP patterns, especially NSIP
- Other patterns:

-usual interstitial pneumonia
-organizing pneumonia
-diffuse alveolar damage
-lymphoid interstitial pneumonia
-bronchiectasis, constrictive bronchiolitis, follicular bronchiolitis
-alveolar hemorrhage,
-pulmonary hypertension
-drug-induced lung disease

Identification of coexisting extrapulmonary abnormalities on CT can support a diagnosis of CVD.

Tanaka et al. Radiology Vol. 232, No. 1: 81-91

CTD-ILD

- Although ILD can occur in association with any CTD, it is more commonly observed in patients with SSc, RA, idiopathic inflammatory myopathies (dermatomyositis and polymyositis), or MCTD, and less commonly observed in patients with SLE or SS
- ILD has a prevalence of up to 90% in patients with SSc, depending on the subtype and definition of scleroderma applied; clinically evident ILD occurs in 10% of patients with RA, with preclinical ILD observed on CT in an additional 20-60% of patients. In patients with inflammatory myopathies, ILD ranges in prevalence of 4-45%
- NSIP is the most common fibrosis pattern observed across all CTDs, showing variable degrees of inflammation (cellular NSIP) and fibrosis (fNSIP). However, UIP also occurs in association with CTDs and is the most common ILD in patients with RA, portending a worse prognosis in such patients

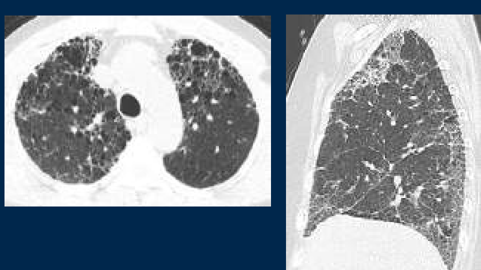
HRCT in CTD- ILD

Three radiographic findings have been identified that suggest an ILD secondary to CTD

- **Anterior upper lobe sign**, which is the concentration of fibrosis in the anterior upper lobes with relative sparing of the rest of the upper lobe. The positive likelihood ratio of CTD-ILD in patients with this finding is 1.99
- **Exuberant honeycombing**, which is extensive honeycombing comprising greater than 70% of the fibrotic areas of the lungs. The positive likelihood ratio of CTD-ILD with this finding is 3.69
- **Straight edge sign**, which is the isolation of fibrosis to the lung bases without extension along the lateral margins of the lung. The positive likelihood ratio of CTD-ILD is 4.22

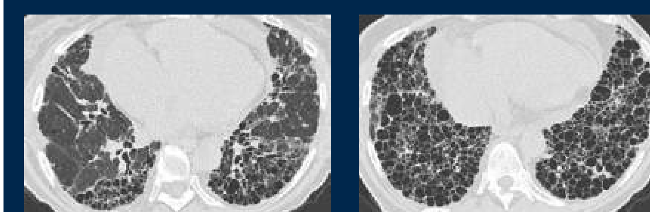
Chung JH, Cox CW, Montner SM, Adegunsoye A, Oldham JM, Husain AN, Vij R, Noth I, Lynch DA, Strek ME. CT Features of the Usual Interstitial Pneumonia Pattern: Differentiating Connective Tissue Disease-Associated Interstitial Lung Disease From Idiopathic Pulmonary Fibrosis. AJR Am J Roentgenol 2018; 210: 307-313.

CTD- ILD .Anterior upper lobe sign



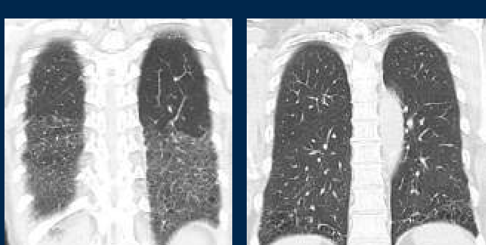
concentration of fibrosis within the anterior aspect of the upper lobes (with relative sparing of the other aspects of the upper lobes) and concomitant lower lobe involvement

CTD-ILD. Exuberant honeycombing sign



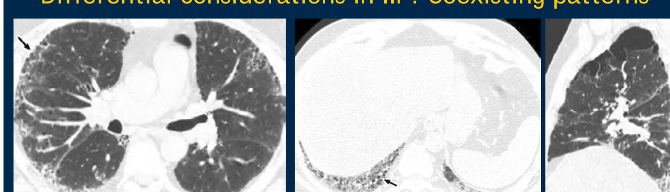
exuberant honeycomb-like cyst formation within the lungs constituting greater than 70% of fibrotic portions of lung

CTD-ILD. Straight-edge sign

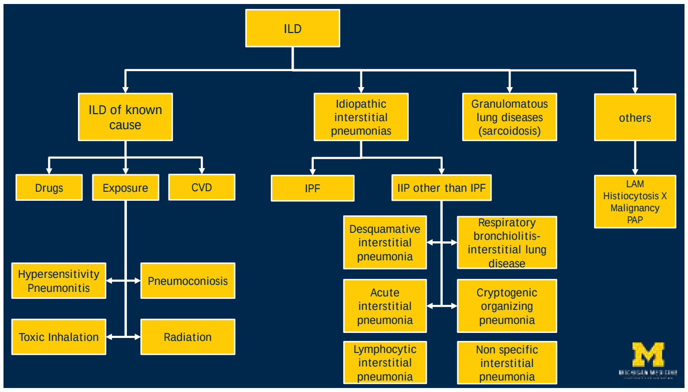


isolation of fibrosis to the lung bases with sharp demarcation in the craniocaudal plane without substantial extension along the lateral margins of the lungs on coronal images

Differential considerations in IIP: Coexisting patterns



Distinctive Features of CPFE
Emphysema in the upper lungs and fibrosis in the lower lungs at high-resolution CT
Severe reduction in diffusion capacity
Relatively preserved lung volumes
High prevalence of pulmonary arterial hypertension



A general approach to the diagnosis of ILD/Lung Fibrosis

- What is the key HRCT abnormality- e.g Reticulation, GGO, consolidation, nodules, cysts?
- Is Fibrosis present – Traction bronchiectasis and or Honeycombing?
- What is the craniocaudal distribution of abnormalities?
- What is the axial (cross sectional) distribution of abnormalities?
- Are there significant imaging associated findings that help in diagnosis?
- Is useful clinical information available?

Clinical information and most likely associated diagnosis presenting with fibrosis

Age > 50 y	IPF, Drug toxicity, asbestosis, pneumoconiosis, hypersensitivity pneumonitis
Age < 50 y	Sarcoidosis, collagen vascular diseases, hypersensitivity pneumonitis
Cigarette smoking	IPF, RB-ILD, DIP
Exposure to dust	Silicosis, CWP, Talcosis and other pneumoconiosis
Exposure to organic antigens	Hypersensitivity pneumonitis
Connective tissue disease	NSIP and UIP

Differential diagnosis of fibrosis based on craniocaudal distribution of fibrosis on HRCT

Upper lobe predominant	Lower lobe predominant
Sarcoidosis	IPF
Prior TB	Connective tissue disease
Prior fungal infection	Drug fibrosis
Radiation fibrosis	Asbestosis
Pneuconiosis	Hypersensitivity pneumonitis
Ankylosing spondylitis	Chronic aspiration

Differential diagnosis of fibrosis based on axial distribution of findings on HRCT

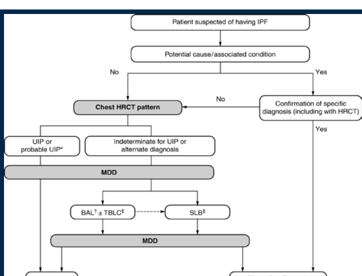
Sub pleural predominant	Diffuse or central distribution
IPF	Sarcoidosis
Connective tissue disease	Pneuconiosis
Drug fibrosis	Hypersensitivity pneumonitis
Asbestosis	Prior TB or fungal infection
Post- ARDS fibrosis	Chronic aspiration

Table 1: Extrapulmonary Thin-Section CT Findings Associated with Diffuse Lung Diseases That Cause Pulmonary Fibrosis

Extrapulmonary Structure	Finding	Associated Diagnosis
Airway	Bronchial wall thickening	Smoking-related lung disease
Mediastinum	Calcified lymph nodes	Sarcoidosis or silicosis
Vasculature	Enlarged main pulmonary artery (> 2.9 cm, or larger than the adjacent ascending aorta)	May indicate the presence of pulmonary hypertension
Heart	Right ventricular dilatation (RV to LV diameter ratio > 1:1)	May indicate the presence of pulmonary hypertension
	Right ventricular hypertrophy (> 4-mm thickness)	
Esophagus	Esophageal dilatation	CTD-ILD (specifically SSc-ILD)
	Hiatal hernia	UIP
Pleura	Pleural thickening	RA or SLE (related to serositis) drug toxicity
	Calcified pleural plaques	Asbestosis
Liver	Hyperattenuating hepatic parenchyma	Amiodarone toxicity
Bones	Distal clavicular erosions	CTD-ILD (specifically RA)

Note.—CTD-ILD = connective tissue disease–related interstitial lung disease, LV = left ventricle, RA = rheumatoid arthritis, RV = right ventricle, SLE = systemic lupus erythematosis, SSc-ILD = systemic sclerosis-related interstitial lung disease, UIP = usual interstitial pneumonia.

Hobbs S, Chung JH, Leb J, Kaproth-Joslin K, Lynch DA. Practical Imaging Interpretation in Patients Suspected of Having Idiopathic Pulmonary Fibrosis: Official Recommendations from the Radiology Working Group of the Pulmonary Fibrosis Foundation. Radiol Cardiothorac Imaging. 2021 Feb 25;3(1):e200279. doi: 10.1148/ryct.2021200279. PMID: 33778653; PMCID: PMC7977697.



Diagnostic algorithm for idiopathic pulmonary fibrosis (IPF), developed using consensus by discussion. *Patients with a radiological pattern of probable usual interstitial pneumonia (UIP) can receive a diagnosis of IPF after multidisciplinary discussion (MDD) without confirmation by lung biopsy in the appropriate clinical setting (e.g., 60 yr old, male, smoker). BAL may be appropriate in some patients with a probable UIP pattern. †BAL may be performed before MDD in some patients evaluated in experienced centers. ‡Transbronchial lung cryobiopsy (TBLC) may be preferred to surgical lung biopsy (SLB) in centers with appropriate expertise and/or in some patient populations, as described in the text. A subsequent SLB may be justified in some patients with nondiagnostic findings on TBLC. Adapted from Reference 2. HRCT = high-resolution computed tomography.

Am J Respir Crit Care Med, 2022
https://www.atsjournals.org/doi/abs/10.1164/rccm.202202-0399ST

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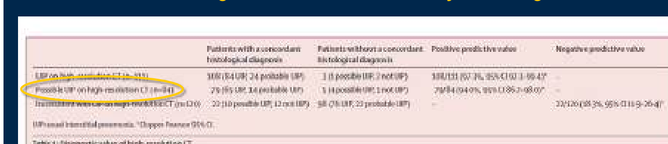
DOI: 10.1164/rccm.202202-0399ST

Diagnosis of IPF with HRCT in patients with little or no radiological evidence of honeycombing

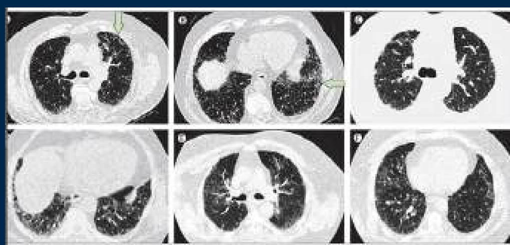


*Conclusion: In the appropriate clinical setting, for patients with possible UIP pattern on HRCT, surgical lung biopsy sampling might not be necessary to reach a diagnosis of IPF if HRCT scans are assessed by experts at regional sites familiar with patterns of UIP and management of IIP

Diagnosis of idiopathic pulmonary fibrosis with high-resolution CT in patients with little or no radiological evidence of honeycombing: secondary analysis of a randomised, controlled trial. The Lancet Respiratory Medicine, Volume 2 issue 4, Pages 277 - 284, April 2014

Fell CD, Martinez FJ, Liu LX, et al. Clinical predictors of a diagnosis of idiopathic pulmonary fibrosis. Am J Respir Crit Care Med 2010; 181: 832-37

Diagnosis of IPF with HRCT in patients with little or no radiological evidence of honeycombing

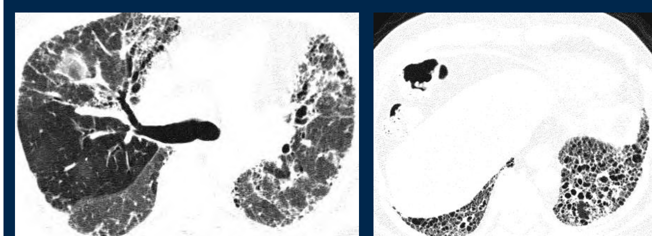


Diagnosis of idiopathic pulmonary fibrosis with high-resolution CT in patients with little or no radiological evidence of honeycombing: secondary analysis of a randomised, controlled trial. The Lancet Respiratory Medicine, Volume 2 issue 4, Pages 277 - 284, April 2014

When is HRCT sufficiently characteristic to allow a confident diagnosis of ILD?

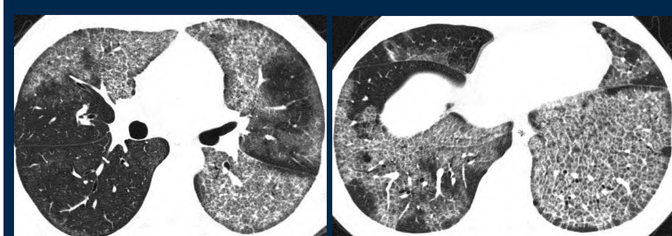
- UIP pattern- Definite or Typical
- Lymphangitic carcinomatosis (nodular 2nd lobules)
- LAM/Tuberous sclerosis (uniform cysts)
- PLCH (bizarre shaped cysts ± nodules)
- Subacute HP (centrilobular micronodules)
- Sarcoid (perilymphatic nodules)
- Infectious bronchiolitis (tree in bud)
- Alveolar proteinosis (crazy paving pattern)
- Lung edema (perihilar ground glass opacity)

UIP

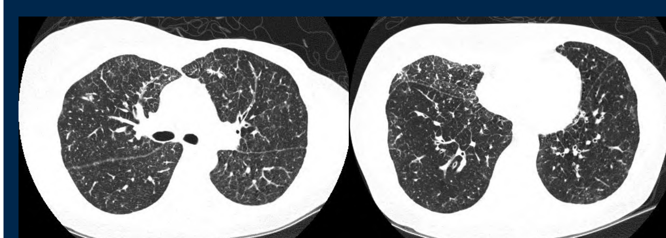


Sarcoidosis

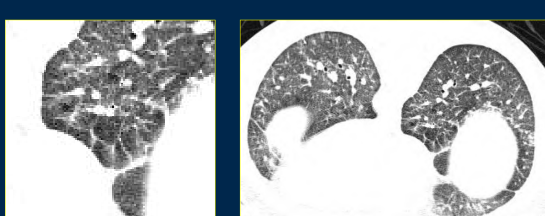
Alveolar Proteinosis



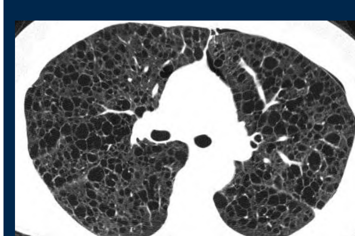
Lymphangitis Carcinomatosis



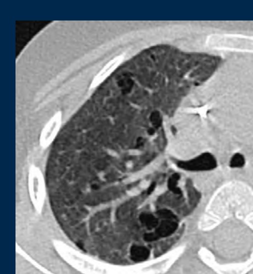
Lung Edema



Cystic Lung Disease



LAM



PLCH

HRCT evaluation of Interstitial Lung Disease (ILD)

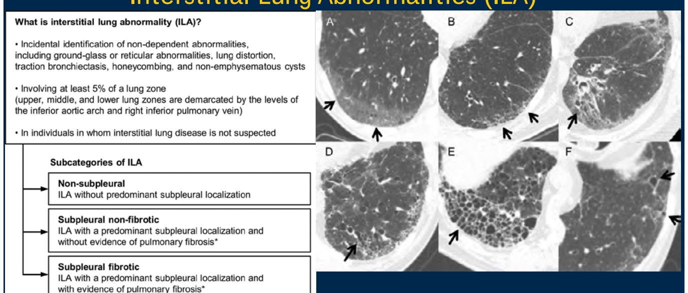
Learning Objectives:

- To understand the HRCT technique and key definitions seen in patients with ILD
- To describe the imaging manifestations of the major ILD encountered in clinical practice
- To review the current classification of Idiopathic Interstitial Pneumonias (IIP) and the role of imaging in the diagnosis of Idiopathic Pulmonary Fibrosis (IPF)

Emerging concepts in ILD

- Interstitial Lung Abnormalities (ILA)
- Progressive Pulmonary Fibrosis (PPF)

Interstitial Lung Abnormalities (ILA)



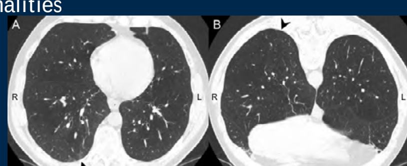
Interstitial Lung Abnormalities: State of the Art . Akinori Hata, Mark L. Schiebler, David A. Lynch, and Hiroto Hatabu. Radiology 2021 301:1, 19-34

Interstitial Lung Abnormalities (ILA)

- Interstitial lung abnormalities (ILAs) are common incidental findings at CT, which progress over 5 years in more than 50% of individuals, and are associated with worsened clinical outcomes, including respiratory symptoms, exercise capacity, lung function, and mortality
- ILA may represent an early or subclinical form of pulmonary fibrosis
- Risk factors for the presence of ILA include increasing age, tobacco smoke exposure, other inhalational exposures (eg, vapors, gases, dusts, fumes, and traffic-related air pollution), and genetic factors

Pitfalls in diagnosis of interstitial lung abnormalities

- Dependent lung abnormalities
- Osteophyte lesions
- Apical lung fibrosis/ pleuroparenchymal fibroelsastosis
- Aspiration
- Centrilobular nodularity



Interstitial Lung Abnormalities: State of the Art . Akinori Hata, Mark L. Schiebler, David A. Lynch, and Hiroto Hatabu. Radiology 2021 301:1, 19-34

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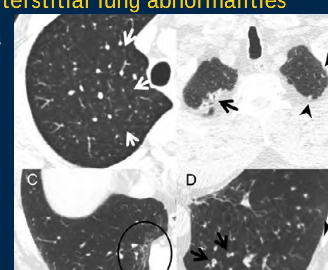
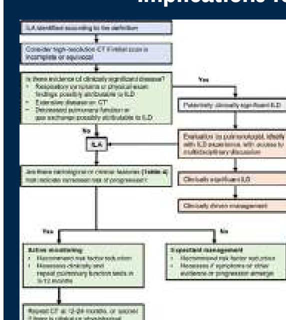


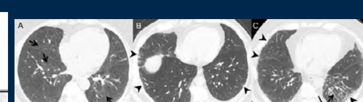
Interstitial Lung Abnormalities: State of the Art . Akinori Hata, Mark L. Schiebler, David A. Lynch, and Hiroto Hatabu. Radiology 2021 301:1, 19-34

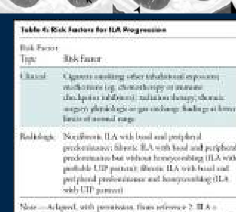
Interstitial Lung Abnormalities (ILA)

- The rate of imaging progression of ILA has ranged from 20% over 2 years in the National Lung Screening Trial to 73% over 5 years in the AGES-Reykjavik study
- The presence of ILA is associated with decreased total lung capacity. Individuals with ILA showed impaired gas exchange compared with those without ILA
- An association between ILA and increased hazard or incidence of lung cancer diagnosis is reported

Implications for Clinical Management







Interstitial Lung Abnormalities: State of the Art . Akinori Hata, Mark L. Schiebler, David A. Lynch, and Hiroto Hatabu. Radiology 2021 301:1, 19-34

Emerging concepts in ILD

- Interstitial Lung Abnormalities (ILA)
- **Progressive Pulmonary Fibrosis (PPF)**

Progressive Pulmonary Fibrosis (PPF)

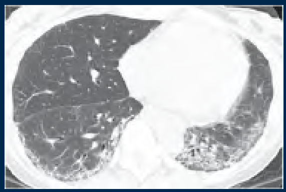
ATS Clinical Practice Guideline published in 2022 defined PPF as a non-IPF fibrosing ILD with the presence of two of the following three features occurring within a year of follow-up:

- deterioration in respiratory symptoms
- demonstrable physiologic evidence of disease progression through pulmonary function tests (PFTs)
- increased fibrosis on imaging

Category	Criteria
Clinical	Respiratory symptoms that have worsened
Physiologic	FVC predicted to show absolute decline of at least 5% within 1 year; or DL_{CO} (corrected for Hb) predicted to show absolute decline of at least 10% within 1 year
Radiologic	At least one of: Traction bronchiectasis and bronchiolectasis becoming more widespread or severe New GGO accompanied by traction bronchiectasis New fine reticulation Reticular abnormality becoming more widespread or more coarse New or increased honeycombing Increased lobar volume loss

Am J Respir Crit Care Med, 2022
https://www.atsjournals.org/doi/abs/10.1164/rccm.202202-0399ST

Progressive Pulmonary Fibrosis (PPF)



Progressive pulmonary fibrosis due to fibrotic nonspecific interstitial pneumonia (NSIP). (A)Computed tomography in a 45-year-oldwoman with scleroderma shows lower lung-predominant reticular and ground-glass abnormality with subpleural sparing, typical for NSIP. (B)Nine years later, the fibrosis has progressed with increased extent of reticular abnormality, increased traction bronchiectasis, and evolution of reticular abnormality to honeycombing. Small bilateral pleural effusions are present.

Am J Respir Crit Care Med, 2022
https://www.atsjournals.org/doi/abs/10.1164/rccm.202202-0399ST

Progressive Pulmonary Fibrosis (PPF)

- PPF applies only to those patients whose fibrosis has progressed despite appropriate management tailored to the underlying ILD
- The diagnosis of PPF holds significant management implications, regardless of the underlying cause of fibrosis
- Anti-fibrotic medications like nintedanib and pirfenidone have demonstrated effectiveness in mitigating forced vital capacity (FVC) decline in patients with non-IPF with PPF who have not responded to conventional therapies targeting their primary condition

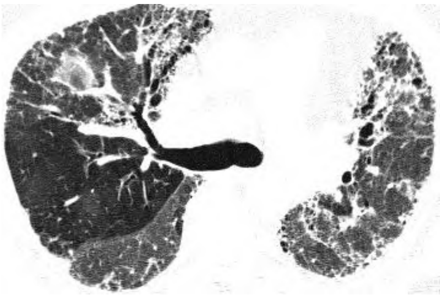
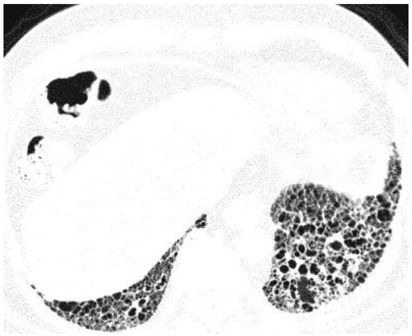
HRCT evaluation of ILD Conclusions:

- Achieving a diagnosis in ILD is dynamic and multidisciplinary with integration of HRCT data with clinical data being essential
- HRCT may obviate the need for surgical lung biopsy in specific instances or may indicate instances in which biopsy is more likely to be useful
- Radiology reports should use recognized standard terminology and categorize imaging patterns of fibrosis according to the Fleischners Society guidelines and /or the ATS guidelines
- Interstitial lung abnormalities (ILA) and progressive pulmonary fibrosis (PPF) are recent emerging concepts in ILD with implications for patient management

SELF EVALUATION

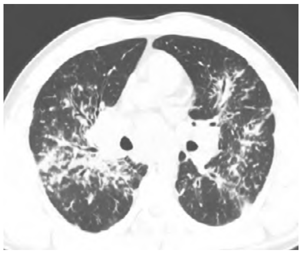
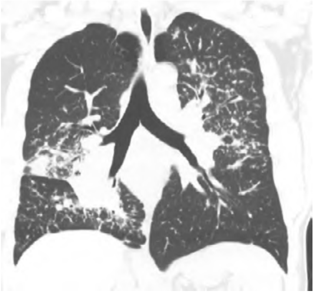
HRCT Evaluation of Interstitial Lung Disease

1. Selected HRCT images from a 70 year old man with dyspnea and restrictive pulmonary function testing are below. The most likely imaging diagnosis/pattern is which of the following?

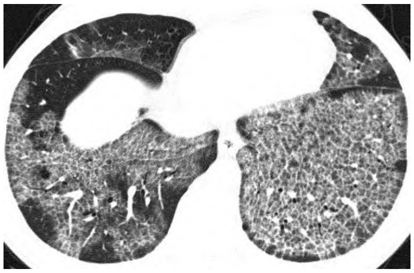
a. Typical UIP
b. Probable UIP
c. Indeterminate for UIP
d. Features most consistent with an alternative non UIP/IPF diagnosis
e. Panlobular emphysema

2. HRCT images (on lung and soft tissue windows) in a 30 year old woman with shortness of breath are presented. The most likely diagnosis is


a. IPF
b. Sarcoidosis
c. Hypersensitivity pneumonitis
d. Alveolar proteinosis
e. Lymphangitis carcinomatosa

3. HRCT images from a 35 year old male smoker with shortness of breath and non resolving opacities on CXR are presented. The most likely diagnosis is which of the following

a. Sarcoidosis
b. IPF
c. Hypersensitivity Pneumonitis
d. Alveolar Proteinosis
e. Lung edema

HRCT Evaluation of Interstitial Lung Disease (cont.)

4. A HRCT image from a 35 year old woman with shortness of breath and chest pain is shown below. The most likely diagnosis is which of the following

a. Emphysema
b. Langerhans cell histiocytosis
c. Lymphangioleiomyomatosis
d. Birt Hogg Dube Disease
e. Desquamative Interstitial Pneumonitis

5. Which of the following HRCT findings are inconsistent with a UIP pattern and should suggest a Non IPF diagnosis

a. Honeycombing in a basal and subpleural distribution
b. Reticulation and traction bronchiectasis in a basal and subpleural distribution
c. Mildly enlarged thoracic lymph nodes with lower lung fibrosis
d. An enlarged main pulmonary artery
e. Profuse micronodules

6. Which of the following clinical features or imaging findings suggests a diagnosis of IPF when a UIP pattern is seen on HRCT?

a. Male sex, age over 60 and cigarette smoking
b. Female sex and age under 50
c. A dilated esophagus
d. Pleural effusions
e. Exposure to dust

Answer Key: 1. A, 2. B, 3. D, 4. C, 5. E, 6. A

Benign Liver Lesions
Robert M. Marks, MD

Disclosures

- Consultant Guerbet LLC

Objectives

1. Be able to describe the pertinent anatomy of the liver.
2. Understand the imaging techniques and contrast agents used in liver imaging.
3. Be able to diagnose benign lesions of the liver.

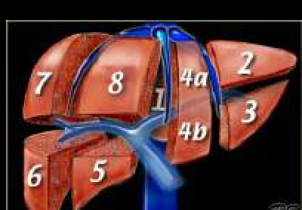
Overview

- Brief Anatomy
- Contrast Agents
- Cystic Lesions
- Solid Lesions

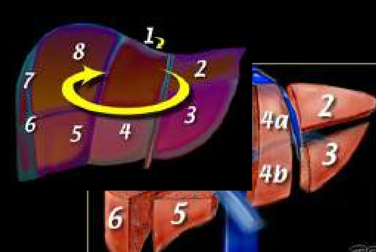
Brief Anatomy

- Segmental Anatomy
  - Morphologic
    - gross anatomy, falciform ligament
  - Functional (Couinaud Classification)
    - 8 functional hepatic segments
    - Hepatic artery, portal vein, bile duct
    - Caudate Lobe
    - Surgeons

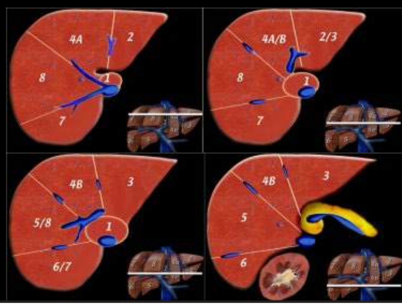
Segments



Segments



Segmental Anatomy



Hepatic Parenchyma

- Homogeneous on CT and MRI
- Non-Con-CT- normal 40-70 Hounsfield Units
  – Should be as bright or brighter than spleen
- Con-CT- Attenuation varies
  – Not the best tool for diagnosing Hepatic Steatosis
- MRI
  – Intermediate on T1, similar to panc, higher than spleen
  – T2, should be brighter than muscle

CT Contrast Agents

- Iodinated Contrast Agent of choice
- Liver 75% of blood from Portal Vein
- Tumors get almost all blood from hepatic arteries
  – Why arterial enhanced images are important
- Typical Liver CT protocol
  – Non-con
  – Arterial – approximately 35 seconds after contrast (bolus tracking)
    - Late arterial phase includes hepatic artery and portal vein opacification
  – Portal Venous Phase - 70 sec
  – Delay – about 4 minutes

MRI Contrast Agents

- Extracellular agents 100% cleared through kidneys
- Hepatobiliary agents (gadoxetate 50% biliary 50% renal excretion)
- Dynamic arterial enhancement key
- Acquire sequential images
  – Arterial (fluoro triggered)
  – PV 70 sec
  – Transitional Phase 3 min, then at 4 and 5 minutes
  – (Eovist) Hepatobiliary phase at 20 mins

Deposition Disease

- Gadolinium deposits in brain, skin, bones, etc.
- No conclusive evidence of clinical significance of deposition
- We educate patients about it at first contrasted MRI
- FDA mandated more research

https://aasldpubs.onlinelibrary.wiley.com/doi/10.1002/cld.1024

Cystic Lesions

- Benign Cyst
- Polycystic Liver Disease/Fibropolycystic Liver Disease
- Biliary Hamartomas
- Caroli's Disease
- Biliary Abscess
  – Pyogenic
  – Amebic
  – Hydatid

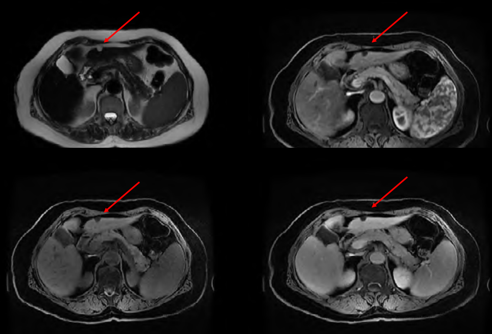
Benign Cyst

- Common non-enhancing lesions
  – No capsule
- CT < 20 HU
  – Partial volume averaging (can call lesions > 1cm)
- MRI T2 BRIGHT, T1 dark

Figure 1a. Hepatic cysts in an asymptomatic 37-year-old woman.

Mortelé K J , Ros P R Radiographics 2001;21:895-910

RadioGraphics



Polycystic Liver Disease

- Autosomal Dominant
  - Assoc. w/ Autosomal dominant polycystic kidney disease
  - If cysts have increased T1 signal, then may represent hemorrhagic cysts.
- *Falls under the umbrella of: Fibropolycystic Liver Disease*

Figure 3a. Autosomal dominant polycystic kidney and liver disease in a 45-year-old patient.

Mortelé K J , Ros P R Radiographics 2001;21:895-910

RadioGraphics

Figure 4a. Polycystic liver disease.

Mortelé K J , Ros P R Radiographics 2001;21:895-910

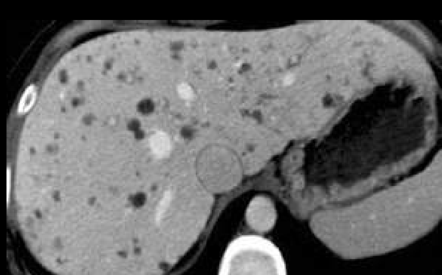
RadioGraphics

Fibropolycysitic Liver Disease

- Spectrum of related lesions of liver and biliary tract caused by abnormal embryologic development of ductal plates
  - Cysts and varying degrees of fibrosis
- Can cause portal HTN, GI Bleeding, cholangitis, infections.
- Includes:
  - Congenital Hepatic Fibrosis
  - Biliary hamartomas
  - ADPKD
  - Caroli disease
  - Choledochal cysts

Biliary Hamartomas

- Usually indistinguishable from benign cysts
- AKA von Meyenburg complexes
- Cysts lined by biliary epithelium
- Can be irregular in shape



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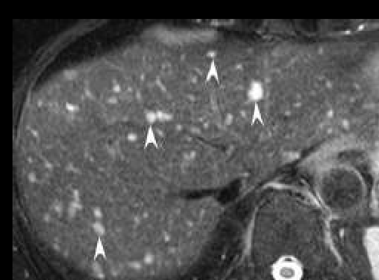


RadioGraphics

Caroli Disease/Syndrome

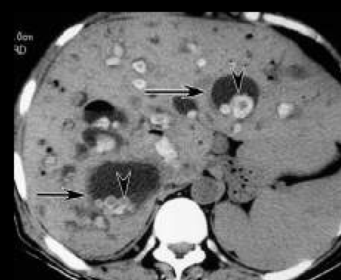
- Multifocal segmental dilatation of the large intrahepatic ducts, which retain their communication with the biliary tree
- Caroli syndrome is disease + fibrosis
- Embryologic origin
- Saccular or fusiform cystic dilatations of bile ducts up to 5 cm in diameter
- Enhancing fibrovascular bundles “central dot sign”
  – Portal vein branch protruding into the lumen of duct
- Can have calculi within the ducts
- Is a risk factor for cholangiocarcinoma

Figure 11a. Caroli disease.

Brancatelli G et al. Radiographics 2005;25:659-670

RadioGraphics

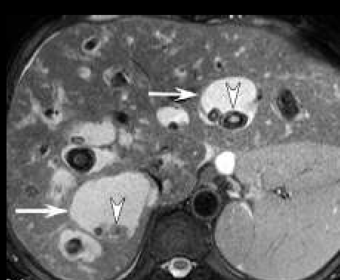
Figure 9a. Caroli disease.



Brancatelli G et al. 2005;25:659-670Radiographics

RadioGraphics

Figure 9b. Caroli disease.

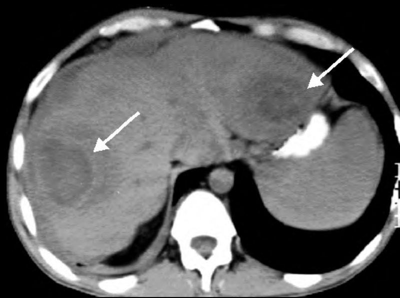


Brancatelli G et al. Radiographics 2005;25:659-670

RadioGraphics

Pyogenic Abscess

- Symptomatic
- E. coli most common bug
- CT: Hypoattenuating mass with an enhancing peripheral capsule
- Can have multiple microabcesses
  – Fungal, staph infection in septicemia
- MRI: variable T1 and T2 intensity, enhacing capsule, diffusion restriction, peripheral edema



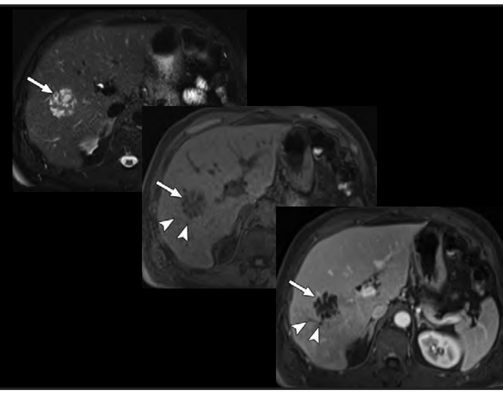


Figure 3. Pyogenic microabscesses.

Mortelé K J et al. Radiographics 2004;24:937-955

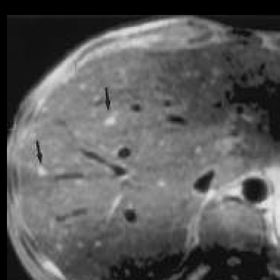
RadioGraphics

Figure 19. Candidiasis.

Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Figure 20. Candidiasis.



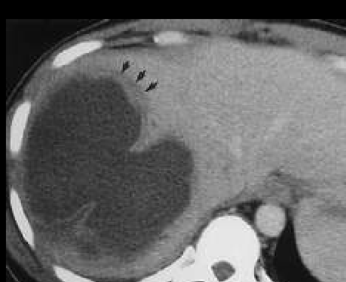
Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Amebic Abscess

- Entamoeba histolytica
- Colonic trophozoites ascend to liver via portal vein
- Patients acutely ill
- Travel history
  - Tropical regions Mexico, South America, Asia, developing countries
- Treated with medications
  - Aspiration carries risk of subcapsular peritonitis
- Looks similar to pyogenic abscess, however can have a thicker capsule

Figure 7a. Amebic abscess.



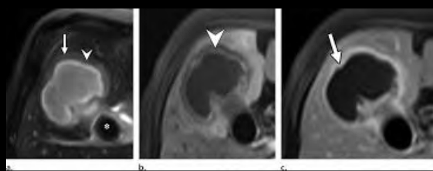
Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Figure 7b. Amebic abscess.

Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics



Hydatid Cyst

- Human infected by ingesting eggs of E granulosus by eating contaminated food or contact with dogs
- Eosinophilia
- Three layers
  - Outer pericyst (fibrosed compressed liver)
  - Ectocyst (thin laminated membrane)
  - Endocyst (inner germinal layer)
- Treated with medications
  - Aspiration risk of anaphylaxis and spillage of contents

Hydatid Cyst Imaging

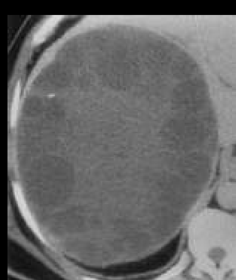
- CT: well defined hypoattenuating lesion with a wall.
  - Course calcs 50%
  - Daughter Cysts 75%
  - Water Lily Sign
    - Contained rupture of endocyst
- MRI:
  - Pericyst: hypointense rim on T1 and T2 (fibrous)
  - Matrix bright on T2, dark on T1
  - Daughter cysts are hypointense relative to the matrix on T1 and T2

Figure 11a. Hydatid disease.

Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Figure 11b. Hydatid disease.



Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Figure 12a. Hydatid disease.

Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Figure 12b. Hydatid disease.

Mortelé K J et al. Radiographics 2004;24:937-955

RadioGraphics

Solid Benign Lesions

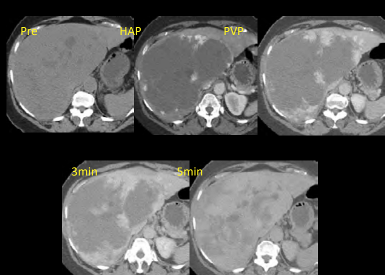
- Hemangioma
- Focal Nodular Hyperplasia
- Hepatic Adenoma
- Rare
  - Angiomyolipoma (tuberous sclerosis)

Hemangioma

- Very common
- Interconnected endothelial-lined vascular channels, enclosed within loose fibroblastic stroma
- Fed by hepatic artery branches
  - Slow flow internally
- Can grow
- Can fibrose

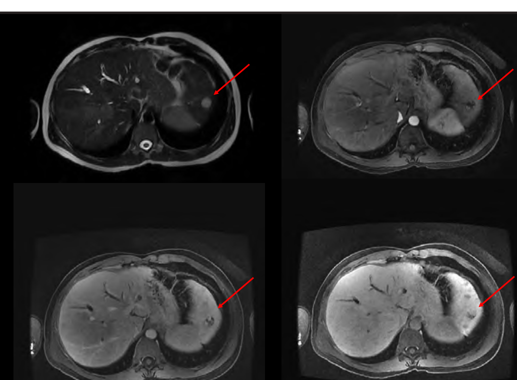
Hemangioma CT

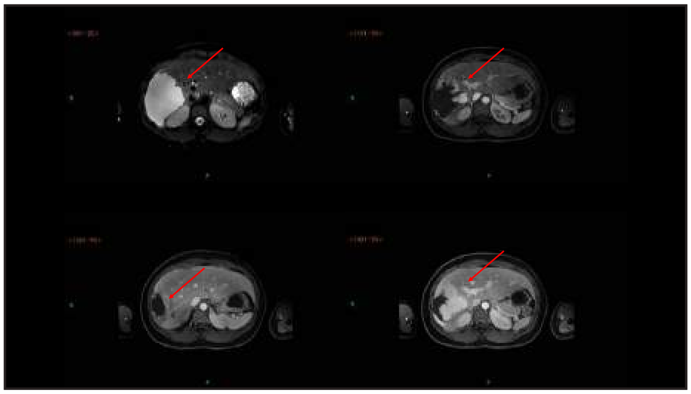
- Sharply defined hypoattenuating masses
- "Discontinuous peripheral puddling enhancement"
- "Centripetal fill-in"
- "Flash filling hemangiomas"
  - Time to fill in varies with size
  - Not a real thing.
  - Small hemangiomas that fill in quickly
- They follow blood pool!!!!

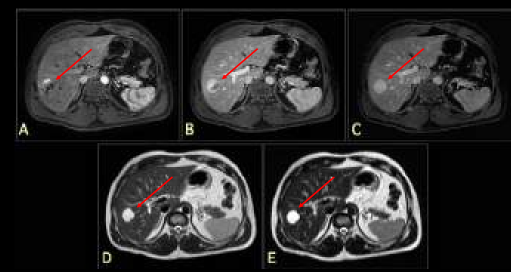


Hemangioma MRI

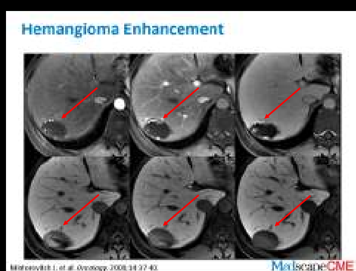
- "Light Bulb Bright" "Benign bright" on T2
- T1 dark
- Dynamic Gad enhancement features are the same as seen on CT
- Can have restricted diffusion
- Atypical features include: scar, fibrosis, calcs, rupture/hemorrhage







Eovist

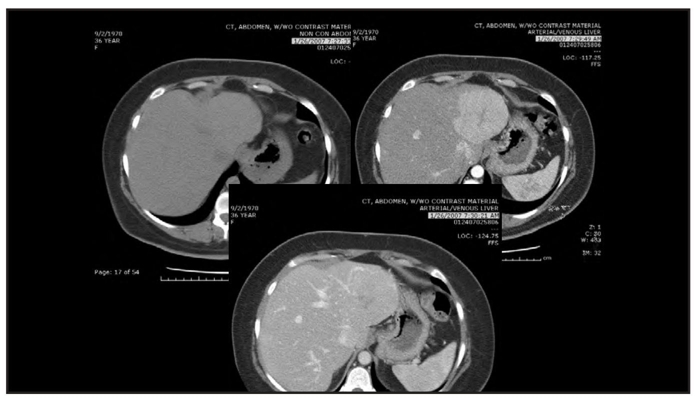


Focal Nodular Hyperplasia

- Second most common tumor
- Benign vascular neoplasm composed of disorganzied hepatocytes, bile ducts, blood vessels, and Kupffer cells.
- Central scar with spoke-wheel fibrous bands which contain arteries and bile ductules
- No central veins or portal tracts, no capsule.
- Hypothesis: Hyperplastic response to vascular malformation

CT FNH

- Non con→ Iso or hypodense “Stealth Lesion”
- Arterial phase → rapid enhancement with hypodense scar
  - HOMOGENEOUS!!!
- Portal Venous Phase → Quickly fades to isointense
- Delayed phase→ Delayed enhancement of central scar



Typical FNH on multiphasic CT scans.

Brancatelli G et al. Radiology 2001;219:61-68

Radiology

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Radiology

—Typical CT findings of focal nodular hyperplasia in 30-year-old woman.

Mortelé K J et al. AJR 2000;175:687-692

AJR

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AJR

MRI FNH

- T1 Iso
- T2 iso or slightly hyper
  - "Stealth lesion" on T2
  - Can have hyperintense central scar
- Gad arterial enhancement rapid, homogeneous
- Rapid fade to iso on portal venous and delayed images
- Can have enhancement of central scar
- EOVIST, will be bright on hepatobiliary phase!

—Typical MR findings of focal nodular hyperplasia in 26-year-old woman.

Mortelé K J et al. AJR 2000;175:687-692

AJR


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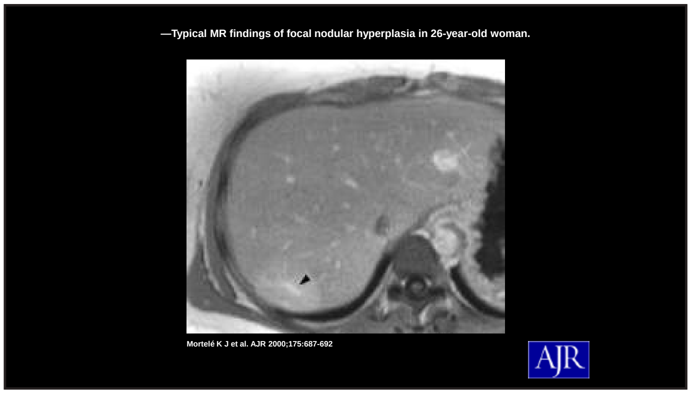
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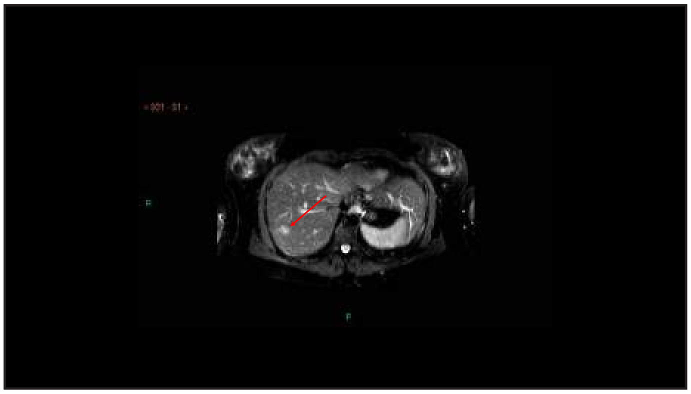
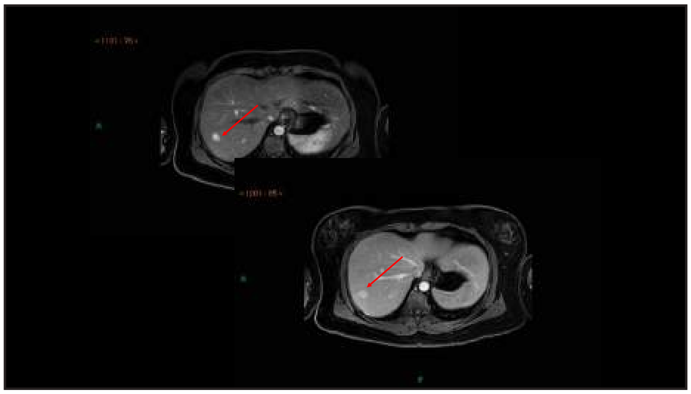
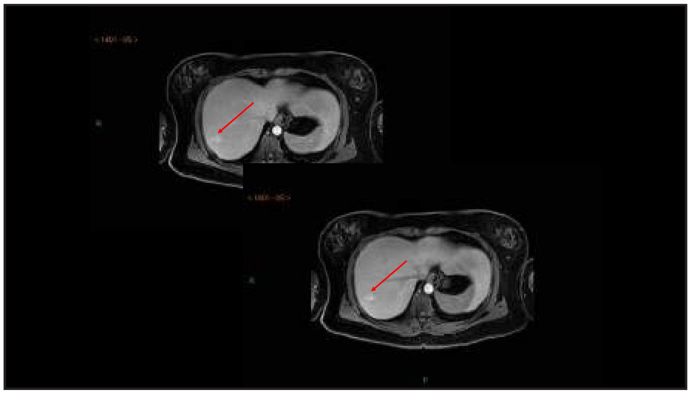
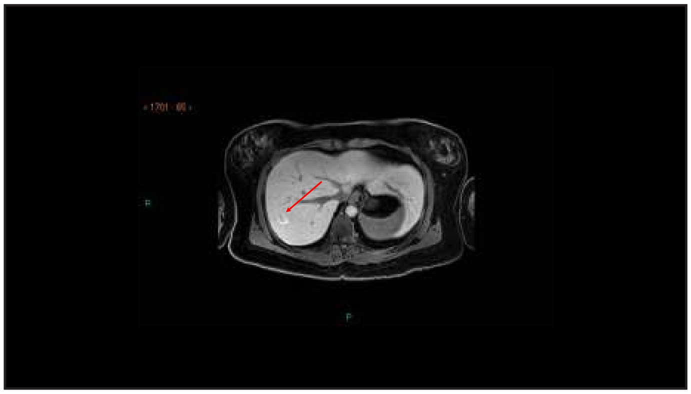
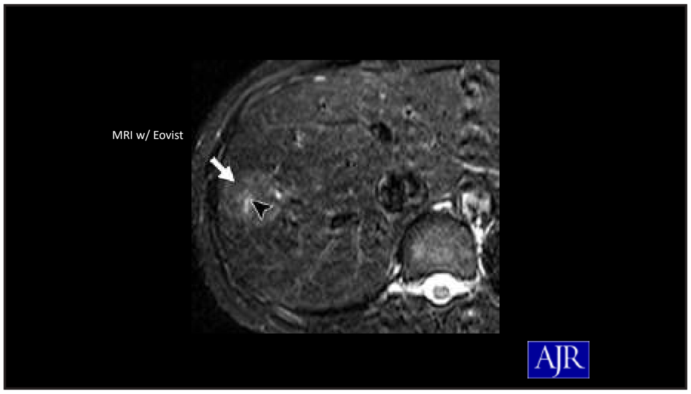
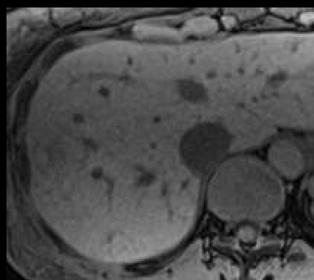


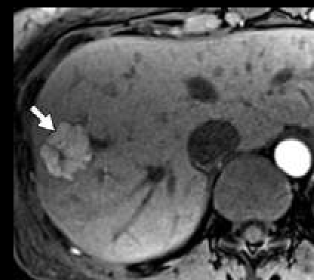


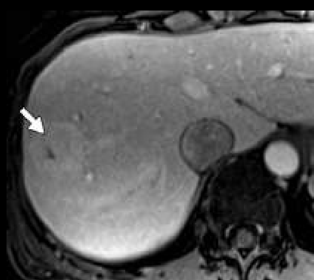


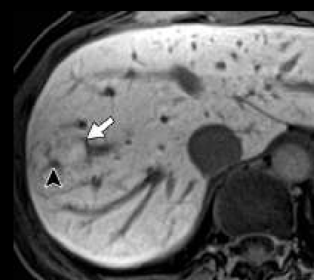



MRI w/ Eovist









Hepatic Adenoma

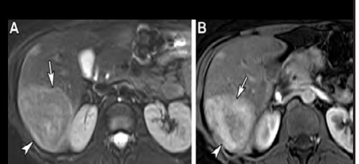
- 3rd most common benign tumor
- Composed of benign hepatocytes
- Almost always in women
  - OCP use
  - Anabolic steroids, ovarian tumors
- Multiple associated with Glycogen Storage Diseases
  - Type 1, von Gierke's
- Rich in glycogen, can have central fat and/or capsule
- Can have malignant transformation, can rupture
  - Stop OCP's, symptomatic excised, followed imaging/AFP

Inflammatory HA

- Most common subtype (40-50%)
- Occur in young women on oral contraceptives and obese women
  - 10% estimated likelihood of malignant degeneration to HCC

Inflammatory HA

- MRI
  - No excessive fat or lipid within masses
  - persistent hypervascularity through arterial and venous phases due to sinusoidal dilation, peliotic areas, and abnormal vessels
  - Mildly bright on T2WI
  - Atoll sign: T2 hyperintense rim
  - Likely to show MR (and clinical) evidence of hemorrhage (up to 30%)



Katabathina VS. Published Online: July 01, 2022
https://doi.org/10.1148/rg.210206

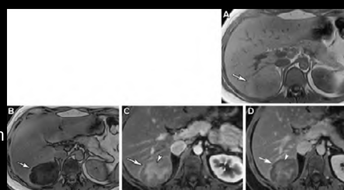
RadioGraphics

Hepatic Nuclear Factor 1 a-mutated HA

- 2nd most common subtype (30-35% of HAs)
- Association with diabetes and familial hepatic adenomatosis
- Exclusively in women; 90% have history of oral contraceptive use
- Mutated *HNF1A* gene promotes lipogenesis and hepatocellular proliferation
- Least aggressive subtype
  - HAs of this subtype < 5 cm rarely bleed and have minimal risk of HCC

Hepatic Nuclear Factor 1 a-mutated HA

- MR: Diffuse lipid deposition within HAs
  - Most evident as signal dropout on opposed-phase GRE T1WI
  - Macroscopic fat deposits are less common
  - Only moderate enhancement on arterial phase; no persistent enhancement on venous and delayed



Katabathina VS. Published Online: July 01, 2022
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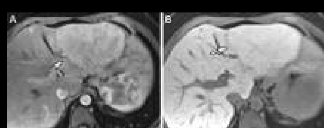
RadioGraphics

Beta Catenin 1-mutated HA

- Least common subtype (10-15% of HAs)
- Subtype most likely to occur in men, those taking androgenic steroids, and in patients with glycogen storage disease
  - Also associated with metabolic syndrome
- Mutation of *CTNNB1* disrupts hepatocyte proliferation, growth, adhesion, etc.
- This subtype carries highest risk of malignant transformation (> 10%)

Beta Catenin 1-mutated HA

- MR features: No distinctive pattern established
  - Usually hypervascular with evidence of hemorrhage or necrosis within tumor
  - Can retain Eovist on the Hepatobiliary Phase (can mimic FNH)



Katabathina VS. Published Online: July 01, 2022
https://doi.org/10.1148/rg.210206

RadioGraphics

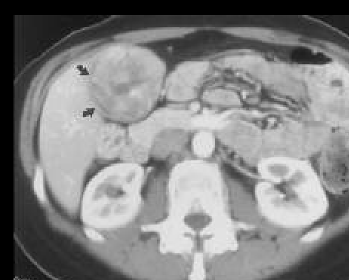
Beta Catenin-mutated HA

Figure 3a. Single adenoma in a 49-year-old woman.

Grazioli L et al. Radiographics 2001;21:877-892

RadioGraphics

Figure 3b. Single adenoma in a 49-year-old woman.



Grazioli L et al. Radiographics 2001;21:877-892

RadioGraphics

Figure 9a. Multiple hepatic adenomas in a 50-year-old woman.

Grazioli L et al. Radiographics 2001;21:877-892

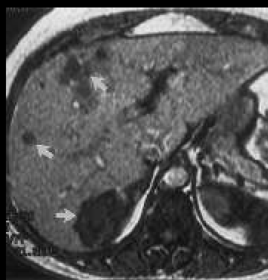
RadioGraphics

Figure 9b. Multiple hepatic adenomas in a 50-year-old woman.

Grazioli L et al. Radiographics 2001;21:877-892

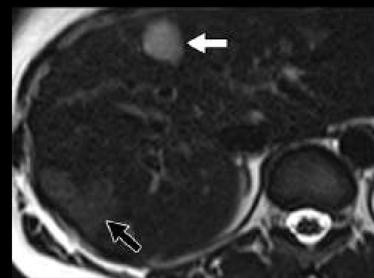
RadioGraphics

Figure 9c. Multiple hepatic adenomas in a 50-year-old woman.



Grazioli L et al. Radiographics 2001;21:877-892

—45-year-old woman with incidentally found liver lesion on ultrasound.



Purysko A S et al. AJR 2012;198:115-123

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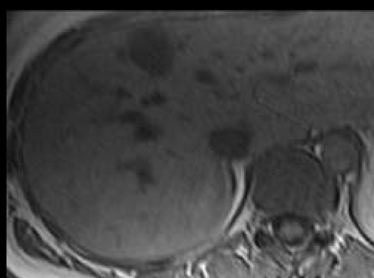

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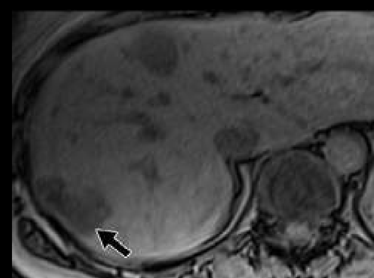

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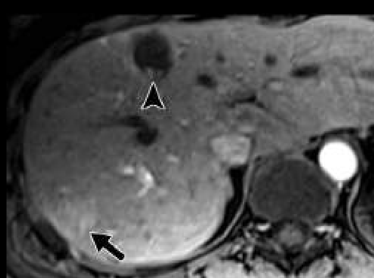

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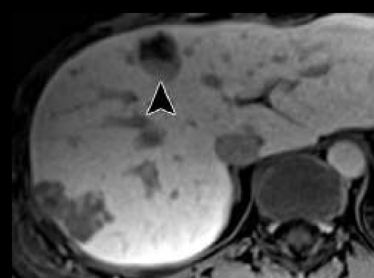

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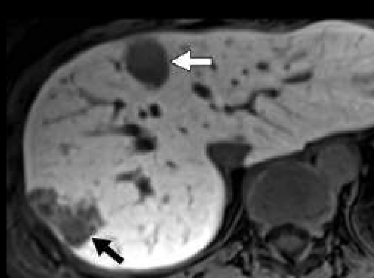


Purysko A S et al. AJR 2012;198:115-123

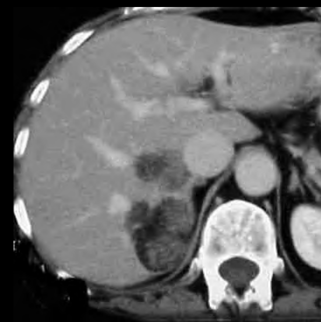
Angiomyolipoma

- Very Rare.
- Unencapsulated mesenchymal tumor composed of smooth muscle cells, thick-walled blood vessels, and mature adipose tissue
- 6% Associated with Tuberous Sclerosis
  - Especially in patients with renal AML's
- Heterogeneous appearance
  - Macroscopic fat on CT
  - No drop out of signal on Dual Echo MRI
- Variable enhancement

Figure 10a. Hepatic angiomyolipoma.

Prasad S R et al. Radiographics 2005;25:321-331

RadioGraphics



In Summary

1. Be able to describe the pertinent anatomy of the liver.
2. Understand the imaging techniques and contrast agents used in liver imaging.
3. Be able to diagnose benign lesions of the liver.

SELF EVALUATION

Benign Liver Lesions

1. Which of the following vessels will be opacified in a proper late arterial phase in liver imaging?

a. Hepatic Arteries only
b. Hepatic Arteries + Portal Vein
c. Hepatic Arteries + Portal Vein + Hepatic Veins
d. Hepatic Arteries + Hepatic Veins

2. The “central dot sign” in Caroli’s Disease is indicative of what?

a. Calculi in the bile ducts
b. Arterial aneurysms
c. Enhancing fibrovascular bundles
d. Multiple perfusion alterations in the liver

3. T/F - Hemangiomas do not follow hepatic blood pool.

4. T/F - Focal Nodular Hyperplasia is characterized by rapid fading to background liver intensity (MRI) or density (CT) on the portal venous and delayed phases when using an extracellular contrast agent.

5. The most common hepatic adenoma to transform to hepatocellular carcinoma is:

a. Inflammatory
b. Beta Catenin 1-mutated
c. Hepatic Nuclear Factor 1 a-mutated

Answer Key: 1. B, 2. C, 3. F, 4. T, 5. B

Diffuse Liver Disease and Malignant Liver Lesions

Robert M. Marks, MD

Disclosures

- Consultant Guerbet LLC

Objectives

1. Describe the imaging findings of diffuse liver disease.
2. Understand the imaging features of and the risk factors for hepatocellular carcinoma.
3. Recognize the imaging findings of common malignant neoplasms in the liver.

Overview

- Diffuse Liver Disease
  - Hepatic Steatosis
  - Iron Deposition
  - Budd-Chiari
  - Inflammatory Liver Disease
- Cirrhosis
  - LI-RADS/HCC
- Fibrolamellar Carcinoma
- Intrahepatic Cholangiocarcinoma
- Metastatic Disease
- Angiosarcoma
- Malignant Cystic Lesions

What does the liver do?

- Synthesizes proteins
  - Clotting factors, albumin, bile
- Manufactures cholesterol, triglycerides, carbs
- Stores essential vitamins and minerals
- Detoxifies the body of ammonia, drugs, and alcohol.
- Diffuse liver disease is typically caused when one of these things breaks down.

Liver Fat

- Hepatic Steatosis
  - Secondary to excess accumulation of fat vacuoles in hepatocytes
- Metabolic Associated Fatty Liver Disease (MAFLD)
  - Affects 20% of American Adults
    - 70-80% in Obese and Diabetic
  - Fat fraction does not predict hepatitis
  - In recent studies up to 20% of patients with MAFLD and HCC did not have cirrhosis!

MASH

- Metabolic Associated Steatohepatitis (MASH)
  - Can be clinically silent , but a major health concern in the U.S.
  - Occurs in 3% of American adults and 20% of obese
  - Fatty Liver + Inflammation
  - 40% will progress to fibrosis
  - 3-10% will progress to cirrhosis
  - Projected to be #1 indication for liver transplant in the near future!

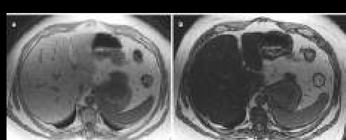
Imaging of Steatosis

- CT
  - HU < 40 high specificity of moderate to severe steatosis
- MRI
  - Drop out of signal on out-of-phase imaging MRI
    - When fat and water a present in the same voxel, their net signal intensity is additive in in-phase, and subtractive in out-phase, thus there will be a loss of signal in the out-phase compared to in-phase.
    - Macroscopic fat will not drop as it is in theory 100% fat

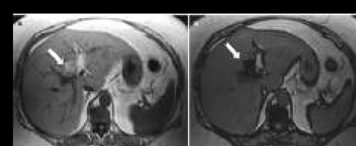
Patterns of Steatosis

- Diffuse
- Focal
- Focal Fatty Sparing (Gallbladder, Falciform lig)
- Multifocal

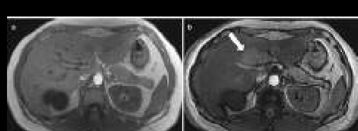
Diffuse



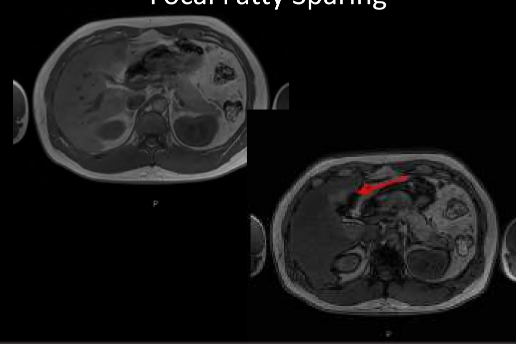
Focal Fat



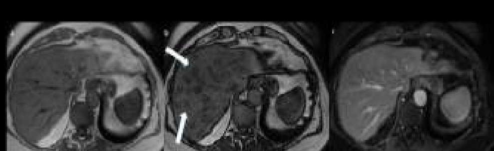
Focal Fatty Sparing



Focal Fatty Sparing



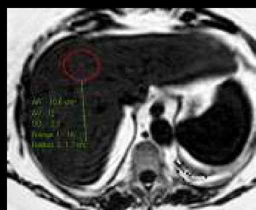
Multi-Focal Steatosis



Proton Density Fat Fraction

- Fat quantification, based on the principles of chemical shift imaging
- Corrects for cofounders like iron, T1 weighting, and noise
- Validated against histology and spectroscopy
- Using ROI's on PDFF maps, the percent fat within ROI can be reported with high accuracy.

PDFF



Iron Deposition

- Hemochromatosis
  - Adult onset, 1.8:1 m>f
  - Prevalence 1/300-500
  - Autosomal Recessive
  - Mutation of the HFE gene on chromosome 6
  - Intestinal iron absorption despite overloaded stores
  - Hepatomegaly, cirrhosis, cardiomyopathy, diabetes, impotence, osteoarthritis

Iron Deposition

- Hemosiderosis
  - Acquired
    - Multiple transfusions, thalassemia and end-stage renal disease
  - Iron in reticuloendothelial system > hepatocytes
    - Less liver damage
    - Cirrhosis and HCC extremely rare

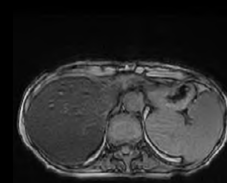
Iron Deposition

- CT
  - High attenuation liver (75-135 HU)
    - Other ddx (Amiodorone Toxicity, Wilson's Dz, Gold therapy, Thorotrast)
- MRI
  - Drop out of signal on longer TE sequence
    - If in-phase is second TE → Drop out relative to OP

Hyperdense Liver

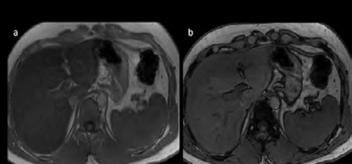
Primary Hemochromatosis

Out of Phase



In Phase

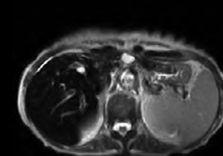
Primary Hemochromatosis



Primary Hemochromatosis

Coronal T2

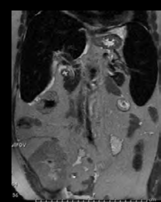
Axial T2



Hemosiderosis

T1 In-Phase

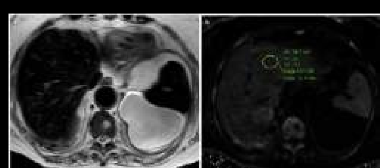
Coronal T2



Iron Quantification

- T2* is T2 with the added incorporation of effects from local magnetic field inhomogeneities
- As iron accumulates, T2* decreases
- R2* = 1/T2*
  - So as iron accumulates, R2* increases
- T2*/R2* maps are commercially available and are validated against biopsy results

Hemosiderosis T2/R2*



Co-existing Fat and Iron

- Fat and Iron may co-exist in the same liver
- If there loss of signal on out of phase compared to in phase, especially when the OP is taken at an earlier TE than IP, it is from fatty liver
  - However, if there is also iron, the later TE in-phase may lose signal to T2* effect
  - Thus, degree of drop in signal could be negligible or reversed
  - May underestimate fat
- Conversely, if there is more fat than iron
  - The drop of signal on out-phase may be greater than drop of in-phase, and iron could be underestimated

Co-existent Fat and Iron/PDFF and R2*

Budd Chiari Syndrome

- Rare
- More common in women
- Hepatic venous outflow obstruction
  - 3 Types
    - Type I: Obstruction at the level of the IVC which may involve the hepatic veins
    - Type II: Occlusion of the main hepatic veins
    - Type III: Obstruction at the level of the centrilobular veins

Budd Chiari Syndrome

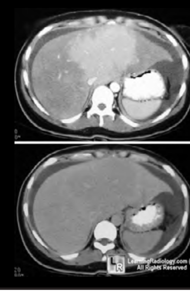
- Increased hepatic venous pressure
  - Portal hypertension/ascites
  - Hepatocyte necrosis
    - Fatty Change
  - Acute
    - Presents with rapid ascites, increased hepatic pressure, "nutmeg liver"
  - Chronic
    - Fibrosis
    - Caudate lobe enlargement
    - Regeneration
    - Cirrhosis

Budd Chiari Syndrome

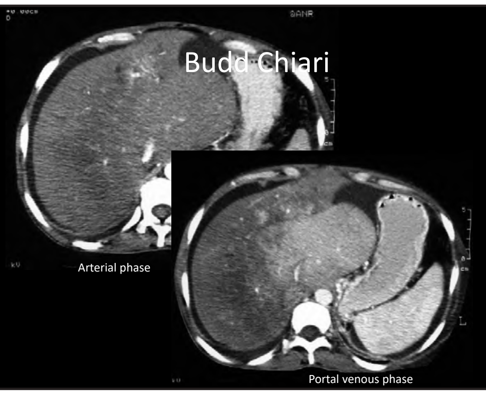
- Imaging (CT or MRI)
  - Hepatomegaly and ascites
  - Non-visualization of the occluded hepatic veins
  - Acute: "Nutmeg liver"
  - Subacute: Patchy enhancement
    - Inversion of portal blood flow
      - Inside out liver enhancement
      - Caudate lobe hyperdense early
      - Periphery is hypodense early, enhancement increases later
  - Chronic
    - Caudate lobe enlargement
      - Spared because drains directly into IVC
    - Collateral circulation through azygous and hemiazygos veins
    - Cirrhosis

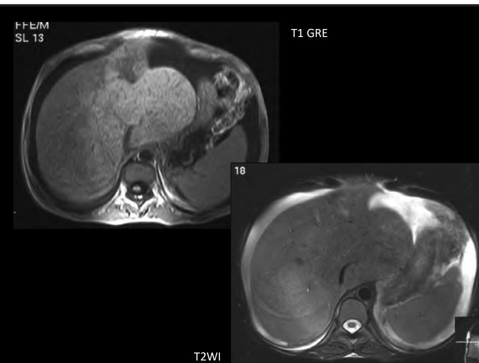
Acute Budd-Chiari: "Nutmeg Liver"

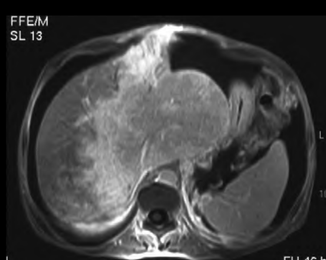
Budd Chiari



Budd Chiari

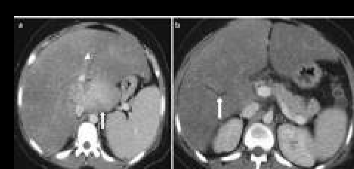






T1WI post-Gd

Chronic Budd-Chiari: Obstructed right hepatic vein, Caudate hypertrophy



Inflammatory Liver Disease

- Viral Hepatitis
  - Hep A, Hep B, Hep C, CMV, Epstein-Barr
  - HBV most common world-wide with 30% of world infected
    - Oncogenic virus, thus can cause HCC without cirrhosis
    - Causes over 5000 deaths per year in U.S. from HCC and complications of cirrhosis

Inflammatory Liver Disease

- Viral Hepatitis
  - HCV less common, world-wide
  - Most go on to cirrhosis
  - #1 leading indication for liver transplant in U.S.
    - MASH is closely behind and will overtake #1 soon
  - Since 2014, two new treatments for HCV
    - Able to cure most people without decompensated cirrhosis or history of liver transplant
  - Imaging really has no role in imaging of viral hepatitis
    - We cannot quantify inflammation…yet

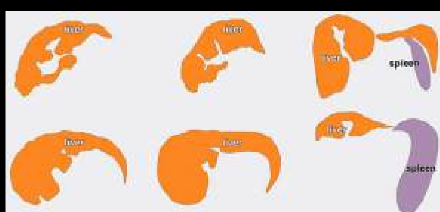
Cirrhosis

- Generalized response by the liver due to hepatocellular injury by a variety of insults.
- Liver organized as portal triads in a ring around a central vein
  - When injury occurs
    - Periportal inflammation
    - Periportal hepatocytes are damaged
    - Portal triads collapse
    - Attempted repair fibrosis starts

Cirrhosis

- Cycle
  - Inflammation/Injury
  - Fibrosis
  - Regeneration
  - Leads to altered circulation, cholestasis
  - Leads to further injury and fibrosis
- Pathologically→ extensive fibrosis with regenerative nodules

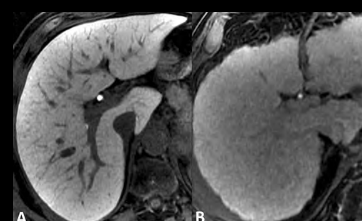
Drawings illustrate how the shape of a cirrhotic liver can be quite variable, with either segmental atrophy or hypertrophy, irregular contours, nodules, and signs of portal hypertension (splenomegaly, collateral vessels and varices, ascites).



Hussain S M et al. Radiographics 2009;29:1637-1652

RadioGraphics

Cirrhosis

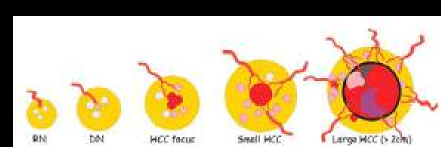


Gadoxetate Disodium–Enhanced MRI of the Liver: Part 2, Protocol Optimization and Lesion Appearance in the Cirrhotic Liver
Irene Cruite, Michael Schroeder, Elmar M. Merkle and Claude B. Sirlin
American Journal of Roentgenology 2010 195:1, 29-41

Cirrhosis

- Risk Factors
  - Hep C
  - Hep B
  - Alcohol
  - NASH
  - Hemochromatosis
  - Biliary Disease/Obstruction
  - Drugs
  - Hereditary Diseases (Wilson, alpha-1 antitrypsin, Type IV glycogen storage disease)

Drawing illustrates the concept of stepwise carcinogenesis of HCC in cirrhosis.

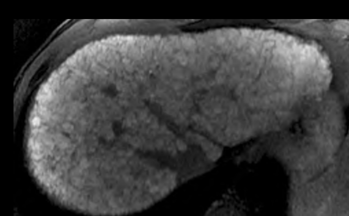


Hussain S M et al. Radiographics 2009;29:1637-1652

RadioGraphics

Regenerative Nodules

- Focal hepatocellular proliferations in response to fibrosis/insult
- Nodular contour of liver
- Major Blood Supply from Portal Vein
  - So they appear similar in density/intensity to the remainder of the liver
  - Isodense on CT and on T1/T2 MRI
  - Nodules can be bright on Hepatobiliary Phase with Eovist
    - Benign Nodules of Cirrhosis



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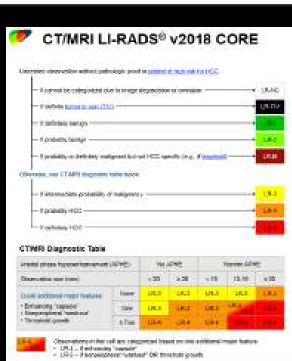
Dysplastic Nodules

- Develop from regenerative nodules
- Present in 15-25% of cirrhotic livers
- Contain atypical hepatocytes but are not malignant on histology

HCC

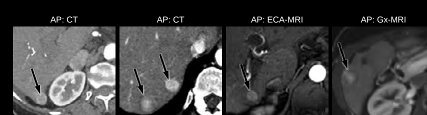
- Malignant hepatocytes
- 2[ND] leading cause of cancer-related death worldwide
- Fastest growing cause of cancer death in the US
  - MASH/MASH cirrhosis now #1 cause of liver transplant with hepatocellular carcinoma
  - Alcohol #1 without HCC
- Strong association with chronic liver disease
  - Cirrhosis
  - Hep B
  - Hep C
  - Hemochromotosis
  - Non-alcoholic Steatohepatitis



CT/MRI LI-RADS v2018

Non-Rim Arterial Phase Hyper-Enhancement (APHE)

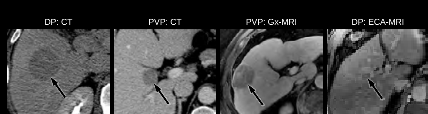
- Enhancement in arterial phase that is unequivocally greater in whole or in part than liver, **NOT** most pronounced in periphery of observation.
- May be diffuse and homogeneous, diffuse and heterogeneous, scattered, nodule-in-nodule, or mosaic.



CT/MRI LI-RADS v2018

Nonperipheral "Washout"

- Reduction in enhancement from the earlier to the later phase, **not** most pronounced in the periphery of the observation
- As a result: hypoenhancement relative to composite liver tissue:
  - For ECA: hypoenhancement in PVP, DP, or both
  - For Eovist: hypoenhancement in PVP **only**. Hypointensity in TP or HBP does not qualify as "washout".



CT/MRI LI-RADS v2018

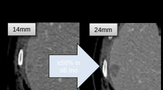
Enhancing "Capsule"

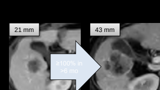
- Smooth, uniform, sharp border around most or all of an observation, unequivocally thicker or more conspicuous than fibrotic tissue around background nodules
- Visible as enhancing rim in PVP, DP or TP

CT/MRI LI-RADS v2018

Threshold Growth

- Size increase of a mass by:
  - ≥ 50% increase in size in ≤ 6 months





Ancillary Features

CT/MRI LI-RADS v2018

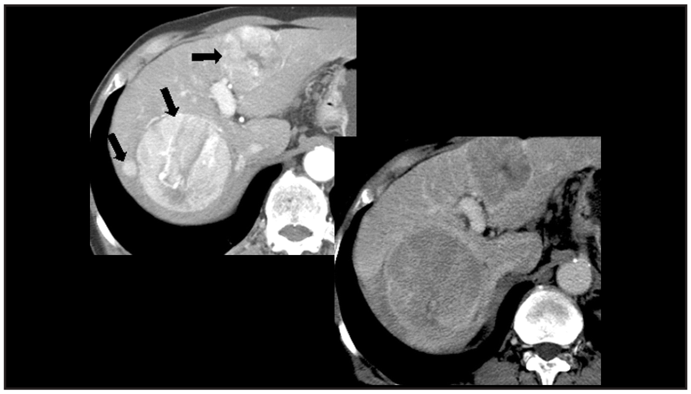
Malignant

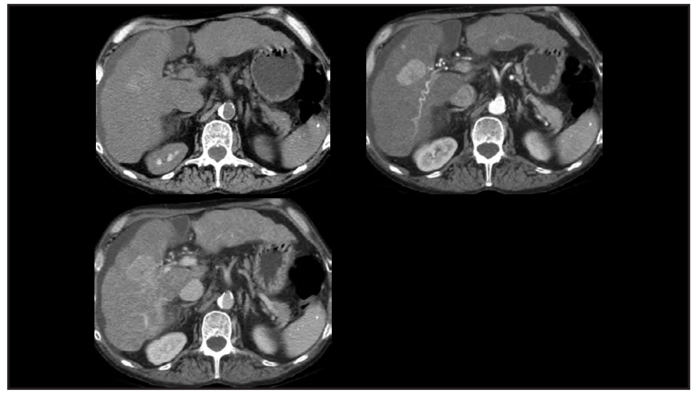
- US visibility as discrete nodule
- Subthreshold growth
- Restricted diffusion
- Mild-moderate T2 hyperintensity
- Corona enhancement
- Fat sparing in solid mass
- Iron sparing in solid mass
- Transitional phase hypointensity
- Hepatobiliary phase hypointensity

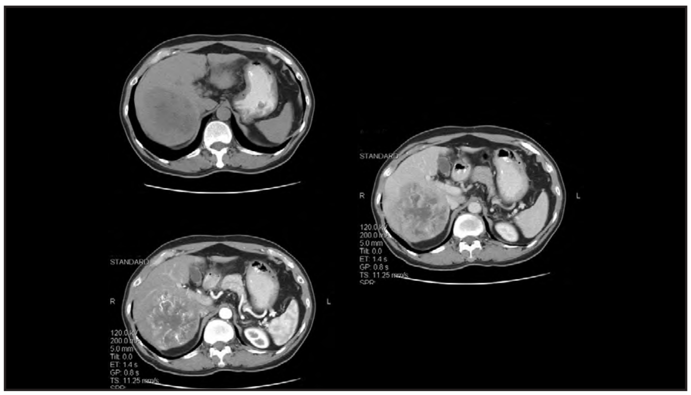
- Nonenhancing "capsule"
- Nodule-in-nodule
- Mosaic architecture
- Blood products in mass
- Fat in mass, more than adj liver

Benign

- Size stability ≥ 2 years
- Size reduction
- Parallels blood pool
- Undistorted vessels
- Iron in mass, more than liver
- Marked T2 hyperintensity
- Hepatobiliary phase isointensity



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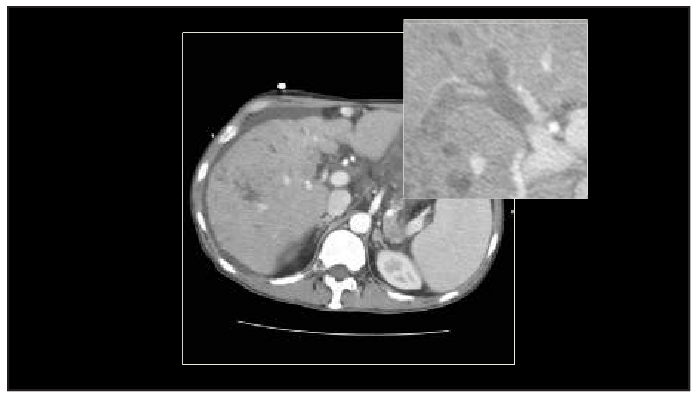


—65-year-old man with chronic hepatitis and solitary hepatocellular carcinoma (HCC) measuring 35 mm in diameter.
Goshima S et al. AJR 2009;192:686-692
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—65-year-old man with chronic hepatitis and solitary hepatocellular carcinoma (HCC) measuring 35 mm in diameter.
Goshima S et al. AJR 2009;192:686-692
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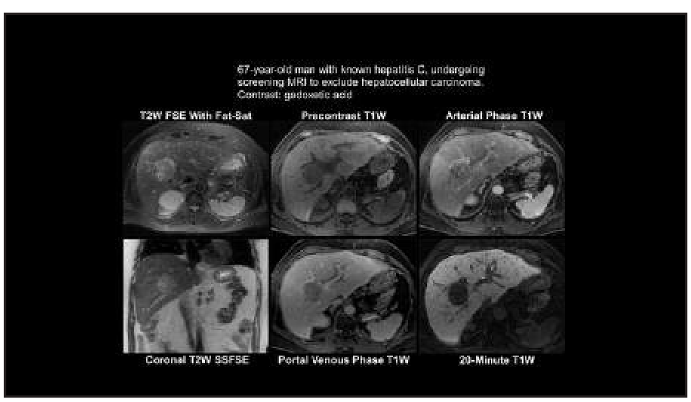
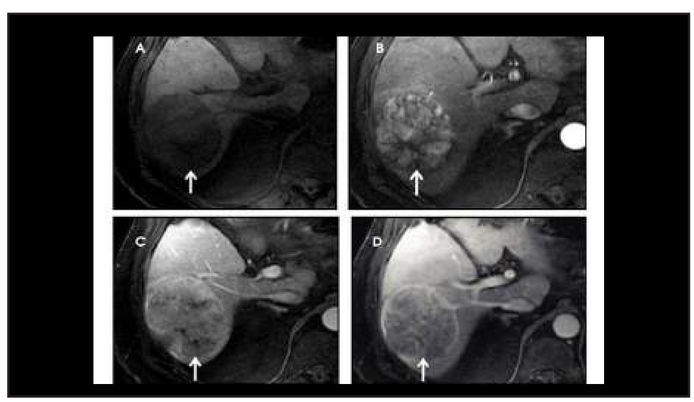

67-year-old man with known hepatitis C, undergoing screening MRI to exclude hepatocellular carcinoma.
Contrast: gadoxetic acid
T2W FSE With Fat-Sat
Precontrast T1W
Arterial Phase T1W
Coronal T2W SSFSE
Portal Venous Phase T1W
20-Minute T1W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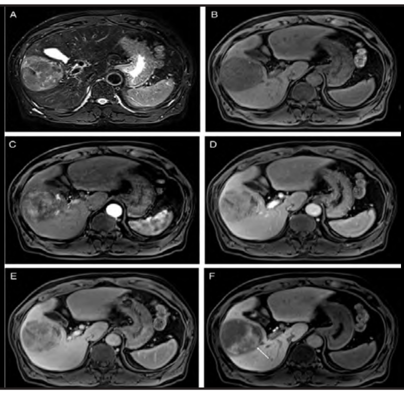


HCC Surveillance

- Sensitivity
  - MRI (85-90%) > CT(76%) > US (64%)
- Who falls into a surveillance program?
  - Cirrhosis
  - Hep B without cirrhosis
    - >40 Asian Men
    - >50 Asian Women
    - >50 Non-Asian, Non-African
    - > 20 African
  - Should we screen MAFLD????

Fibrolamellar Carcinoma

- Variant of HCC
- Young patients, mean age 23 years
  - M=F
- No cirrhosis
- AFP normal
- Central scar, radiating septa, calcs, lobulated contour

FLC - CT

- Lobulated, well-defined margins
- Heterogeneous Mass
  - Arterial phase heterogeneous enhancement
- Central Scar
  - Hypodense in all phases of enhancement
  - Calcification in 40%

Fibrolamellar HCC in a 19-year-old man.

Ichikawa T et al. Radiology 2000;217:145-151

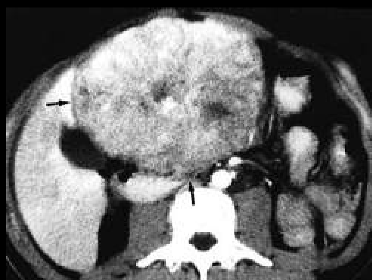
Recurrent fibrolamellar HCC in a 50-year-old woman 11 months after primary resection.

Ichikawa T et al. Radiology 2000;217:145-151

Left-lobe fibrolamellar HCC in a 19-year-old man.

Ichikawa T et al. Radiology 1999;213:352-361

Left-lobe fibrolamellar HCC in a 19-year-old man.



Ichikawa T et al. Radiology 1999;213:352-361

Left-lobe fibrolamellar HCC in a 19-year-old man.

Ichikawa T et al. Radiology 1999;213:352-361

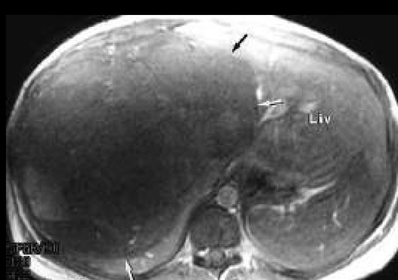
FLC - MRI

- "Central Scar Dark on T2"
  - Actually dark on all pre-contrast sequences
  - Does not enhance
- Heterogeneous enhancement
- Will be a hypointense defect on hepatobiliary phase of imaging with Eovist

Large fibrolamellar HCC mainly in the right lobe in a 25-year-old woman.

Ichikawa T et al. Radiology 1999;213:352-361

Large fibrolamellar HCC mainly in the right lobe in a 25-year-old woman.



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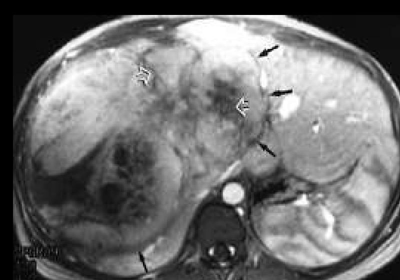
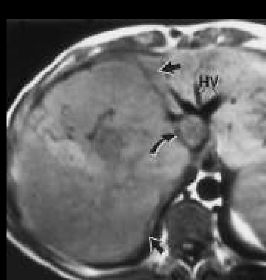
Large fibrolamellar HCC mainly in the right lobe in a 25-year-old woman.



Ichikawa T et al. Radiology 1999;213:352-361

Fibrolamellar HCC in a 28-year-old man.



Ichikawa T et al. Radiology 2000;217:145-151

Fibrolamellar vs. FNH

Fibrolamellar Carcinoma

- Heterogeneous Enhancement
- Nonenhancing scar
- Dark T2 scar
- Lymphadenopathy
- Eovist Defect on HB phase

Focal Nodular Hyperplasia

- Homogeneous Enhancement
- Delayed Enhancing Scar
- Scar T2 bright
- No lymphadenopathy
- Takes up Eovist on HB phase

Intrahepatic Cholangiocarcinoma

- Adenocarcinoma arising from the intrahepatic bile ducts
- 10% of bile duct adenocarcinomas
- 10X more common in Japan than US
- Biphenotypic tumors are part iCCA and part HCC…treatment is not standard treatment for HCC (LR-M).

Etiologic Associations

- Chronic Cholestatic Disease
  - Primary Sclerosing Cholangitis
  - Primary Biliary Cirrhosis
  - Caroli disease/Fibrosis
  - Chronic Biliary Inflammation
  - Recurrent Pyogenic Cholangitis
  - Parasitic Infection
- Hepatitis B and C
- Alcohol abuse
- Radiation

Intrahepatic Cholangiocarcinoma CT/MRI

- Irregular borders
  - Infiltrative
- Delayed peripheral to central enhancement
  - Due to fibrosis/hypovascularity
- Biliary dilatation peripheral to the tumor
- Capsular retraction
  - Due to fibrosis of the tumor
- Vascular Invasion

Figure 2a. Peripheral cholangiocarcinoma.

Han J K et al. Radiographics 2002;22:173-187

RadioGraphics

Figure 2b. Peripheral cholangiocarcinoma.

Han J K et al. Radiographics 2002;22:173-187

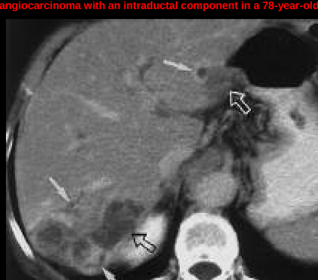
RadioGraphics

Figure 3a. Intraductal intrahepatic cholangiocarcinoma in a 53-year-old man.

Han J K et al. Radiographics 2002;22:173-187

RadioGraphics

Figure 4a. Intraductal intrahepatic cholangiocarcinoma and mass-forming cholangiocarcinoma with an intraductal component in a 78-year-old man.



Han J K et al. Radiographics 2002;22:173-187

RadioGraphics

Figure 7a. Exophytic hilar cholangiocarcinoma.

Han J K et al. Radiographics 2002;22:173-187

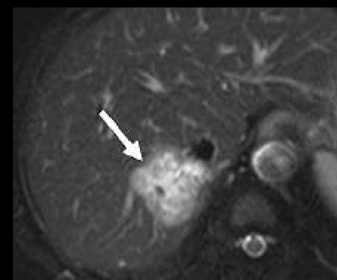
RadioGraphics

Figure 7b. Exophytic hilar cholangiocarcinoma.

Han J K et al. Radiographics 2002;22:173-187

RadioGraphics

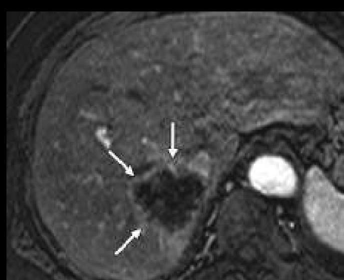
Figure 7a. Typical MR imaging features of mass-forming cholangiocarcinoma.



Chung Y E et al. Radiographics 2009;29:683-700

RadioGraphics

Figure 7b. Typical MR imaging features of mass-forming cholangiocarcinoma.



Chung Y E et al. Radiographics 2009;29:683-700

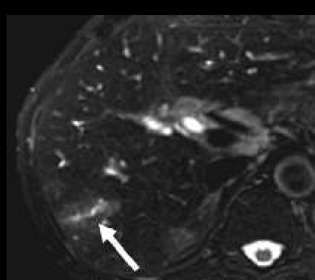
RadioGraphics

Figure 7c. Typical MR imaging features of mass-forming cholangiocarcinoma.

Chung Y E et al. Radiographics 2009;29:683-700

RadioGraphics

Figure 9a. Periductal infiltrating cholangiocarcinoma.



Chung Y E et al. Radiographics 2009;29:683-700

RadioGraphics

Figure 9b. Periductal infiltrating cholangiocarcinoma.

Chung Y E et al. Radiographics 2009;29:683-700

RadioGraphics

Metastases

- Most common malignant tumors
- Liver is most common site for GI mets
  - Hypodense mass with rim enhancement
  - Targetoid appearance on T2/DWI/CT
    - LI-RADS M
  - Only 20% solitary at time of diagnosis
- Sensitivity better than 90% with MRI
  - Eovist increases sensitivity for mets < 1cm

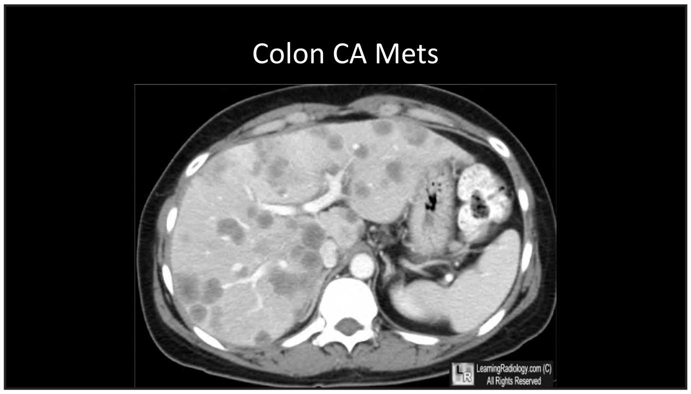
Vascularity of Liver Mets

HyPOvascular

- Adenocarcinoma
  - Colorectal
  - Pancreatic
  - GI
- Lung
- Lymphoma

HyPERvasular

- Carcinoid
- Islet Cell Ca
- Renal Cell Ca
- Thyroid
- Breast
- Melanoma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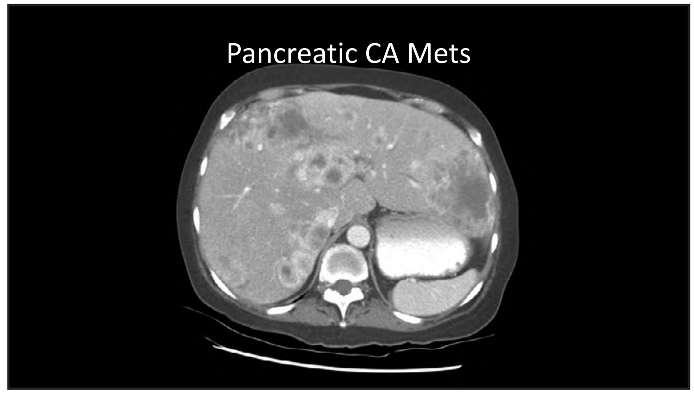
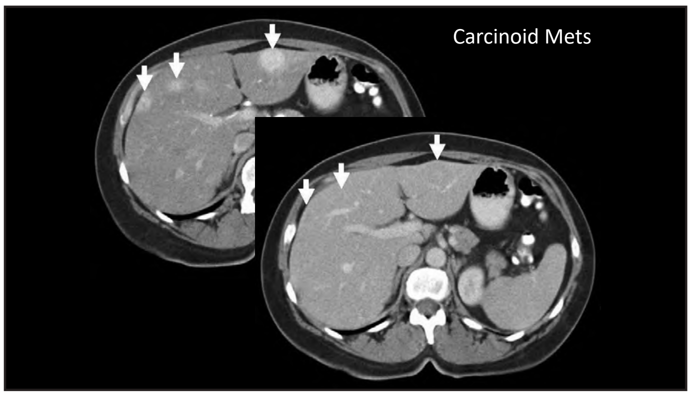
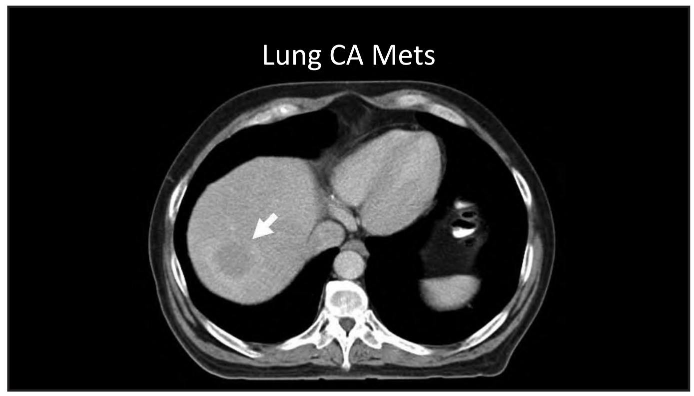
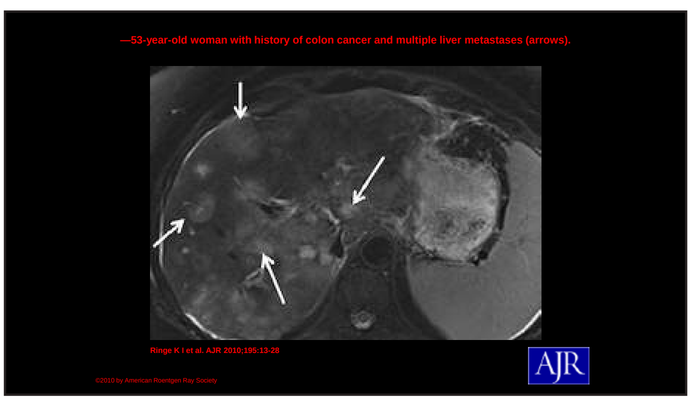

Pancreatic CA Mets


Carcinoid Mets


Lung CA Mets


—53-year-old woman with history of colon cancer and multiple liver metastases (arrows).
Ringe K I et al. AJR 2010;195:13-28
AJR
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—27-year-old woman with history of breast cancer.
Ringe K I et al. AJR 2010;195:13-28
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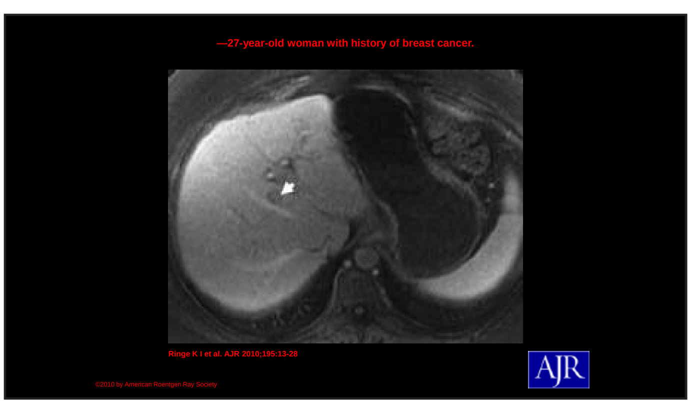
—27-year-old woman with history of breast cancer.
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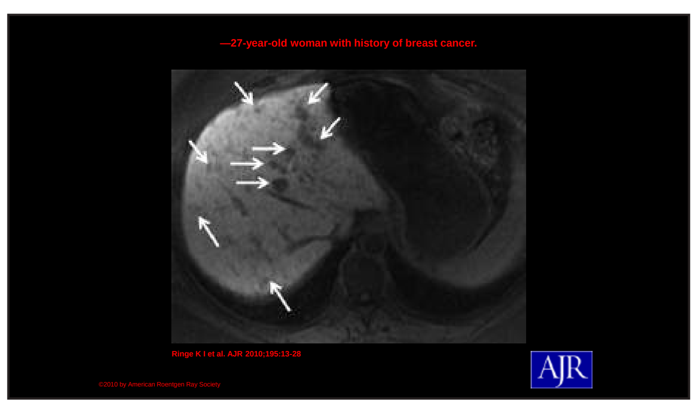
—27-year-old woman with history of breast cancer.
Ringe K I et al. AJR 2010;195:13-28
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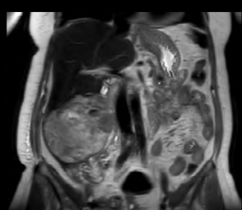
Angiosarcoma

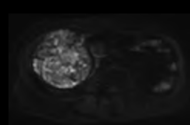
- Rare, malignant neoplasm of endothelial cells
- Most common hepatic sarcoma
- Men 3:1 to women
- Presents with hemoperitoneum, mets to spleen and lung
- Associated with vinyl chloride, arsenic, Thorotrast, radiation therapy, anabolic steroids

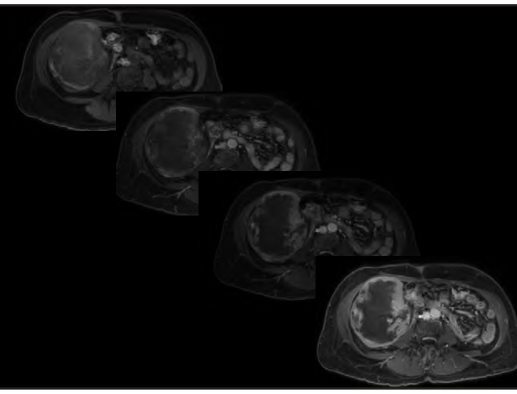
Angiosarcoma CT/MRI

- Solitary or multifocal
- Evidence of hemorrhage
- Peripheral or heterogeneous enhancement
- Mets to spleen and lung

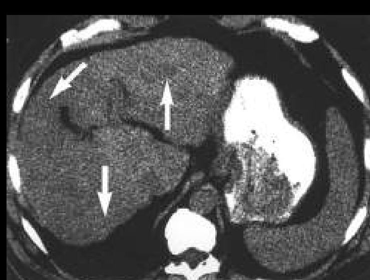
Path Proven Angiosarcoma







—63-year-old man with multifocal angiosarcoma.



Peterson M S et al. AJR 2000;175:165-170

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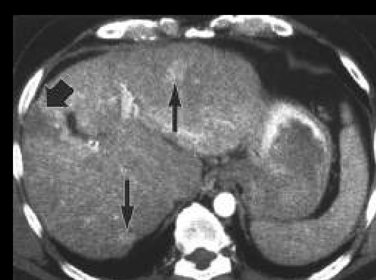
—63-year-old man with multifocal angiosarcoma.



Peterson M S et al. AJR 2000;175:165-170

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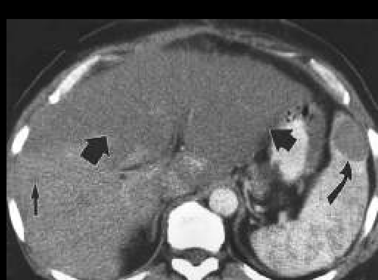
—54-year-old man with multifocal angiosarcoma.



Peterson M S et al. AJR 2000;175:165-170

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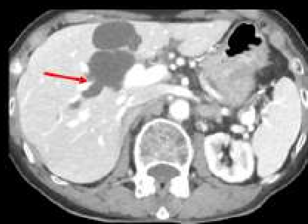
Mucinous Cystic Neoplasm Liver

- Mucinous tumor of liver
  - Malignant (only 6%)
- May have ovarian stroma
- No communication to bile duct
- Nearly exclusively in females
- Has less malignant potential than MCN pancreas

Intraductal papillary mucinous neoplasm – Biliary Duct

- Has communication with bile ducts
- More malignant potential than IPMN of pancreas (40-60%)



In Summary

1. Describe the imaging findings of diffuse liver disease.
2. Understand the imaging features of and the risk factors for hepatocellular carcinoma.
3. Recognize the imaging findings of common malignant neoplasms in the liver.

THANK YOU!

rmarks@health.ucsd.edu
Robert Marks, MD, FSAR

UC San Diego
SCHOOL OF MEDICINE
Department of Radiology

Disclosures

- Consultant Guerbet LLC

SELF EVALUATION

Diffuse Liver Disease and Malignant Liver Lesions

1. T/F - Patients with metabolic liver disease but without cirrhosis can get hepatocellular carcinoma.

2. Which of the following has a high incidence of liver cirrhosis?

a. Hemochromatosis
b. Hemosiderosis
c. Both
d. Neither

3. Which of the following is not true of fibrolamellar hepatocellular carcinoma?

a. Typically affects young patients
b. Typically affects non-cirrhotic patients
c. AFP is high
d. Central scar may have calcifications

4. T/F - Metabolic associated steatohepatitis/cirrhosis is now the #1 cause of liver transplant in patients with hepatocellular carcinoma.

5. What is true of mucinous cystic neoplasms of the liver?

a. They have connection with the bile ducts
b. They have a higher malignant rate than intraductal papillary neoplasm biliary
c. They are more common in men
d. They commonly have ovarian stroma

Answer Key: 1. T, 2. A, 3. C, 4. T, 5. D

Paul M. Bunch, MD

Paul M. Bunch, MD is Director of Head and Neck Imaging and an Associate Professor of Radiology at the Wake Forest University School of Medicine in Winston-Salem, NC.

Dr. Bunch earned his medical degree from the University of Virginia School of Medicine in Charlottesville and recently received a Master of Science in Translational and Health System Science from Wake Forest University. He completed his radiology residency at Brigham and Women's Hospital and a neuroradiology fellowship at Massachusetts General Hospital, both in Boston.

Dr. Bunch's primary clinical and research interests relate to head and neck imaging, including primary hyperparathyroidism, head and neck cancer, and head and neck anatomy. He has received multiple teaching awards and frequently gives invited lectures on head and neck topics at national meetings.

Dr. Bunch is co-editor of a recently published neuroradiology textbook and holds positions on multiple journal editorial boards, including Assistant Editor of Neuroradiology for *RadioGraphics*. He also actively serves within the American College of Radiology, the American Society of Neuroradiology, and the American Society of Head and Neck Radiology.

You may contact Dr. Bunch with your questions and comments at paul.m.bunch@gmail.com.

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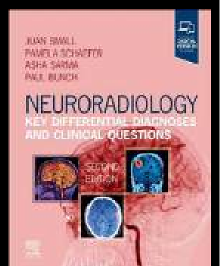
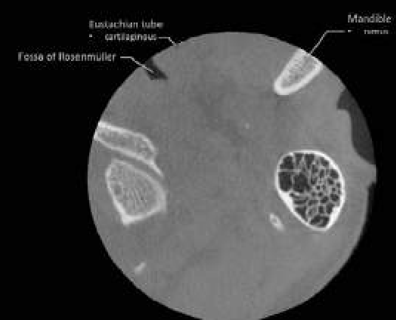
Winston-Salem, NC 27157

Temporal Bone CT: Anatomy and Pathology

Disclosures

- Financial relationships:
  - Medical advisor, Guerbet
  - Author royalties, Elsevier
  - Research funding, GE HealthCare

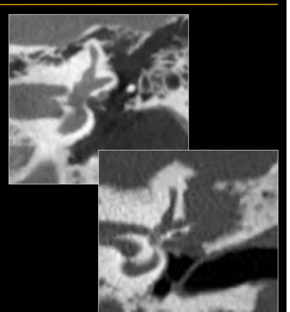




bit.ly/tboneCT

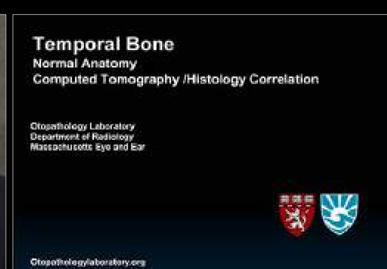
Objectives

- Key temporal bone anatomy CT slices
  - 5 axial
  - 5 coronal
- Relevant pathology

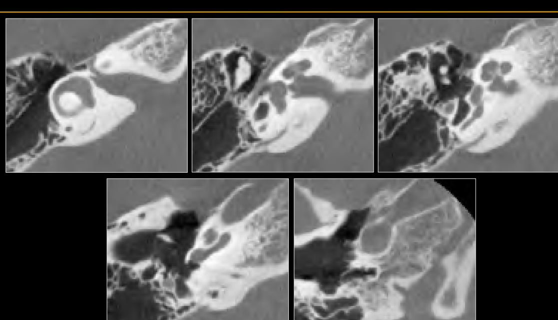


Acknowledgement

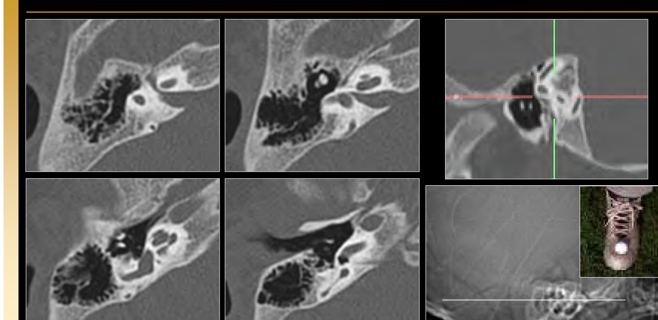
Hugh D. Curtin, MD

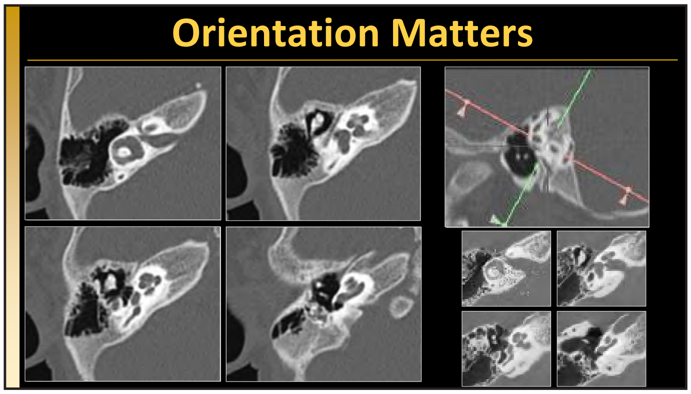


Axial



Orientation Matters

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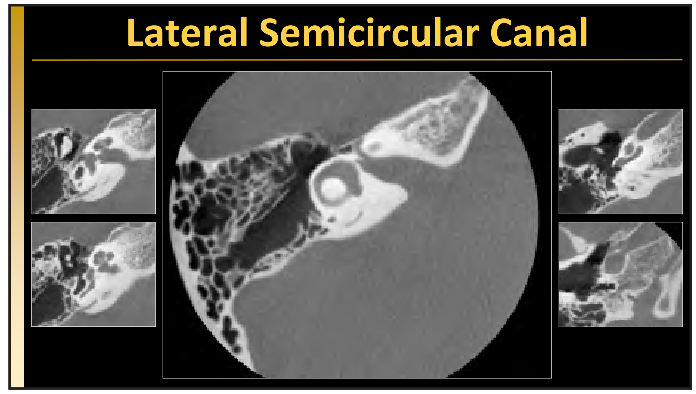
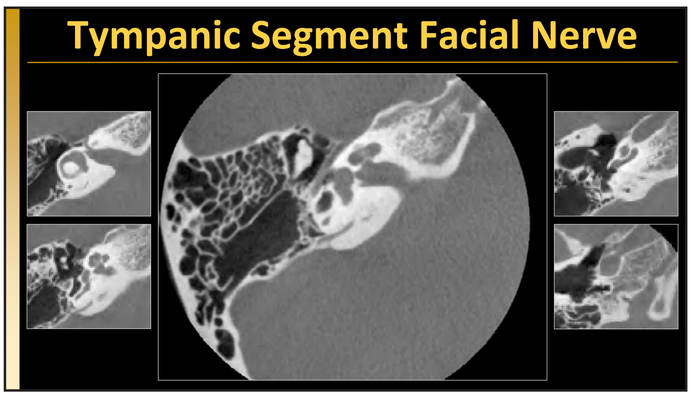
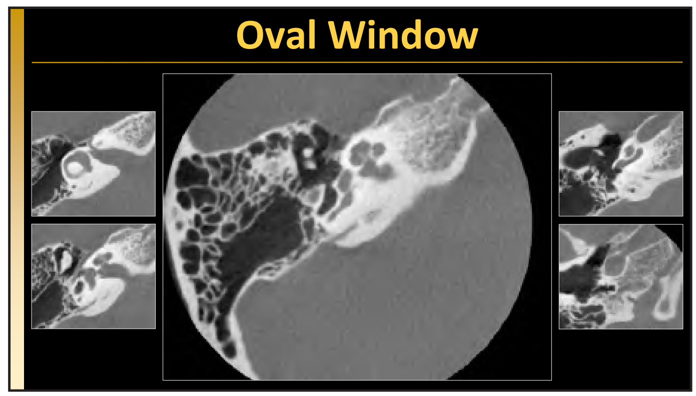
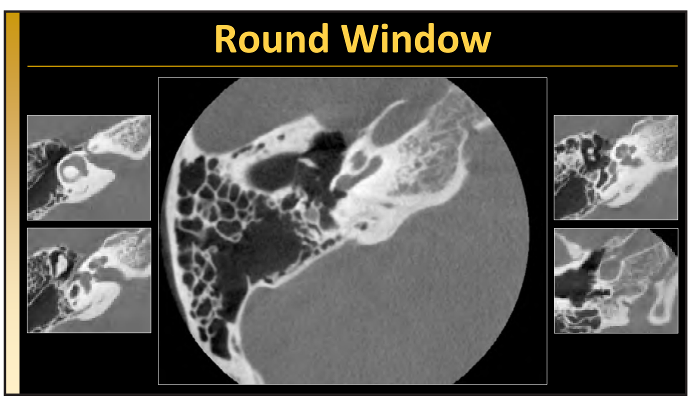
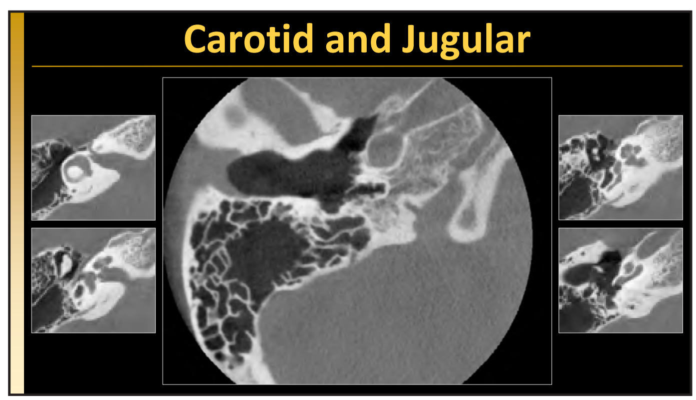
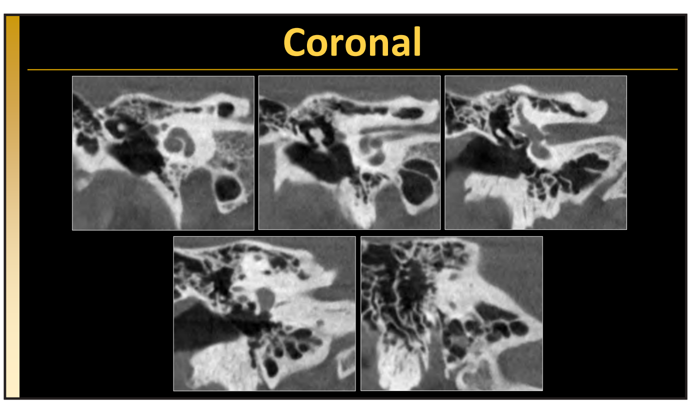

Lateral Semicircular Canal

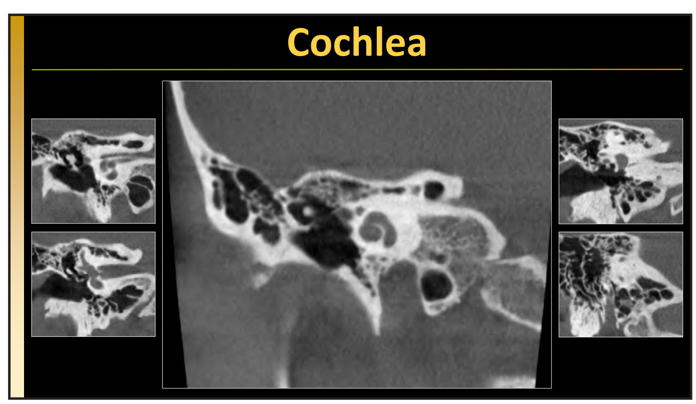

Tympanic Segment Facial Nerve

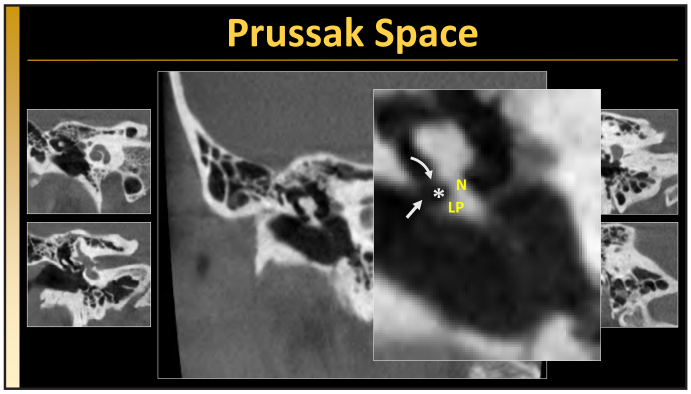

Oval Window

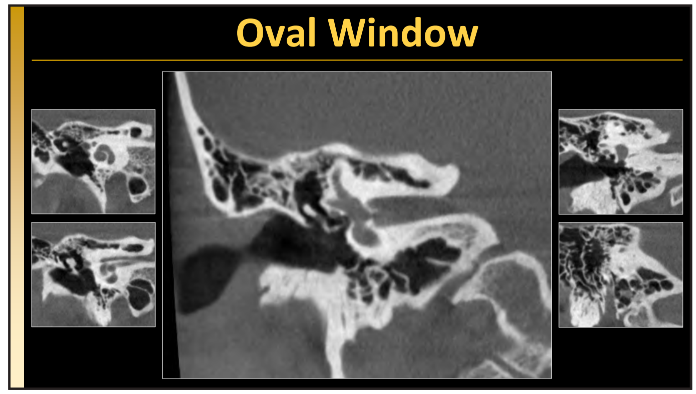

Round Window


Carotid and Jugular


Coronal


Cochlea


Prussak Space
N
LP
*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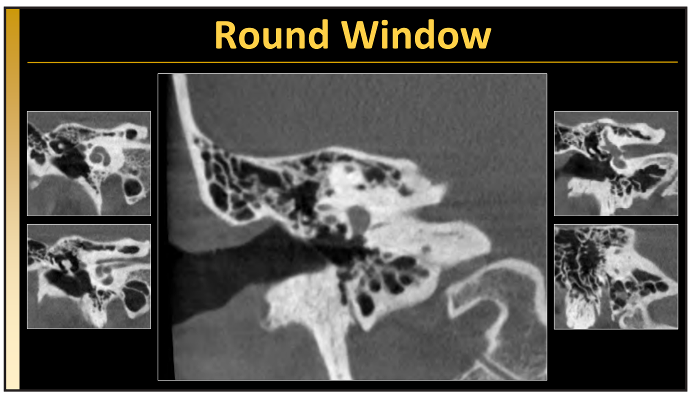
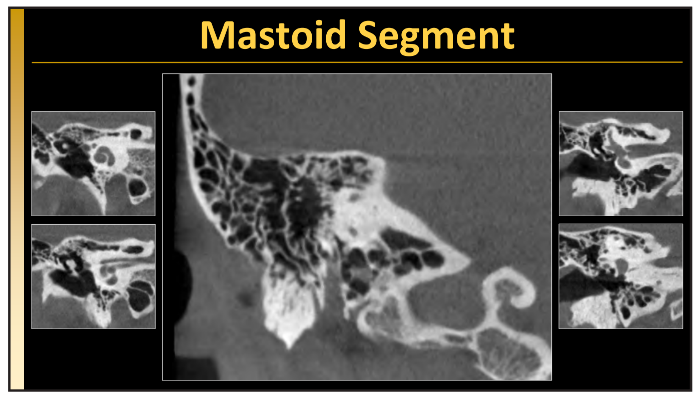
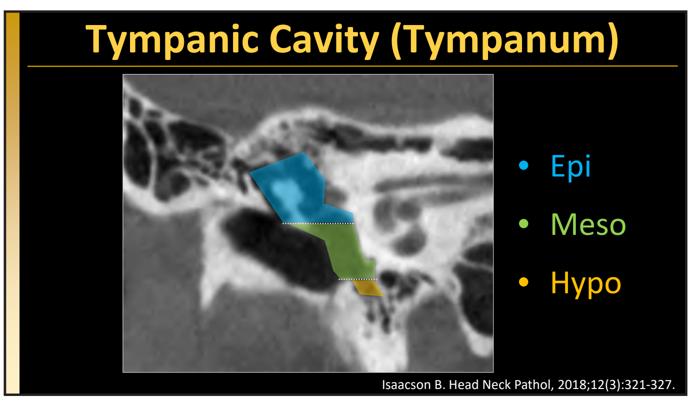
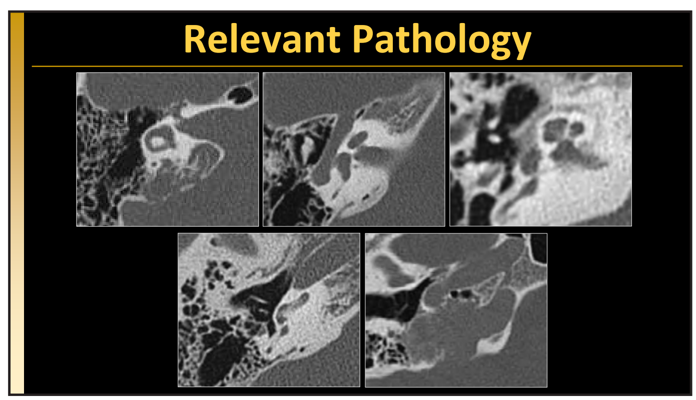
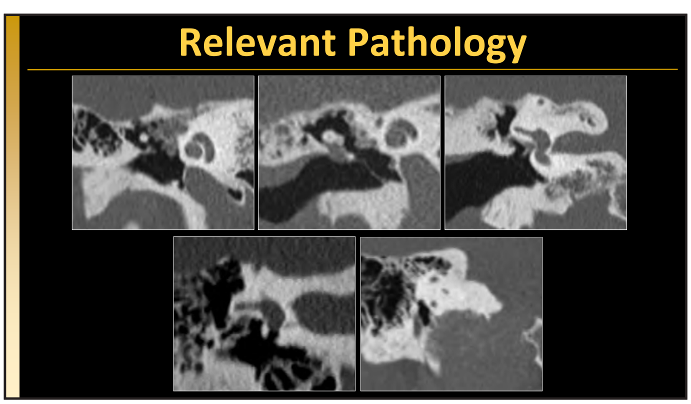

Round Window

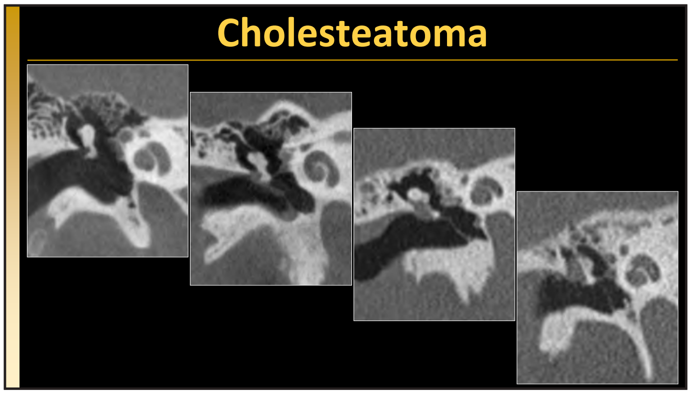

Mastoid Segment

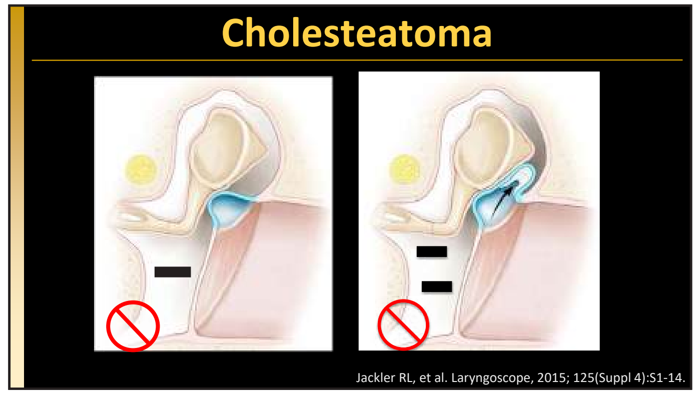

Tympanic Cavity (Tympanum)
Epi
Meso
Hypo
Isaacson B. Head Neck Pathol, 2018;12(3):321-327.

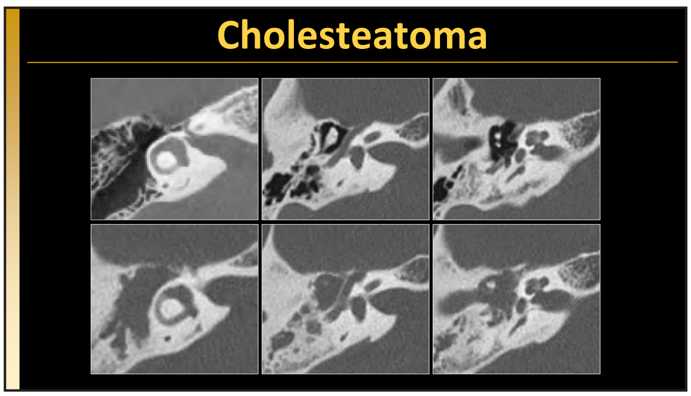

Relevant Pathology


Relevant Pathology


Case #1


Cholesteatoma


Cholesteatoma
Jackler RL, et al. Laryngoscope, 2015; 125(Suppl 4):S1-14.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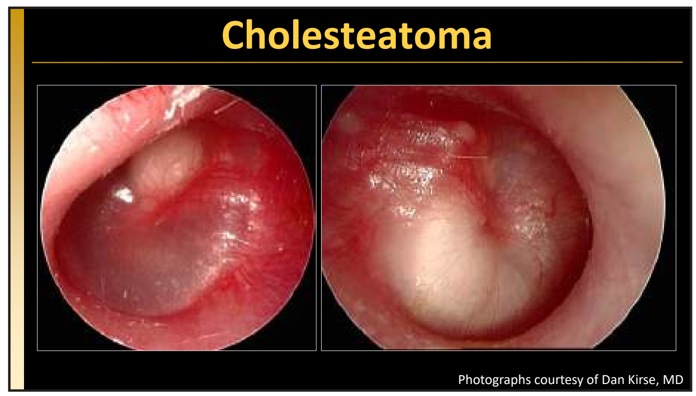
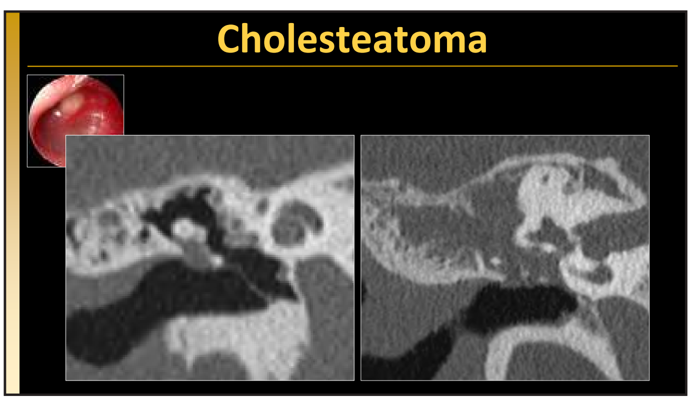
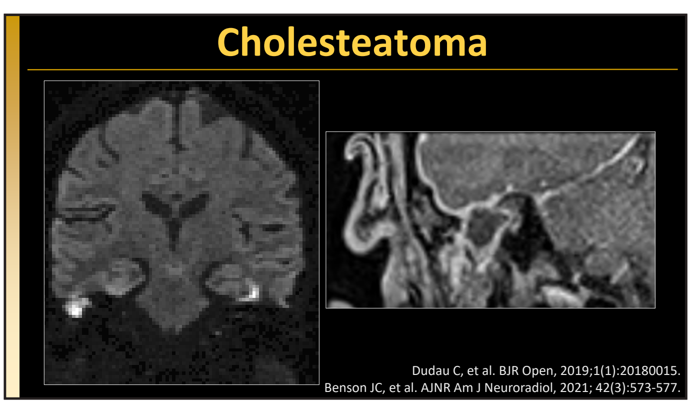

Cholesteatoma
Photographs courtesy of Dan Kirse, MD


Cholesteatoma


Cholesteatoma


Cholesteatoma
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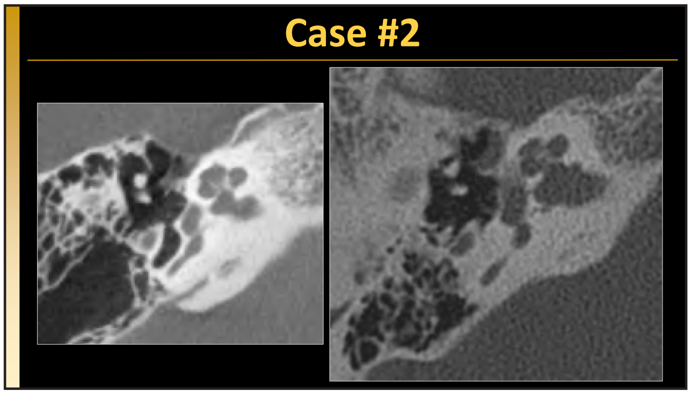
Benson JC, et al. AJNR Am J Neuroradiol, 2021; 42(3):573-577.


Cholesteatoma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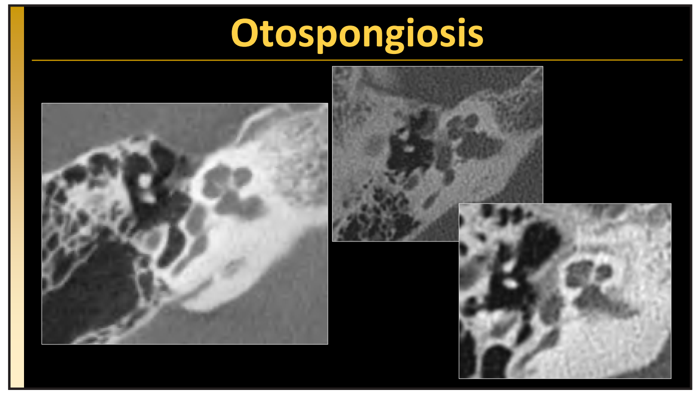
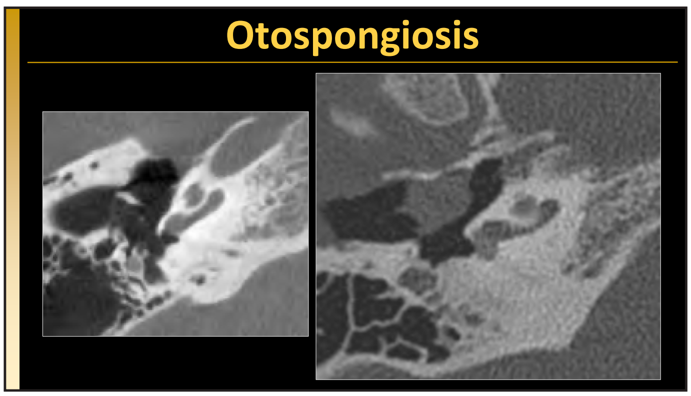
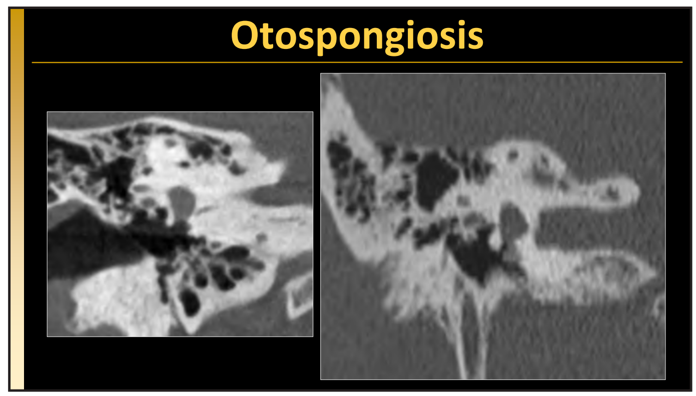

Otospongiosis


Otospongiosis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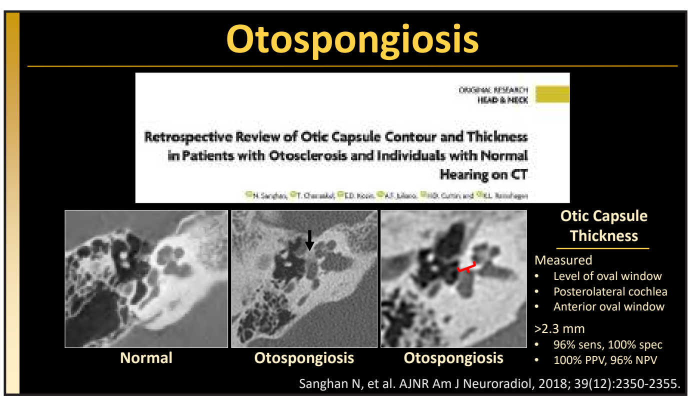
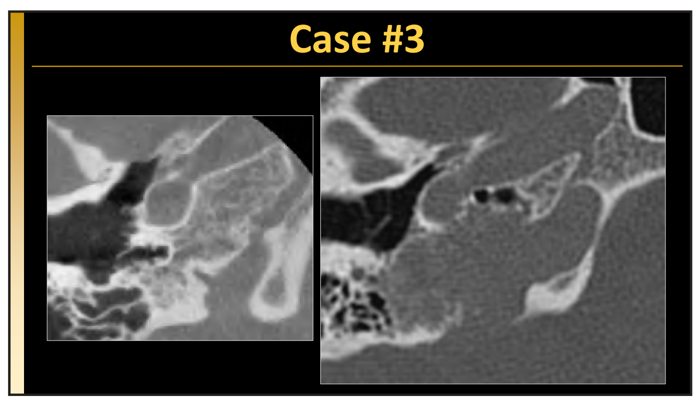
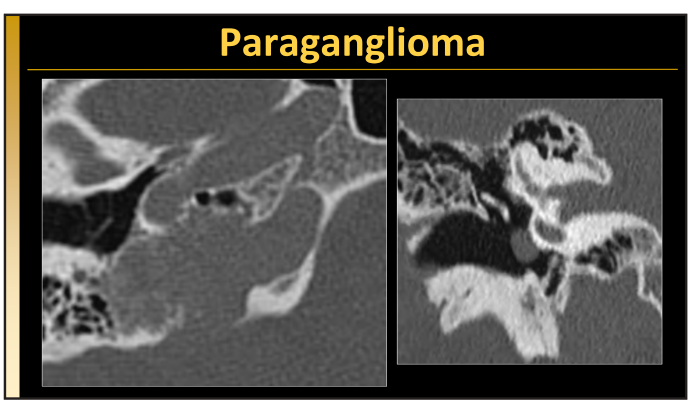
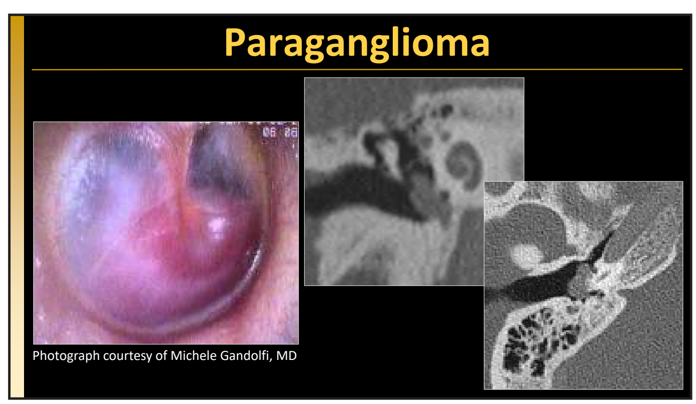
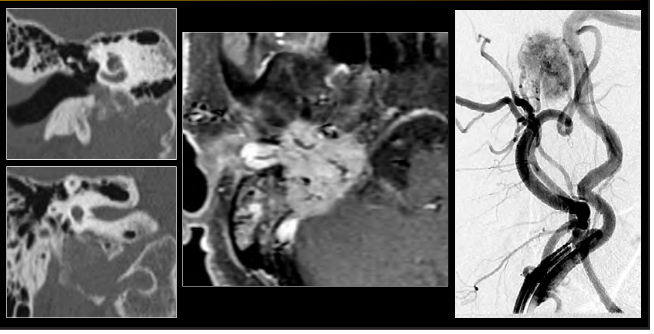

Otospongiosis
ORIGINAL RESEARCH
HEAD & NECK
Retrospective Review of Otic Capsule Contour and Thickness in Patients with Otosclerosis and Individuals with Normal Hearing on CT
Otic Capsule Thickness
Measured
• Level of oval window
• Posterolateral cochlea
• Anterior oval window
>2.3 mm
• 96% sens, 100% spec
• 100% PPV, 96% NPV
Normal
Otospongiosis
Otospongiosis
Sanghan N, et al. AJNR Am J Neuroradiol, 2018; 39(12):2350-2355.


Case #3

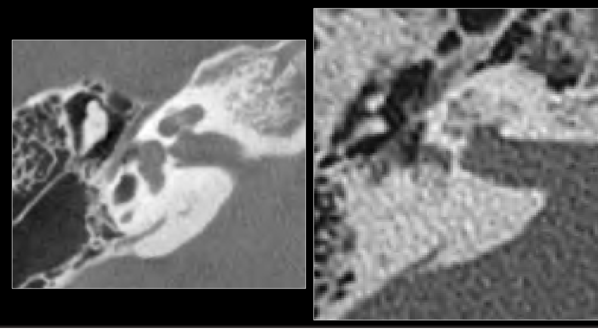

Paraganglioma


Paraganglioma
Photograph courtesy of Michele Gandolfi, MD

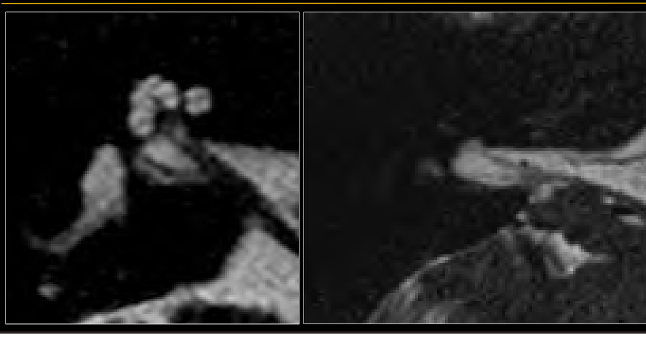
Paraganglioma



Case #4

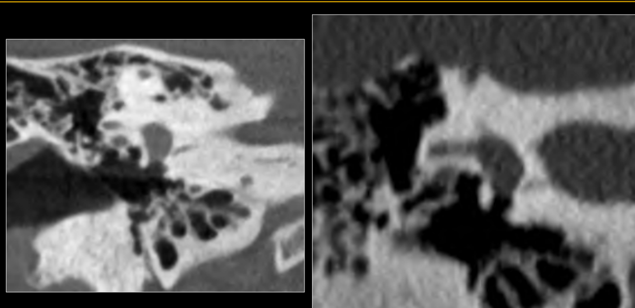


Labyrinthitis Ossificans

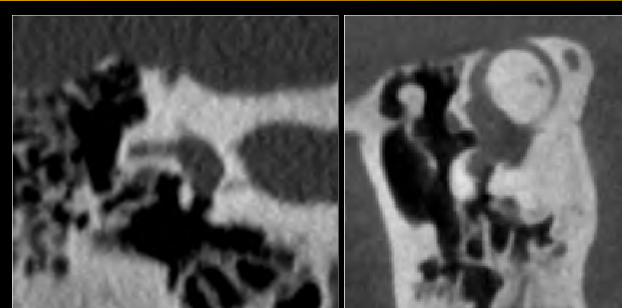


Labyrinthitis Ossificans

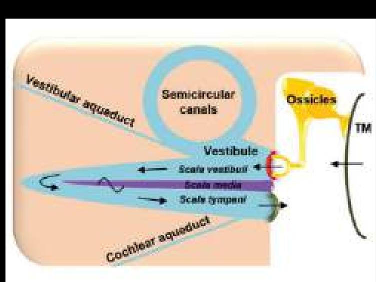
Case #5



Superior Semicircular Canal Dehiscence

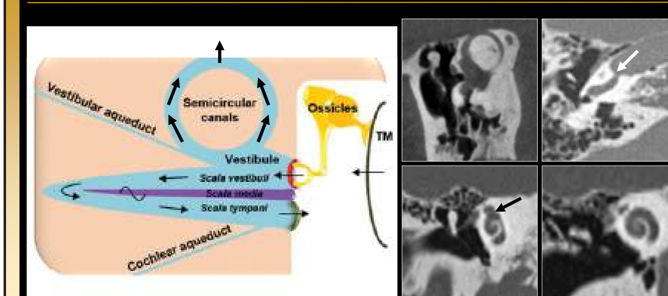


Windows ("Third" and "Single")

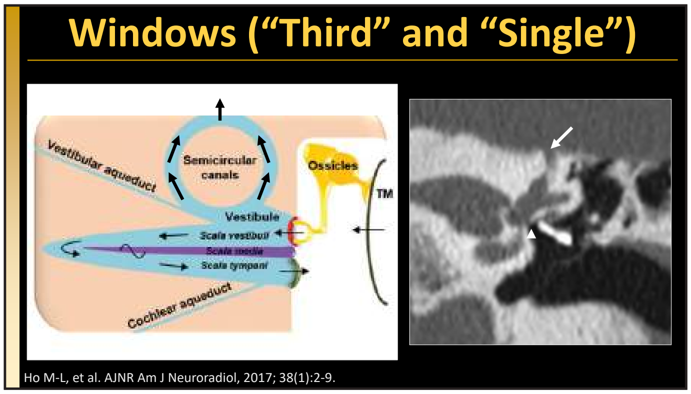


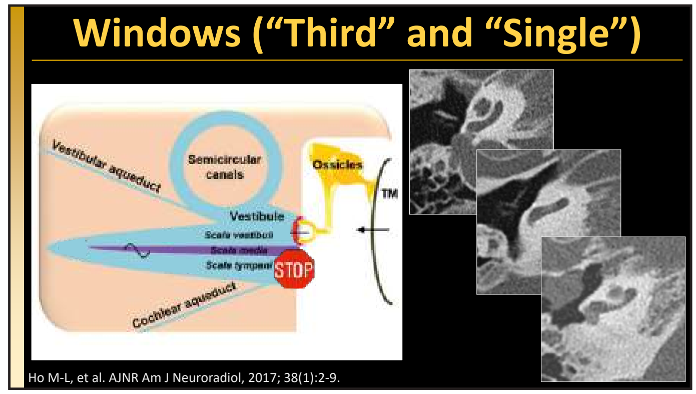
Ho M-L, et al. AJNR Am J Neuroradiol, 2017; 38(1):2-9.

Windows ("Third" and "Single")

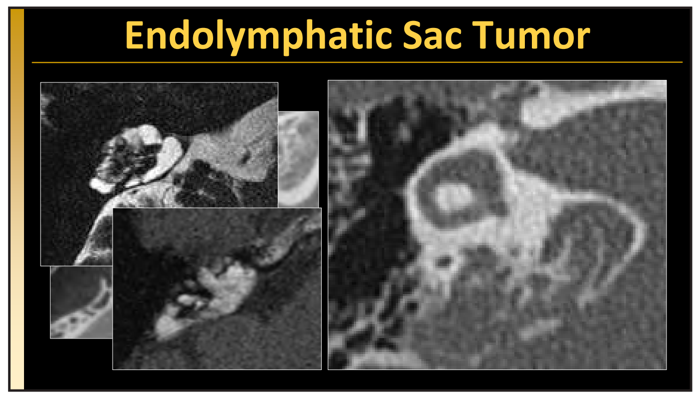


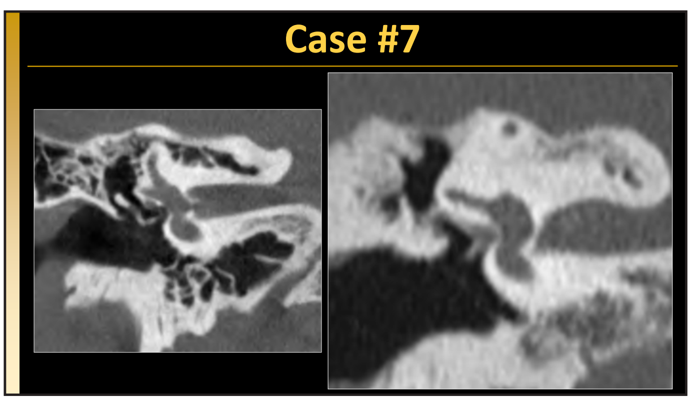
Ho M-L, et al. AJNR Am J Neuroradiol, 2017; 38(1):2-9.

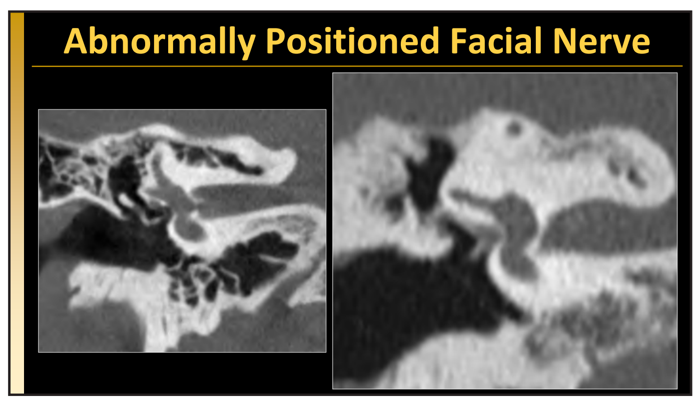

Windows ("Third" and "Single")
Vestibular aqueduct
Semicircular canals
Ossicles
TM
Vestibule
Scala vestibuli
Scala media
Scala tympani
Cochlear aqueduct
Ho M-L, et al. AJNR Am J Neuroradiol, 2017; 38(1):2-9.

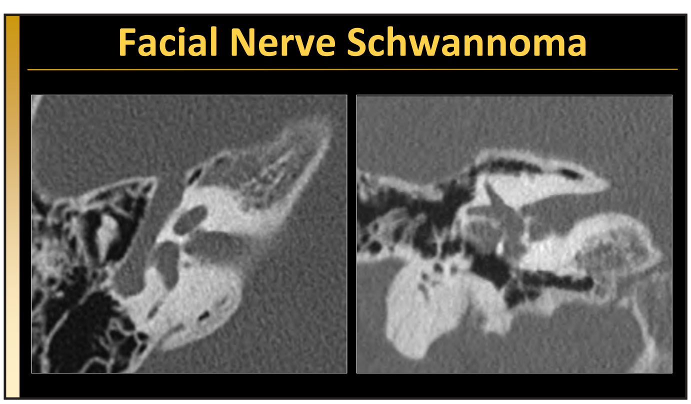

Windows ("Third" and "Single")
Vestibular aqueduct
Semicircular canals
Ossicles
TM
Vestibule
Scala vestibuli
Scala media
Scala tympani
STOP
Cochlear aqueduct
Ho M-L, et al. AJNR Am J Neuroradiol, 2017; 38(1):2-9.

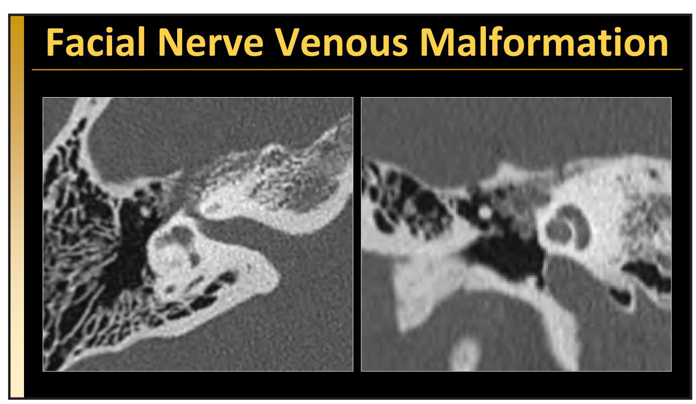

Case #6

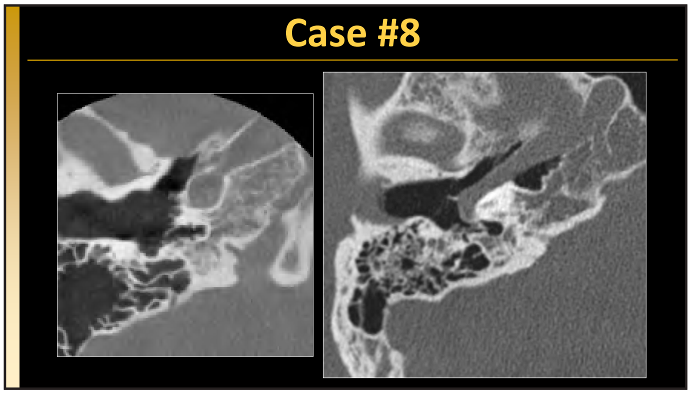

Endolymphatic Sac Tumor

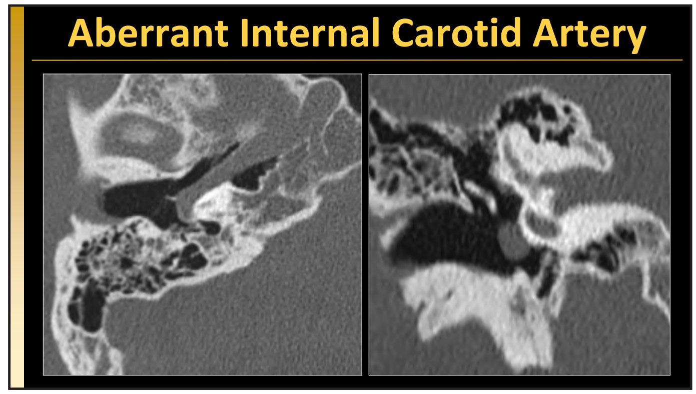

Case #7

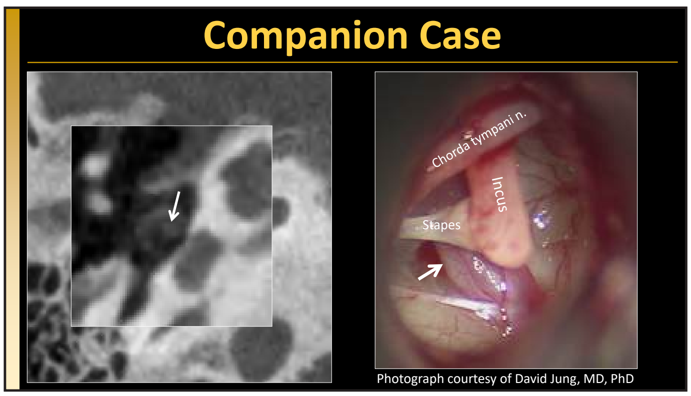

Abnormally Positioned Facial Nerve

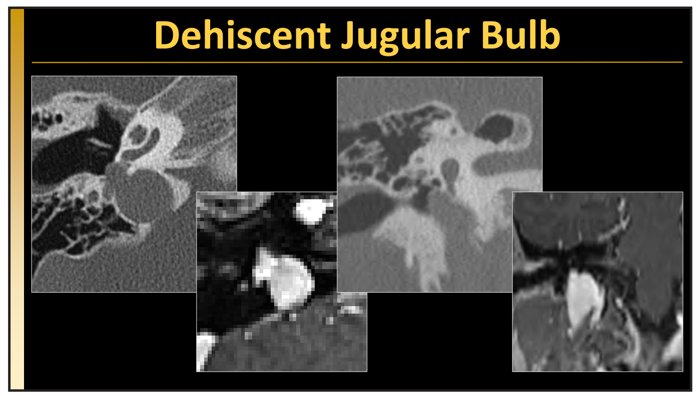

Facial Nerve Schwannoma


Facial Nerve Venous Malformation

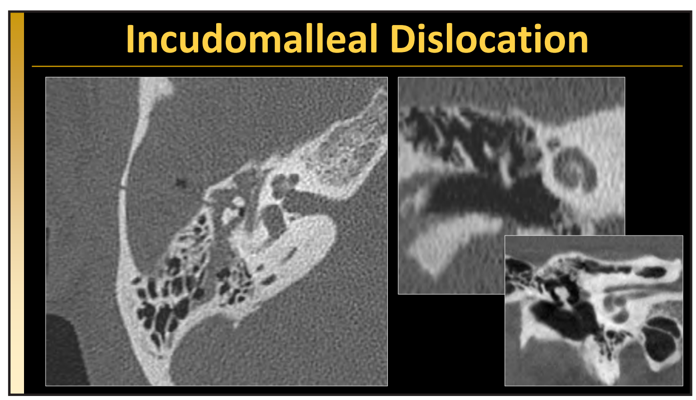

Case #8

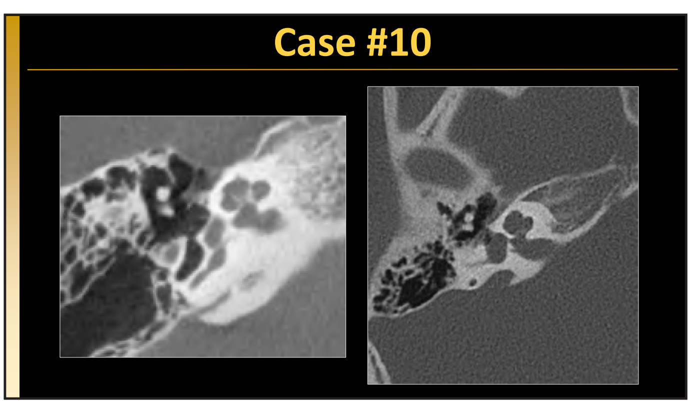

Aberrant Internal Carotid Artery

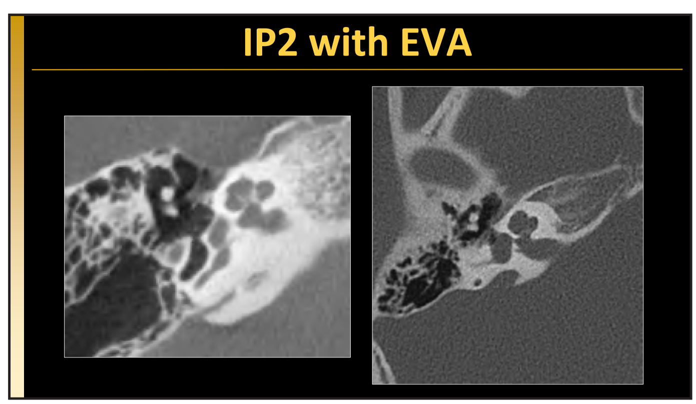

Companion Case
Chorda tympani n.
Incus
Stapes
Photograph courtesy of David Jung, MD, PhD


Dehiscent Jugular Bulb


Case #9


Incudomalleal Dislocation


Case #10

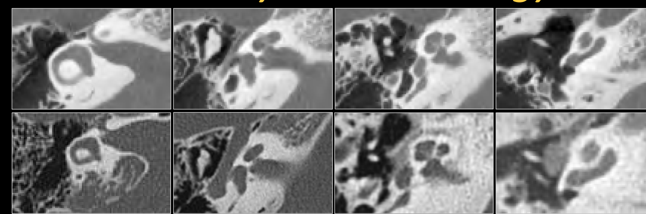

IP2 with EVA

Summary

- Anatomy is **learnable**
  - 5 axial slices
  - 5 coronal slices
- Knowledge of anatomy informs understanding of pathology

Temporal Bone CT:

Anatomy and Pathology



Wake Forest School of Medicine

Paul M. Bunch, MD

SELF EVALUATION

Temporal Bone CT: Anatomy and Pathology

1. The most common type of cholesteatoma is:

a. Acquired pars flaccida
b. Acquired pars tensa
c. Congenital
d. Iatrogenic

2. The most common site of otospongiosis involvement is:

a. Internal auditory canal
b. Anterior aspect of the oval window
c. Round window
d. Vestibular aqueduct

3. Paragangliomas occurring in the temporal bone may present clinically as a _____ mass behind the tympanic membrane:

a. Red
b. White
c. Yellow
d. Black

4. Dehiscence of the bone covering which of the following structures represents the most common third window lesion?

a. Cochlea
b. Facial nerve
c. Vestibule
d. Superior semicircular canal

5. Endolymphatic sac tumors are most closely associated with which of the following hereditary syndromes?

a. von Hippel-Lindau
b. Tuberous sclerosis
c. Neurofibromatosis type 1
d. Cystic fibrosis

Answer Key: 1. A, 2. B, 3. A, 4. D, 5. A

MICHIGAN MEDICINE
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Cardiac MRI and Cardiac CTC Basics

Imaging evaluation of Heart Disease: CMR and CCT

Learning Objectives
- Understand advantages and limitations
- Discuss applications in routine clinical practice
- Review current appropriate use criteria

Clinical presentations and scenarios needing imaging in patient with suspected heart disease
- Chest pain
- Shortness of breath
- Heart failure
- Palpitations /Arrhythmias
- Syncope/fall
- Fatigue
- Asymptomatic

What aspects of Cardiovascular disease need imaging ?
- Coronary arteries
- Myocardial perfusion
- Left and Right ventricular function (EF) and size
- Heart muscle tissue characterization
- Valve morphology and function
- Pericardium
- Aorta and great vessels

Imaging modalities available for Heart disease
- Echocardiography including stress echo
- Nuclear medicine- SPECT and PET
- Cardiac MR
- Cardiac CT
- Catheter angiography

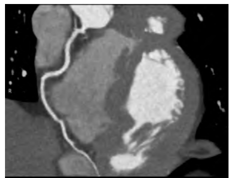
Imaging options:
- Echocardiography including stress echo
- Nuclear medicine- SPECT and PET
- Cardiac MR
- Cardiac CT
- Catheter angiography

Which test to order? Depends on :
- Clinical presentation and pathology to be investigated
- Pretest probability
- Patient factors
- Availability and expertise at the site

Wish list!. Ideal noninvasive imaging modality for cardiac disease. Add value by imaging!
- Safe
- Detailed high quality assessment of cardiovascular structure
- Accurate evaluation of ventricular function, myocardial perfusion and flow
- Myocardial tissue characterization(e.g infarct, edema, inflammation, infiltration, fibrosis)
- Well tolerated
- Accessible

- Diagnose etiology
- Guide treatment
- Monitor therapy
- Offer prognostic information
- Improve outcome

Cardiac CT



Anatomical coronary artery evaluation for Atherosclerosis- Coronary CT Angiography (CCTA)

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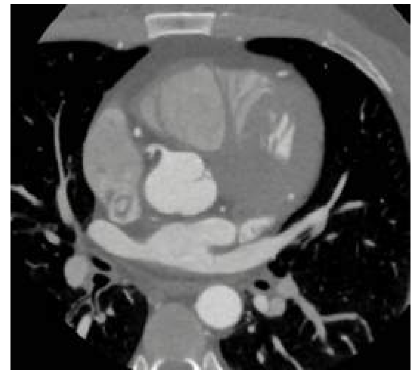
45 M veteran with chest pain

Inconclusive Nuc med stress testing

CTA requested



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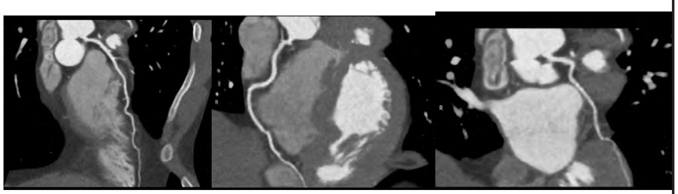
45 M veteran with chest pain- - Normal coronary arteries on CTA



LAD RCA LCX

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45 M veteran with chest pain- - Normal coronary arteries on CTA

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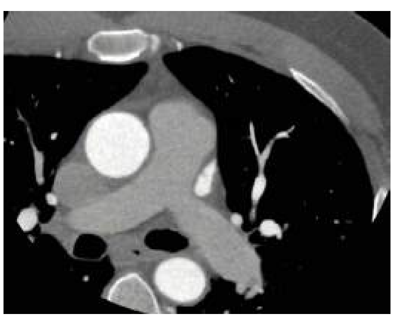
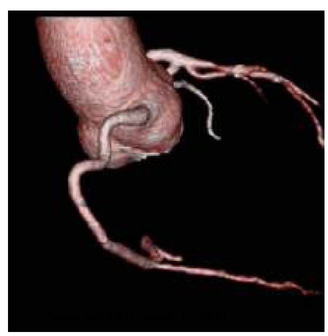
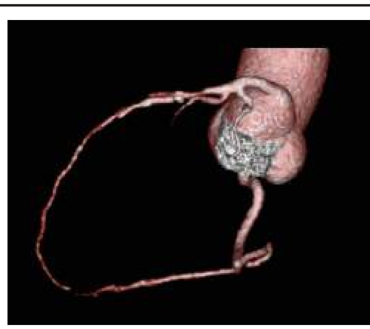
60 M veteran with new onset chest pain on exertion





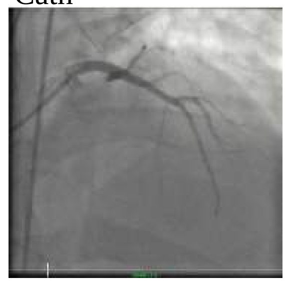


Severe Mid LAD stenosis

Severe Mid LAD stenosis

Case. Severe Mid LAD stenosis

Cath



Successful PCI of culprit lesion in mid LAD with implantation of Resolute Onyx 3.0 x 26mm drug-eluting stent

Cardiac CT (CCT) : **Advantages** and Limitations

- Rapid high spatial resolution anatomical imaging of cardiovascular disease
- Spatial resolution of modern CT scanners is in the range of 0.2-0.4mm.
- State of art MDCT allows single heart beat scanning and coverage of the entire heart in one gantry rotation
- Wide range of modern CT scanners including 256, 320 MDCT and dual source scanners and more recently Photon counting CT
- CCT is widely available. Radiation doses are low in the range of 1-3 mSv with proper attention to technique and patient preparation

Cardiac CT (CCT) : **Advantages** and Limitations

- Mainly used in clinical practice for exclusion of obstructive CAD in a wide variety of setting both acute and non acute
- In the acute setting appropriate for exclusion of obstructive CAD in low to intermediate risk patients with negative ECG and cardiac enzymes
- In chronic chest pain it can be used as a 1st line testing for diagnosis or exclusion of obstructive in low to intermediate risk patients with suspected CAD
- High negative predictive value, cost effective, gate keeper for cath, judicious use and treatment of CAD based on CCT has been shown to reduce cardiovascular mortality and MI (*SCOT-HEART NEJM 2018*)

Cardiac CT (CCT) : Advantages and **Limitations**

- Requires iodinated contrast – Allergic reactions. Renal dysfunction
- Highly calcified arteries- Limited positive predictive value

FFR-CT improves accuracy

- Purely an anatomical test as performed in clinical routine

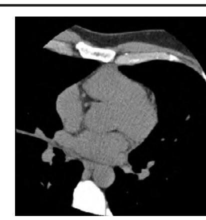
CCTA Reporting : CAD RADS

CAD-RADS Category	Interpretation	Degree of Maximal Coronary Stenosis	Further Cardiac Workup	Management
0	Absence of CAD	0%, no plaque or stenosis	None	Consider nonatherosclerotic causes of chest pain
1	Minimal CAD	1%–24%, minimal stenosis or plaque without stenosis	None	Consider nonatherosclerotic causes of chest pain Preventive therapy and risk modification
2	Mild CAD	25%–49%	None	Consider nonatherosclerotic causes of chest pain Preventive therapy and risk modification, especially for plaque in multiple segments
3	Moderate stenosis	50%–69%	Functional assessment	Consider symptom-guided anti-ischemic and preventive pharmacotherapy and risk factor modification per guideline-directed care
4A	Severe stenosis	One or two vessels, 70%–99%	ICA or functional assessment	Consider symptom-guided anti-ischemic and preventive pharmacotherapy and risk factor modification per guideline-directed care
4B	Severe stenosis	Left main artery >50% or three vessels ≥70%	ICA is recommended	Other treatments including revascularization should be considered per guideline-directed care
5	Total occlusion	100%	ICA and/or viability assessment	Same as for CAD-RADS 4A and 4B
N	Obstructive CAD cannot be excluded	Nondiagnostic	Additional or alternate evaluation	Additional or alternate evaluation

Coronary artery calcium scoring CT: Imaging an asymptomatic patient.

- The 2018 ACC/AHA Cholesterol Guideline suggests that coronary artery calcium (CAC) testing may be considered in adults 40-75 years of age without diabetes mellitus and with LDL-C levels ≥70 mg/dl-189 mg/dl at a 10-year atherosclerotic cardiovascular disease (ASCVD) risk of ≥7.5% to <20% (i.e., intermediate risk group) if a decision about statin therapy is uncertain
- In such patients, if CAC is zero, treatment with statin therapy may be withheld or delayed, except in cigarette smokers, those with diabetes mellitus, and those with a strong family history of premature ASCVD. According to the guideline, a CAC score of 1 to 99 favors statin therapy, especially in those ≥55 years of age. For any patient, if the CAC score is ≥100 Agatston units or ≥75th percentile, statin therapy is indicated unless otherwise deferred by the outcome of clinician-patient risk discussion

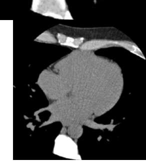
Grundy SM, Stone NJ, Bailey AL, et al. 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA guideline on the management of blood cholesterol: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2018

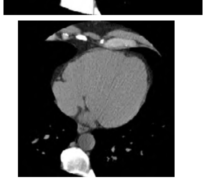


46 M veteran. CAD risk factors including a FH of SCD

? Prescribe statins

AJ I30 calcium score 0





Coronary artery calcium scoring CT

Identification of subclinical atherosclerosis rather than use of serum biomarkers is preferred, because of the extensive body of evidence demonstrating the superior utility of atherosclerosis disease assessment, particularly with CAC measurement, over any serum biomarker for the prediction of future ASCVD events, including both coronary heart disease and stroke.

Top three take home points from the guideline:

1. **When to consider CAC testing?** In intermediate-risk or selected borderline-risk adults, if the decision about statin use remains uncertain, it is reasonable to use a CAC score in the decision to withhold, postpone or initiate statin therapy.

2. **Emphasis on "power of zero:" use of CAC testing to identify low risk patients.** As opposed to risk enhancers and screening tools that may be used to identify higher risk patients, CAC testing is now mostly used for identifying lower risk patients among those who would otherwise be candidates for statin therapy but who have a preference to avoid such therapy.

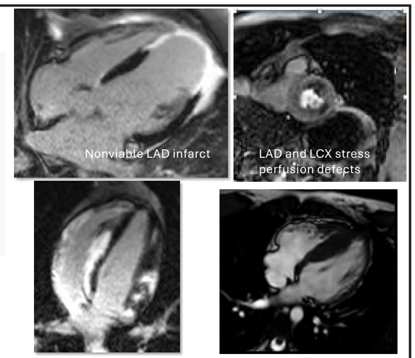
3. **Not everyone benefits from CAC testing: selective use encouraged.** Many individuals can be treated with statin therapy and do not require CAC testing. However, when there is uncertainly about patient risk or a desire to defer statin therapy, CAC testing may be used to enhance shared decision making.

1. **CAC may also be useful in older individuals.** The new guideline also supports the utility of CAC measurement in identifying the absence of atherosclerotic plaque in older adults. Specifically, the guideline states that in adults 76 to 80 years of age with an LDL-C level of 70 to 189 mg/dL, it may be reasonable to measure CAC to reclassify those with a CAC score of zero to avoid statin therapy.

Grundy SM, Stone NJ, Bailey AL, et al. 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA guideline on the management of blood cholesterol: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2018

Cardiac MR

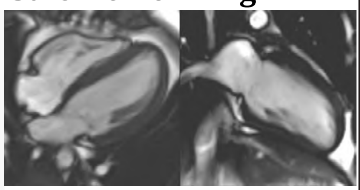
Cardiac morphology, function, perfusion, and tissue characterization



Cardiac Sarcoidosis

Hypertrophic Cardiomyopathy

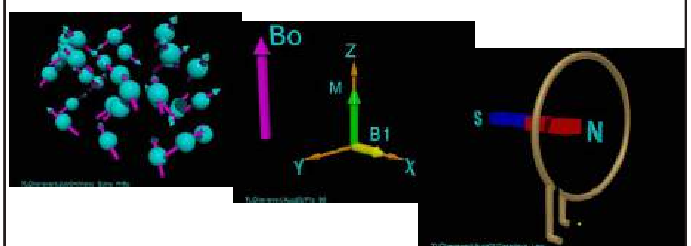
CMR Advantages: Safe Nonionizing



4 chamber and 2 chamber cine CMR. Normal heart

1.5 or 3T Tesla magnet strength
Wide bore aperture- 70 cm
250kg/550 lbs. table weight limit

CMR Advantages: Safe Nonionizing



CMR Safety: Generally considered safe. No long term or short-term adverse affects if precautions are followed

- **Potential projectiles**: Magnet always on. Hazard from ferromagnetic material. Local guidelines and safety policies
- **Implanted devices**: MR safe, MR conditional, MR unsafe. Refer to package inserts or MR safety websites (www.mrisafety.com).

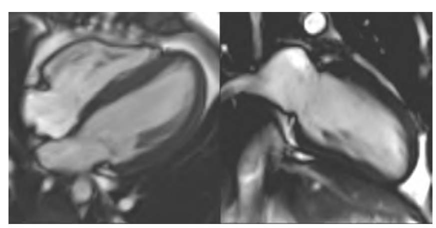
-Not contraindications: Most metallic heart valves, stents, prosthetic joints, sternal wires, dentures, cardiac closure and occluder devices

-Contraindications: *Most pacemakers, ICD*, Insulin pumps, metallic foreign eye bodies, cochlear implants, neurostimulators

-MR safe/conditional: Evera ICD, Medtronic Revo; St Jude's accent MRI pacemaker; Biotronik Pro MRI;

- Safety issues pertaining to stress agents (adenosine and dobutamine)
- Gadolinium administration: Currently used Gadolinium agents can be safely used in renal dysfunction. *Macrocyclic*. NSF is a rare scleroderma like condition associated with GBCA use in severe renal dysfunction (glomerular filtration rate < 30 mL/min/1.73m^2) . Rare reactions (severe anaphylaxis 1 in 250000 to 300000)

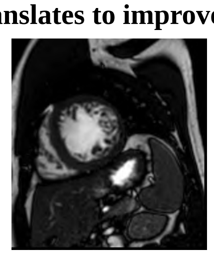
CMR Advantages: High quality 3D imaging of cardiac structure



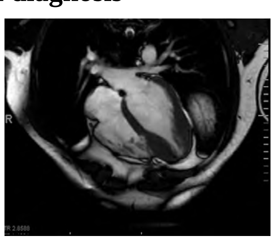
CMR Cine (bright blood) images normal heart
4 chamber and 2 chamber planes

- ECG gated high temporal resolution cine images (~ 40ms)
- High spatial (1.2-1.8mm) and contrast resolution
- Unrestricted imaging windows
- Large field of view
- 3D Multiplanar imaging

CMR Advantages: High image quality translates to improved diagnosis

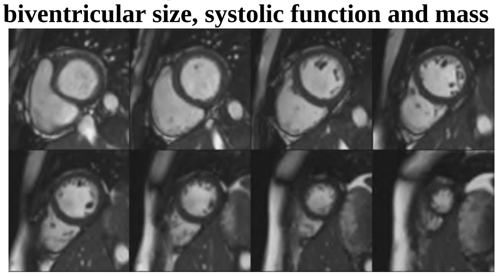


LV noncompaction

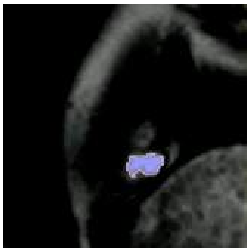


Apical HCM

CMR Advantages: Accurate evaluation of biventricular size, systolic function and mass

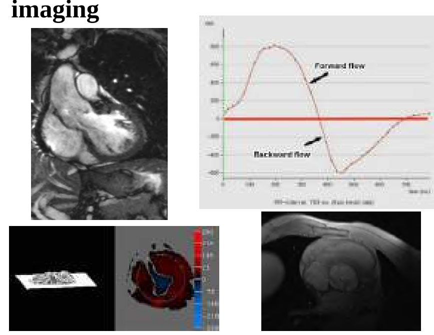


CMR Advantages: Accurate evaluation of biventricular size, systolic function and mass



- Precise, reproducible and does not assume geometric assumptions
- Reference standard for LV and RV size, systolic function and myocardial mass

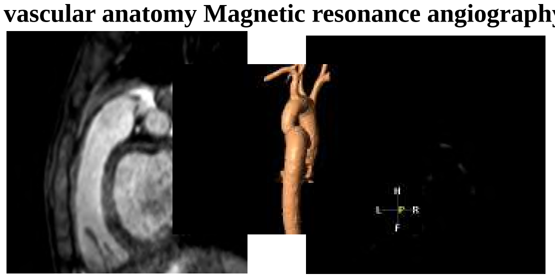
CMR Advantages: Evaluation of flow. 2D phase contrast imaging



Applications:

- Quantification of regurgitation in cardiac valves
- Calculation of shunts

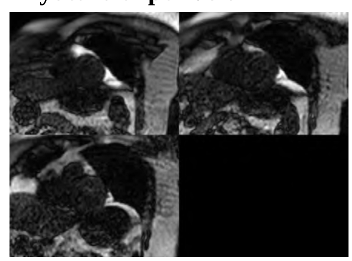
CMR Advantages: 3D evaluation of extracardiac vascular anatomy Magnetic resonance angiography



Non contrast MRA: 3D gated SSFP

Gadolinium enhanced MRA. Time resolved

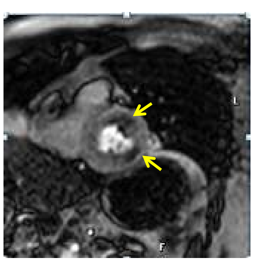
CMR Advantages: Visualize and quantify Myocardial perfusion



- Myocardial perfusion during the 1st pass transit of IV gadolinium
- Adenosine and Regadenoson commonly used vasodilators
- High spatial resolution (~2mm in plane)
- Multicenter and large single center studies demonstrate CMR stress perfusion has superior diagnostic accuracy to SPECT
- Increasing prognostic data

Perfusion defects in the anterior wall and inferior lateral wall : Obstructive lesions in LAD and LCX on catheter angiography

Stress CMR



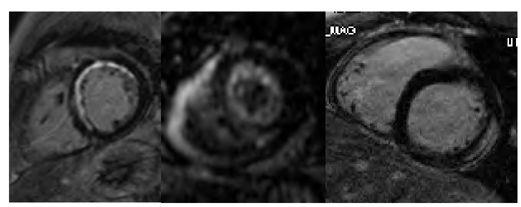
Nonionizing noninvasive evaluation of ischemia

High spatial resolution (< 3mm in plane); allows distinction of subendocardial layer separately

Good image quality irrespective of body habitus ; breast or diaphragm attenuation or gender

Allows comprehensive assessment of morphology, function, ischemia and tissue characterization/viability as part of a Multiparametric CMR study

CMR Advantages: Myocardial tissue characterization Late Gadolinium enhancement (LGE)/Delayed enhancement (DE)



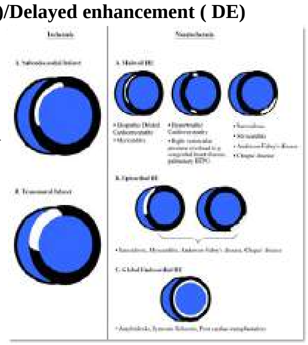
LAD infarction | Amyloidosis | Myocarditis

Characteristic LGE patterns in specific etiologies of heart disease

CMR Advantages: Myocardial tissue characterization Late Gadolinium enhancement (LGE)/Delayed enhancement (DE)

MRI Late gadolinium enhancement

- Gadolinium- Extravascular, extra cellular agent that accumulates in regions of infarcted, inflamed, fibrotic or infiltrated myocardium
- The subendocardium is more vulnerable to ischemia



CMR Advantages: One stop shop for form, function, perfusion, flow and tissue characterization

- Safe: Nonionizing. No short- or long-term adverse effects
- High quality 3D assessment of cardiovascular structure
- Reference standard for ventricular size, systolic function and mass
- Allows evaluation of myocardial perfusion and large vessel flow
- Enables myocardial tissue characterization: Detection of infarction, infiltration, edema and fibrosis

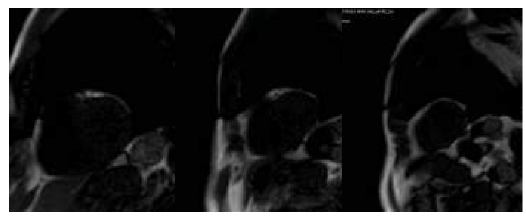
CMR Limitations : Advantages outweigh limitations if appropriately used

- Direct anatomical evaluation of CAD limited by spatial resolution. CCT spatial resolution ~ 0.4mm. CMR can be used for evaluation of coronary anomalies
- Examination times: 45mins (20-60min). Claustrophobia
- Accessibility:
  - -Available at most regional medical centers
  - -complex exams requires considerable training and experience to perform and interpret correctly
  - - Cost: Nuclear stress test: ~$1800
    Cardiac MRI: ~$2200

Stress CMR- Multiparametric exam in stable CAD

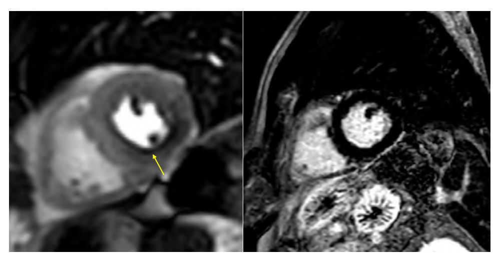
- 70 M. Chest pain on exertion. Hyperlipidemia
- Stress ECG – 2-3 mm flat to upsloping ST depression in II, III, aVF, V4, V5, V6 and 1 mm ST elevation at peak exercise
- Stress Echo - Bruce protocol,13 minutes, 99% MPHR, 2 mm horizontal STD inferior leads and V4-V6 during stress. Baseline LV function normal. Stress induced mid-basal inferior wall and posterior wall HK
- CTA- CAC 1200. Obstructive CAD RCA
- Declined cath. Offered Nuc med perfusion or MRI and preferred MRI

Stress CMR - Multiparametric exam in stable CAD



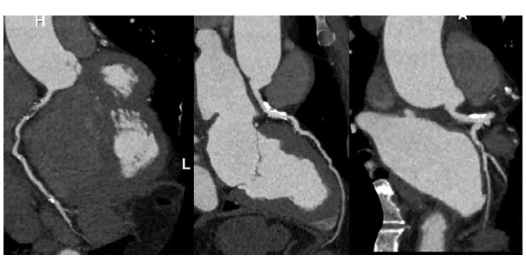
CMR Multiparametric exam in stable CAD

CMR Multiparametric exam in stable CAD



70 M. Asymptomatic. Physically very active. Stress ECG and Echo positive for ischemia. CTA – Obstructive CAD RCA. Moderate sized inducible perfusion defect on CMR

CMR Multiparametric exam in stable CAD



RCA > 70% stenosis LAD < 50% stenosis LCX non obstructive disease

Stress CMR- Multiparametric exam in stable CAD

RCA > 70% stenosis

2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

J Am Coll Cardiol. Oct 28, 2021. Epublished DOI: 10.1016/j.jacc.2021.07.053

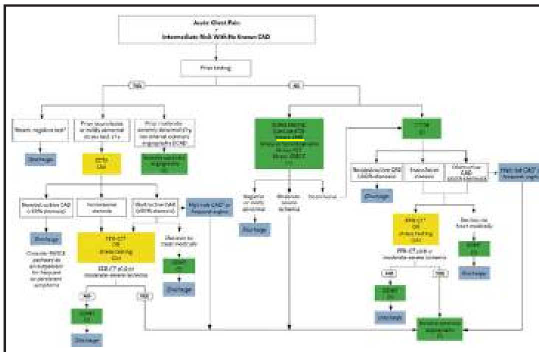
The choice of imaging depends on the clinical question of importance, to either a) ascertain the diagnosis of CAD and define coronary anatomy or b) assess ischemia severity among patients with an expected higher likelihood of ischemia with an abnormal resting ECG or those incapable of performing maximal exercise.

Testing choice will be influenced by site expertise and availability, but knowledge regarding which test may be preferable is useful when selecting between different modalities.

Cost should also be considered, when known by the ordering clinician and there is equipoise between available modalities

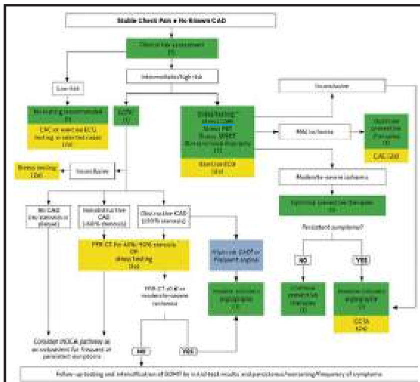
Exercise ECG is the lowest cost procedure used in the diagnostic evaluation when compared with stress imaging or anatomic procedures, with the exception of coronary artery calcium (CAC) scoring . For all imaging procedures, costs vary by payer and site of services.

JACC



CMR stress testing and CCTA are Class 1 indications

2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines



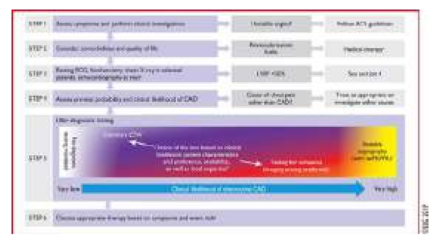
CMR stress testing and CCTA are Class 1 indications

The 2021 AHA/ACC Guideline for the Evaluation and Diagnosis of Chest Pain suggests either non-invasive functional imaging or coronary CTA as the initial test without specifying a preference for one or the other

2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

Figure 2 Approach for the initial diagnostic management of patients with angina and suspected coronary artery disease. ...

ESC European Society of Cardiology

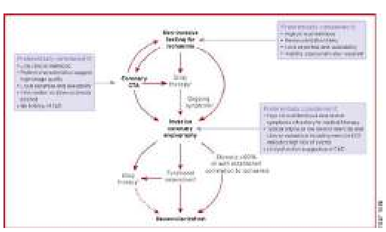


Eur Heart J, Volume 41, Issue 3, 14 January 2020, Pages 407–477, https://doi.org/10.1093/eurheartj/ehz425

OXFORD

Figure 4 Main diagnostic pathways in symptomatic patients with suspected obstructive coronary artery disease. ...

ESC European Society of Cardiology



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OXFORD

Other specific scenarios where CCT and CMR can be used apart from chest pain syndrome

- Preoperative evaluation for non cardiac or non coronary cardiac surgery
- New onset heart failure
- Bypass graft and stent patency
- After an equivocal functional test e.g., dobutamine echo or nuclear medicine stress test e.g., SPECT
- Structural heart disease e.g., AS (TAVR planning), LAA thrombus or Watchman device

CT First approach in stable chest pain

Advantages of a CT 1st approach in intermediate risk CAD (Stable Chest Pain) :

-CTA is the only test among the noninvasive tests (vs SPECT, CMR, Stress echo) that actually visualizes with a good degree of precision and accuracy the amount of plaque and vessel blockages that could be causing the patient's symptoms

- High negative predictive value for ‘ Rule out” obstructive CAD

- Easily accessible, rapid, cheaper and well tolerated

Detection of Myocardial infarction: CMR Late gadolinium enhancement (LGE)

- Accurately delineates infarction
- High spatial resolution
- Appropriate for determining the location and extent of myocardial necrosis in IHD*

Circulation. 2010;121:2462-2508

Evaluation of myocardial viability : CMR late Gadolinium enhancement (LGE)

Almost transmural LGE

Small subendocardial MI

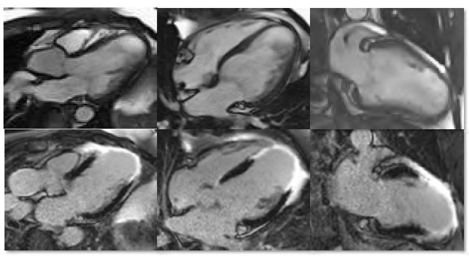
- Transmural extent of infarct scar is inversely related to the likelihood of functional recovery after revascularization
- <25% viable; 25-50% is mixed, mostly viable, 51-75% is mixed, mostly non-viable; > 75% is non-viable
- Appropriate for determining viability prior to revascularization*

Circulation. 2010;121:2462-2508

Evaluation of myocardial viability : CMR

Hibernating myocardium before and after revascularization

Case: 58yo man with PMH of HTN, HLD, paroxysmal AF initially presented to OSH with 3 day of chest pain

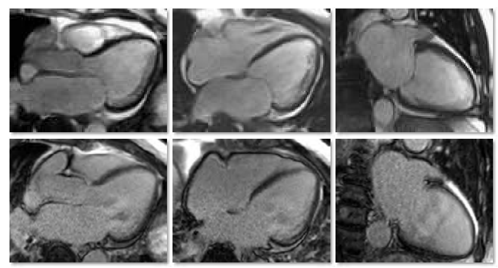


- LHC : LAD: mid-segment occlusion; LCx: large diffusely ectatic vessel; RCA: 50% stenosis in the mid-segment

Mildly dilated LV (LVEDVi 104mL/m2); LVEF 38%
Medical management

58

Case: 76yo man with no significant PMH admitted with new onset CHF and atrial fibrillation



LHC: LAD CTO; RCA with 50% stenosis;

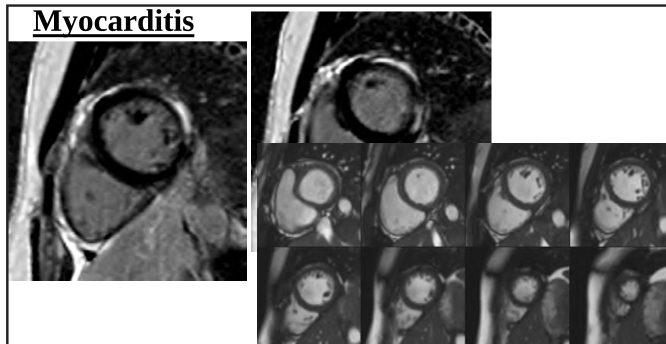
59

Severely dilated LV (LVEDVi 135mL/m2); LVEF 29%
Status-post PCI to CTO LAD

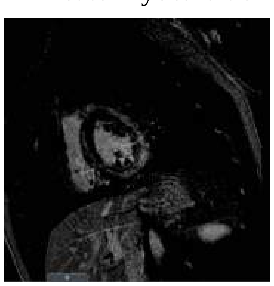
Myocarditis

- Symptoms consistent with myocarditis are a frequent cause of visits specially in young and middle-aged males. Most frequent disease in patients with ACS yet normal coronary arteries.
- CMR is the diagnostic tool of choice in tertiary care centers for patients with evidence for acute nonischemic myocardial injury. Suspected myocarditis is one of the most frequent indications for CMR scans and, in Europe, represents about one third of CMR referrals
- CMR allows for targeting several features of myocarditis: inflammatory hyperemia and edema, necrosis/scar, contractile dysfunction, and accompanying pericardial effusion (Lake Louis criteria)
- The presence of LGE is the best independent predictor of all-cause mortality and of cardiac mortality. Patients with normal CMR have a good prognosis

Myocarditis



Acute Myocarditis

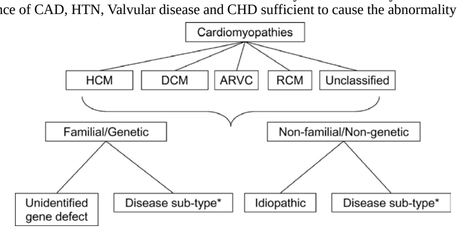


LGE

T2 STIR Fat suppressed black blood imaging

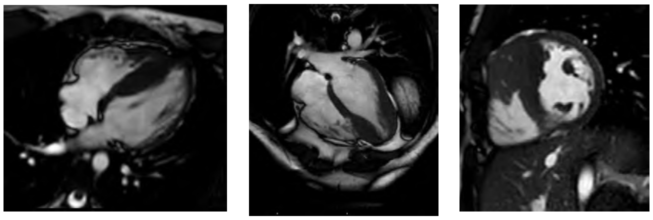
Classification of Cardiomyopathies

Myocardial disorders in which the heart muscle is structurally and functionally abnormal in the absence of CAD, HTN, Valvular disease and CHD sufficient to cause the abnormality



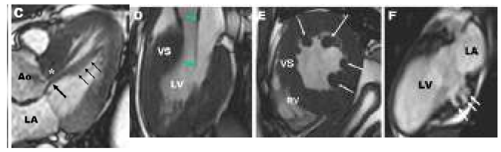
Elliott P et al. Eur Heart J 2008;29:270-276

Hypertrophic Cardiomyopathy (HCM)



Most common genetic cardiomyopathy with a prevalence of 0.2%. Most common cause of SCD in young people
CMR accurately detects location and extent of hypertrophy, adds a measure of clarity to the diagnosis
In adults, HCM is defined by wall thickness ≥15 mm in ≥1 LV myocardial segments

Additional morphological abnormalities in HCM



Elongated MV leaflets
Abnormalities of the papillary muscles
Myocardial crypts

Genotype positive and phenotype negative family members

The subclinical hypertrophic cardiomyopathy phenotype measured by cardiovascular magnetic resonance in a multicenter environment and consisting of crypts (particularly multiple), anterior mitral valve leaflet elongation (> 21mm), abnormal trabeculae, and smaller LV systolic cavity is indicative of the presence of sarcomere gene mutations and highlights the need for further study.

Circ Cardiovascular imaging 2014 Nov;7(6):863-71

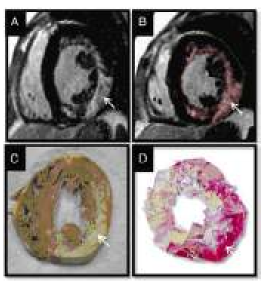
CMR HCM Risk stratification :LGE

- Conventional risk factors:

-Prior cardiac arrest
-Unexplained syncope
-Massive LV hypertrophy (> 30mm)
-FH of HCM related SCD
-Frequent and prolonged (> 10 beats) NSVT
-Hypotensive or attenuated BP response to exercise

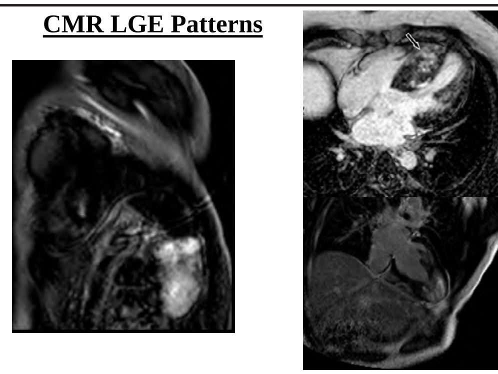
- Multiple studies have demonstrated a high prevalence (60-70%) of LGE, predominantly in a patchy, multifocal mid-wall distribution in regions of hypertrophy
- LGE in HCM corresponds to fibrosis a potential arrhythmogenic focus

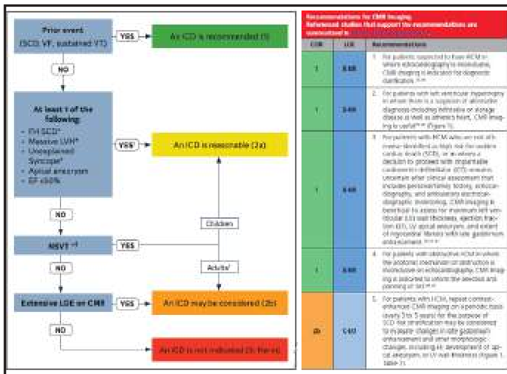
Autopsy Correlation of Fibrosis With In Vivo LGE-CMR



O'Hanlon, R. et al. J Am Coll Cardiol 2010;0:2010.05.010v1-15844

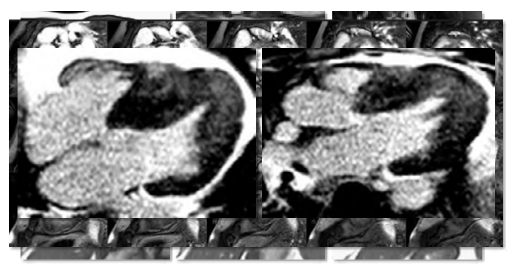
CMR LGE Patterns





Ommen SR et al. 2020 AHA/ACC guideline for the diagnosis and treatment of patients with hypertrophic cardiomyopathy: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2020;142:e533–e557. doi: 10.1161/CIR.0000000000000938

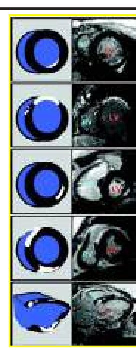
Case: 49yo man with PMH of HCM followed in clinic. TTE shows IVS 26mm. Holter monitor shows NSVT.



IVS >30mm and NSVT: 5 year risk based on ESC SCD calculator: 4.92% (intermediate risk; ICD may be considered) → referred to EP for ICD

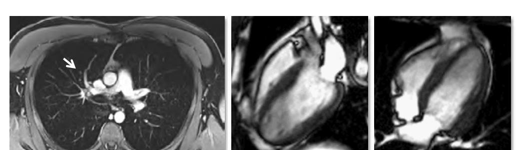
Cardiac Sarcoidosis (CS)

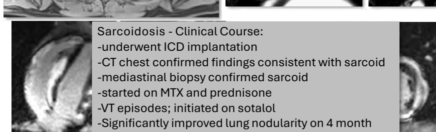
- 20-30% of patients with sarcoidosis have cardiac involvement at autopsy. 3-5% of sarcoid patients will have clinically apparent CS. ~ 25% of all deaths from sarcoid due to CS
- Presentations: Arrhythmic, cardiomyopathy and pericardial. Risk of sudden death
- Various degrees DE ;predilection for the basal and mid ventricular septum
- Higher rate of detection of CS with LGE CMR compared to standard clinical assessment



Patel MR et al . *Circulation.* 2009 Nov 17;120(20):1969-77

Case: 42yo man with no prior PMH admitted with syncope. "High degree AV block" on telemetry in ED. TTE showed mildly reduced LVEF otherwise no abnormalities.





Sarcoidosis - Clinical Course:
-underwent ICD implantation
-CT chest confirmed findings consistent with sarcoid
-mediastinal biopsy confirmed sarcoid
-started on MTX and prednisone
-VT episodes; initiated on sotalol
-Significantly improved lung nodularity on 4 month repeat HRCT

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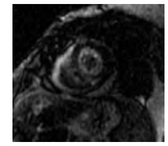
Cardiac Amyloidosis

- In the clinical workup of patients with diastolic heart failure and myocardial hypertrophy, cardiac amyloidosis is an important differential diagnosis
- 2 major subtypes : AL and ATTR
- Previously considered a rare disease, CA is increasingly recognized among patients who may be misdiagnosed as undifferentiated heart failure with preserved ejection fraction (HFpEF), paradoxical low-flow/low-gradient aortic stenosis, or otherwise unexplained left ventricular hypertrophy
- Effective treatments for some forms of cardiac amyloidosis exist, but treatment options are extremely limited once severe symptoms of heart failure become clinically apparent
- Consequently, the early diagnosis of cardiac amyloidosis may significantly improve the clinical outcome

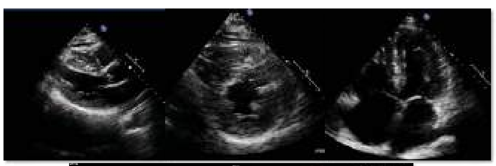
CMR. Cardiac Amyloidosis

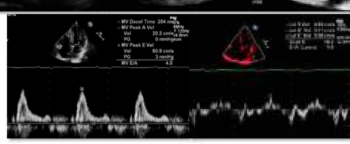


- In patients with biopsy-proven cardiac amyloidosis, LGE frequently occurs in a peculiar pattern.
- Global transmural or subendocardial LGE is most common, but suboptimal myocardial nulling and focal patchy LGE are also observed
- On the basis of the gold standard EMB, CMR can be used to diagnose or rule out cardiac amyloidosis with good sensitivity (80-88%) and excellent specificity in a clinical routine setting.

Role of cardiac magnetic resonance imaging in the detection of cardiac amyloidosis.
JACC Cardiovascular imaging 2010 Feb ; 39(2) 155-64

Case: 71yo man followed in clinic for non-ischemic cardiomyopathy. Mild non-obstructive CAD. Atypical episodes of chest pain. No major CHF symptoms.





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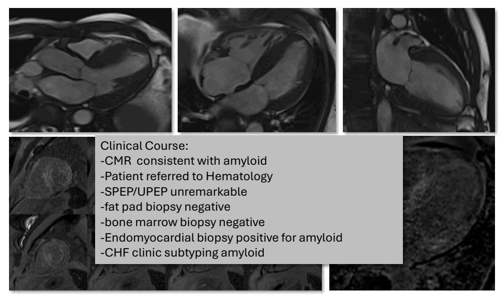
Case: 71yo man followed in clinic for non-ischemic cardiomyopathy. Mild non-obstructive CAD. Atypical episodes of chest pain. No major CHF symptoms.



Clinical Course:
-CMR consistent with amyloid
-Patient referred to Hematology
-SPEP/UPEP unremarkable
-fat pad biopsy negative
-bone marrow biopsy negative
-Endomyocardial biopsy positive for amyloid
-CHF clinic subtyping amyloid

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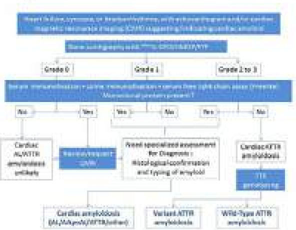
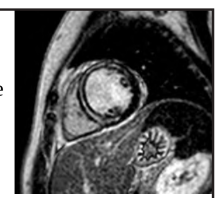
Cardiac Amyloidosis Imaging

- The advent of bone scintigraphy has enabled noninvasive diagnosis of ATTR, limiting the need for EMB
- Differentiating ATTR from other types of amyloidosis, especially AL, is critical. Emerging targeted ATTR therapies offer the potential to improve outcomes of these patients previously treated only palliatively
- CMR is unable to definitely distinguish between ATTR and AL amyloid



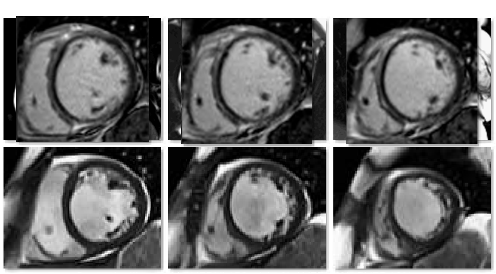
Darbola et al. Multimodality imaging in cardiac amyloidosis. Journal of Nuclear Cardiology. 2019 Dec;26 (6): 2065-2123

Dilated Cardiomyopathy



- LV dilatation and systolic dysfunction in the absence of HTN, CAD, Valve disease, CHD and other overloading conditions
- Most common cardiomyopathy worldwide ; 25% of HF cases in the US
- Aetiology: Familial and genetic, infectious causes, autoimmune, cytotoxicity (e.g., alcohol, drugs, HIV, etc.)
- While the majority of patients with DCM do not have LGE, 10-26% of patients exhibit patchy or longitudinal striae of mid wall enhancement corresponding to fibrosis on histology

Case: 53yo woman with no significant PMH admitted with 3-week history of progressive shortness of breath *LHC:* 50% stenosis in OM1; severe global hypokinesis; LVEF 10%.



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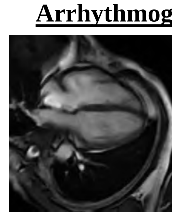
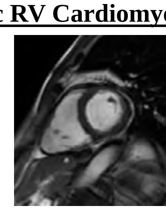
Arrhythmogenic RV Cardiomyopathy (ARVC)





Regional RV akinesia or dyskinesia

•**Major Criteria**
-RV EDV ≥ 110ml/m2 (males) or ≥ 100ml/m (female)
-RV EF ≤ 40%

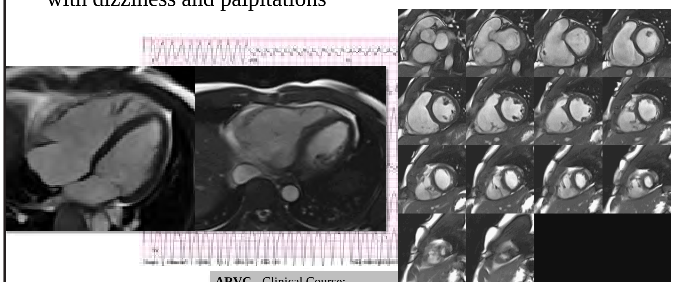
•**Minor Criteria**
-RV EDV 100-110ml/m2 (males) or 90-100 (females)
-RV EF 40-45%

35-year-old female. Syncope. T wave inversion in right pre-cordial leads and epsilon waves. Dilated RV. Focal dyskinetic areas in the anterior free RV wall.

- CMR is the test of choice for imaging evaluation of RV structure and function in suspected ARVC
- Diagnosis of ARVD requires a combination of criteria derived from structural , histological, ECG, arrhythmic features and family history

Marcus FI et al. Circulation 2010; 131 (13): 1533-1541

Case: 35yo firefighter with no PMH presents to the ED with dizziness and palpitations



ARVC - Clinical Course:
-underwent ICD implantation
-VT episode; started on sotalol

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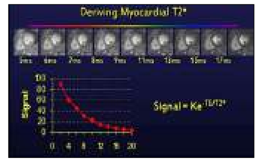
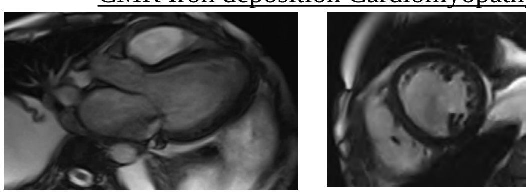
CMR Iron overload cardiomyopathy



— Myocardial T2* values >20ms are normal and those < 20ms indicate iron loading. Severe iron overloading T2* <10ms.
— Myocardial T2* values have a strong relation with EF.

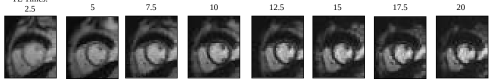
- HF caused by iron overload is the leading cause of death in patients with iron overload states such as beta-thalassemia major . Cardiomyopathy reversible if chelation therapy is commenced early
- **T2* imaging** allows quantitative assessment of myocardial iron, useful to guide treatment and monitor response to iron chelating drugs.
- Myocardial iron content cannot be predicted from serum ferritin or liver iron, and conventional assessments of cardiac function can only detect those with advanced disease.

CMR Iron deposition Cardiomyopathy



- 36-year-old male with primary hemochromatosis resulting in liver and pancreatic dysfunction.
- Dilated globally hypokinetic LV with EF of 20%.

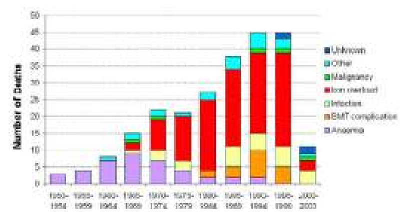
TE Times: 2.5 5 7.5 10 12.5 15 17.5 20



- T2 * sequence with 8 echoes at different echo times calculates a value of T2 at * 8.6ms

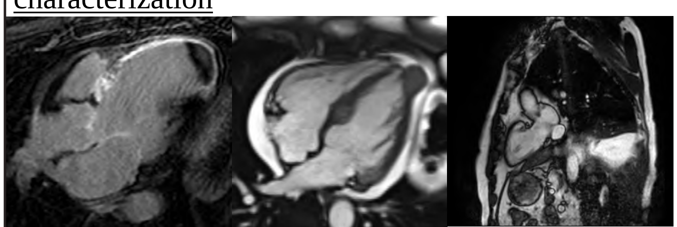
Improved survival of thalassaemia major in the UK and relation to T2* CMR

71% reduction in the annualized death-rate from iron overload since 2000



Modell B et al.J Cardiovasc Magn Reson. 2008 Sep 25;10:42

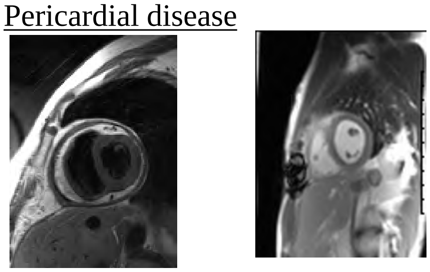
Cardiac masses: Location, extent, tissue characterization



LV thrombus | Metastatic neuroendocrine tumor | Right atrial myxoma

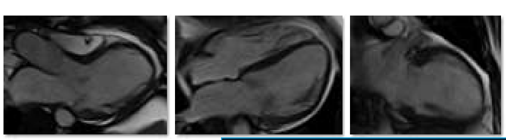
Pericardial disease

- Comprehensive structural and functional evaluation of the pericardium
- Physiological consequences of pericardial constriction



Pericardial thickening (> 4mm) and ventricular interdependence using cine sequences (abrupt cessation of diastolic filling, septal bounce, or respirophasic variation in septal excursion

Valvular heart disease. 43yo woman with PMH of mitral valve prolapse presenting with dyspnea on exertion. TTE and TEE both showed eccentric moderate to severe MR.



LVEDVi: 100cc/m2
LV stroke volume: 144cc
Aortic stroke volume: 75cc
MR regurgitant volume: 69cc
MR regurgitant fraction: 48%
Clinical course: Referred for surgery

When to consider CMR for VHD:
- Regurgitant valves: Aortic, pulmonary, AV valves
- Discrepancy between studies
- Impact of regurgitation on ventricular function and/or volume
- Assessment of serial changes in ventricular volumes and funtion

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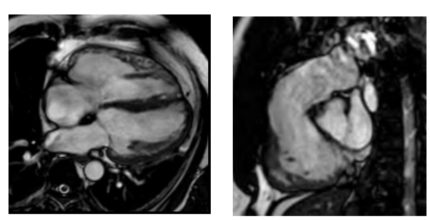
Adult congenital heart disease (ACHD)

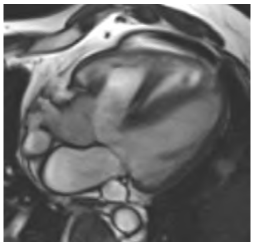
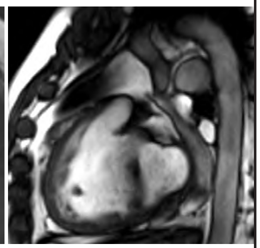


Comprehensive evaluation of intracardiac and extracardiac anatomy, biventricular size, systolic function and flow

3D comprehensive evaluation, Nonionizing, well suited for life long follow up

Post operative TOF. Dilated RV. Severe PR

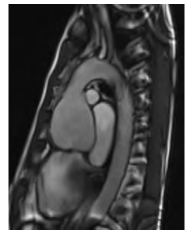
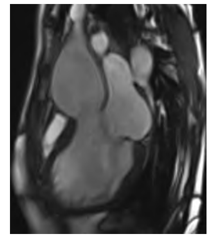
Adult congenital heart disease (ACHD) Unoperated

Scimitar syndrome

Tetralogy of Fallot. 56 M

Diseases of the aorta and great vessels

Comprehensive evaluation of the entire thoracic aorta, valvular disease and heart

Marfans syndrome. Aortic root dilation 6cm. ST junction effaced. MV prolapse

	Cardiac CT	Cardiac MRI
Ionizing radiation	Involved	Non ionizing technique
Use in renal failure	Caution needed with Egfr< 30 due to requiring iodinated contrast	Currently used macrocyclic gadolinium agents safe for use in renal failure
Evaluation of coronary artery anatomy for CAD	Test of choice in intermediate to low-risk patients in a variety of scenarios. Accurate, rapid and easily accessible. High quality anatomical evaluation possible	Limited by spatial resolution
Myocardial perfusion imaging	Not routine clinical practice	Accurate and has advantages over comparative imaging techniques e.g SPECT
Evaluation of ventricular size, wall motion and systolic function (EF)	Not routine clinical practice	Reference standard for LV and RV EF and size- accurate and reproducible
Myocardial tissue characterization e.g etiology of cardiomyopathy	Not a routine clinical application	Enables identification of scar, inflammation, infarction or infiltrative disease to identify etiology of cardiomyopathy
Accessibility and tolerance	Widely available and accessible Rapid exam	Available at regional medical centers. 45-1 hr exam times

Imaging of Heart Disease CMR and CCT Conclusions:

CMR and CCT are both Essential imaging modalities in Cardiac disease

- CMR is a powerful and versatile technique " one stop shop" for cardiac morphology, function, perfusion and tissue characterization. Test of choice for myocardial tissue characterization
- CCT allows high resolution anatomical imaging and exclusion of obstructive CAD in a wide variety of acute and non acute chest pain syndromes
- Judicious use of CMR and CCT avoids the need for cardiac cath in many instances
- Image wisely- Echocardiogram 1st line testing in Heart disease
- CMR and CCT interpretation should be considered in conjunction with the patients clinical status prior to decision making. Multidisciplinary collaboration is essential

SELF EVALUATION

Cardiac MRI and Cardiac CTC Basics

1. Which of the following statements is FALSE regarding the applications of CMR in ischemic heart disease (IHD)?

a. Late gadolinium enhancement (LGE) has a higher spatial resolution and accuracy than cardiac single-photon emission computed tomography (SPECT) for detection of MI and viability.
b. CMR myocardial stress perfusion imaging has a higher sensitivity and specificity than cardiac SPECT for detection of obstructive coronary artery disease.
c. CMR is appropriate for evaluation of ventricular size and function in IHD when echo windows are unsatisfactory.
d. CMR is the test of choice for direct anatomical evaluation of coronary stenosis.
e. The identification of microvascular obstruction on CMR is an adverse prognostic finding in IHD.

2. Linear mid-wall enhancement in the septum is a feature of which of the following conditions?

a. Idiopathic DCM
b. HCM
c. Ischemic cardiomyopathy
d. Cardiac amyloidosis
e. Eosinophilic myocarditis

3. Which of the following is NOT an appropriate indication for coronary CTA (CCTA)?

a. Suspected coronary anomaly
b. Asymptomatic patient with a strong family history of coronary artery disease (CAD) and risk factors
c. Ischemic symptoms, low to intermediate probability of CAD, and unable to exercise
d. Persistent chest pain with a prior normal exercise stress test
e. Acute chest pain low to intermediate probability of CAD with negative electrocardiogram and cardiac enzymes

4. Which ONE of the following is NOT an advantage of cardiac CMR?

a. Higher spatial and contrast resolution compared to echocardiography
b. Imaging is not affected by patient body habitus.
c. It is the test of choice for detection of diastolic dysfunction.
d. Allows accurate noninvasive quantification of large vessel flow
e. Provides superior evaluation of biventricular size and systolic function compared to echocardiography

Answer Key: 1. D, 2. A, 3. B, 4. C

Prostate MRI

Robert M. Marks, MD

DISCLOSURES

- Guerbet LLC

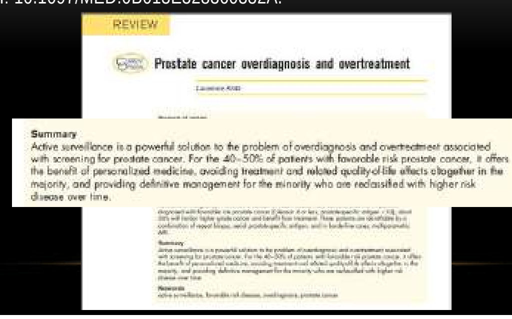
OBJECTIVES

- Understand the reasons for prostate cancer screening and surveillance
- Review the anatomy of the prostate
- Describe the basics of PI-RADS v2.1
- Identify the imaging features of prostate cancer on MRI

PROSTATE CANCER

- The second most common cause of death from cancer in men
  - In 2021
    - 248,530 new cases in the US
    - 34,130 cancer deaths
    - 1 in 8 men will be diagnosed with prostate cancer in their lifetime
- Screening performed with prostate-specific antigen (PSA) and digital rectal exam
  - However, 2 clinical trials demonstrated that screening with PSA leads to overdiagnosis and overtreatment
    - In OCT 2011, US Preventive Services Task Force recommended against PSA-based screening in asymptomatic men
    - As of 2013, AUA discourages screening of men at average risk less than 55
    - Men between 55-69 must outweigh risks to benefits
  - 1.2 million prostate biopsies performed per year in US
    - Cost $2 billion/year
    - Gleason Score upgraded 30% of time in prostatectomy specimens compared to biopsy
  - Thus, the decision to undergo definitive treatment (surgery, radiation) vs. conservative active surveillance is challenging

CURR OPIN ENDOCRINOL DIABETES OBES. 2013 JUN;20(3):204-9. DOI: 10.1097/MED.0B013E328360332A.


REVIEW

Prostate cancer overdiagnosis and overtreatment

Summary

Active surveillance is a powerful solution to the problem of overdiagnosis and overtreatment associated with screening for prostate cancer. For the 40–50% of patients with favorable risk prostate cancer, it offers the benefit of personalized medicine, avoiding treatment and related quality-of-life effects altogether in the majority, and providing definitive management for the minority who are reclassified with higher risk disease over time.

ANATOMY

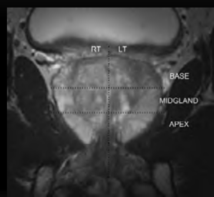
- Prostate divided into 2 major compartments
  - Peripheral Zone and the Central Gland
  - Peripheral zone
    - 70% of volume in young males
    - Surrounds the entire transitional zone posterolaterally and extends anteriorly to the fibromuscular stroma
    - High in water content = T2 bright
    - 75% of prostate cancers arise in peripheral zone
  - Central Gland
    - Transitional zone, central zone, and peri-urethral glandular tissue
    - In young males, the transitional zone and central zone make up 5% and 25% of the gland, respectively
    - As men get older, the transitional zone becomes more predominant (BPH)

ANATOMY

- Prostate tissue divided into two components
  - Glandular and non-glandular components
    - Glandular tissue makes up 75-80% of prostate
    - Non-glandular tissue
      - Fibromuscular stroma anterior to urethra
        - Common site for transitional gland tumors
      - Muscular stroma
        - Posterior base of the prostate
        - Inverted Y or V

ANATOMY

- Inverted cone on coronal images
  - Apex at inferior gland
  - Base superior adjacent to the bladder



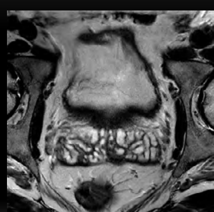
Jung AJ, Westphalen AC. Imaging Prostate CancerRadiol Clin North Am. 2012 Nov;50(6):1043-59. doi: 10.1016/j.rcl.2012.08.001.

ANATOMY

- Sagittal
  - Lies anterior to rectal wall
  - Bladder anterior superior
  - Seminal vesicles posterior superior
  - Apex lies superior to urogenital diaphragm

ANATOMY

- Axial
- Seminal vesicles superior posterior
  - Should be T2 bright
    - May not be filled in older men

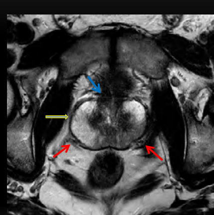


ANATOMY

- Axial
- Base
  - Muscular stroma posteriorly "inverted V"
    - Central Gland
      - Tumors exceedingly rare here
  - Prostate separated from rectum by Denovillier's fascia

ANATOMY

- Axial
- Neurovascular bundles
  - Insert into prostate at the 5 and 7 o'clock positions towards the base
  - Fibromuscular capsule of prostate
    - Not a true capsule
    - Pseudocapsule
  - Fibromuscular stroma



ANATOMY

- Axial
  - Mid Gland
  - Verumontanum
    - Inverted V
    - Paired ejaculatory ducts from seminal vesicles enter the prostatic urethra

BENIGN PROSTATIC HYPERTROPHY

ANATOMY

- Axial
  - Apex
  - Almost entirely glandular tissue
  - Location of the distal prostatic sphincter
    - Responsible for urinary continence

INDICATIONS FOR PROSTATE MRI

- Diagnosis of Prostate Cancer
  - Elevated PSA
- Staging a Known Prostate Cancer
- Surveillance for recurrence after prostatectomy or radiation therapy
- Pre-radiation therapy planning (brachytherapy)

DIAGNOSIS OF PROSTATE CANCER

- Diagnosis primarily based on PSA screening and TRUS-guided biopsy
  - PSA low specificity (36%)
  - TRUS-guided biopsy systematic, non-targeted and directed towards peripheral gland
    - Can miss tumors (anterior)
    - Can underestimate extent of tumor or tumor grade

ROLE OF MRI IN DIAGNOSIS

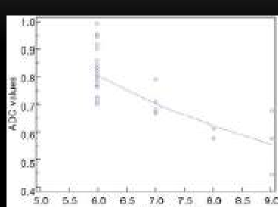
- MRI can find tumors not detected by biopsy
  - Especially anterior and transitional zone tumors
  - Determine the most aggressive tumor
  - Can guide further targeted biopsy
    - US-guided
    - MRI-guided
    - MRI-US Fused

MRI IN STAGING PROSTATE CANCERS

- MRI can determine:
  - Extracapsular extension (stage T3A) (78% sensitive, 96% specific)[1]
  - Involvement of the neurovascular bundle
  - Seminal vesicle invasion (stage T3B) (88 % sensitive, 98% specific) [1]
    - T3 lesions have a worse prognosis and more likely to recur after treatment or surgery
  - Invasion into adjacent structures (bladder or rectum)
  - Local lymph node involvement
- MRI correlates with Gleason grade
  - Apparent diffusion coefficients

1. Porcaro AB, Borsato A, Romano M, et al. Accuracy of preoperative endo-rectal coil magnetic resonance imaging in detecting clinical understaging of localized prostate cancer. *World J Urol* 2012; [Epub 2012 Jul 7]

CORRELATION BETWEEN ADC AND GLEASON SCORE



Manetta R, Palumbo P, Gianneramo C, Bruno F, Arrigoni F, Natella R, Maggialetti N, Agostini A, Giovagnoni A, Di Cesare E, Splendiani A, Masciocchi C, Barile A. Correlation between ADC values and Gleason score in evaluation of prostate cancer: multicentre experience and review of the literature. Gland Surg. 2019 Sep;8(Suppl 3):S216-S222. doi: 10.21037/gs.2019.05.02. PMID: 31559188; PMCID: PMC6755951.

CORRELATION BETWEEN ADC AND GLEASON SCORE

TABLE 2: Apparent Diffusion Coefficient (ADC) Values for Tumors Visible on Diffusion-Weighted Imaging According to Gleason Score

		ADC ($\times 10^{-3}$ mm^2/s)		
Gleason Score	No. of Tumors	Least-Squares Mean	Standard Error of Mean	Range
6	25	0.860	0.036	0.659-1.263
7	37	0.702	0.030	0.108-0.963
8	10	0.672	0.057	0.417-0.875
9	9	0.686	0.067	0.534-0.848

Woodfield CA, et al. Diffusion-Weighted MRI of Peripheral Zone Prostate Cancer: Comparison of Tumor Apparent Diffusion Coefficient With Gleason Score and Percentage of Tumor on Core Biopsy. AJR. April 2010, Volume 194, Number 4

PROSTATE MRI TECHNIQUE

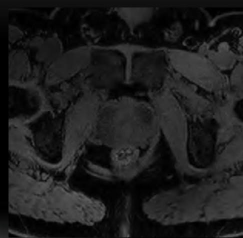
- 1.5 vs. 3.0 Tesla
  - Both are satisfactory
  - Do not need endorectal coil with 3.0 T
- In 2012, The European Society of Urogenital Radiology and the European Association of Urology published guidelines for multiparametric MRI of the prostate (PI-RADS v1)
  - T1 weighted sequences
  - T2 weighted sequences
  - Diffusion weighted sequences
  - Dynamic contrast enhanced sequences
  - +/- MR spectroscopy

PROSTATE MRI TECHNIQUE (PIRADS-2.1)

- In 2019, The ACR PI-RADS Steering Committee with the European Society of Urogenital Radiology published updated guidelines for multiparametric MRI of the prostate (PI-RADS v2.1)
  - T1 weighted sequences
  - T2 weighted sequences
  - Diffusion weighted sequences
  - Dynamic contrast enhanced sequences
- PI-RADS is primarily a prostate cancer detection and diagnosis system
- PI-RADS categories communicate the likelihood of clinically significant cancer

T1 WEIGHTED IMAGES

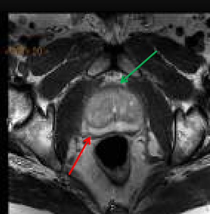
- Prostate is homogeneously low in signal
  - Difficult to see zonal anatomy and tumors
- Good for looking for post-biopsy hemorrhage
  - High T1 signal
    - Low T2 signal
      - Mimic cancer



T1 WITH HEMORRHAGE

T2 WEIGHTED IMAGING

- Fluid sensitive sequence
- Used to depict zonal anatomy
- Peripheral gland is bright
- Prostate cancer is T2 dark
  - Helps to make prostate cancer conspicuous
- Blood/hemorrhage can cause T2 dark spots in prostate
  - Thus recommend waiting at least 8 weeks after biopsy before MRI
- Also fibrosis, scarring, inflammation are T2 dark
- T2 alone sensitivity 75-94% but only 37-53% specific[2]



2. Gillian Murphy, Masoom Haider, Sangeet Ghai, and Boraiah Sreeharsha. The expanding role of MRI in prostate cancer. American Journal of Roentgenology 2013 201:6, 1229-1238

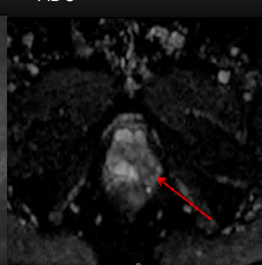
DIFFUSION WEIGHTED IMAGING (DWI)

- Uses changes in the Brownian motion of water molecules on a microscopic scale
- Apparent Diffusion Coefficient (ADC) correlates inversely with tumor cellularity
- The higher the grade, the higher the degree of restricted diffusion
- Improves detection of transitional zone tumors
- Improved sensitivity and specificity of T2 when combined with DWI
  - Sensitivity 77%, Specificity 81%[2]

2. Gillian Murphy, Masoom Haider, Sangeet Ghai, and Boraiah Sreeharsha. The expanding role of MRI in prostate cancer. American Journal of Roentgenology 2013 201:6, 1229-1238

DWI B990

ADC



DYNAMIC CONTRAST ENHANCED (DCE) MRI

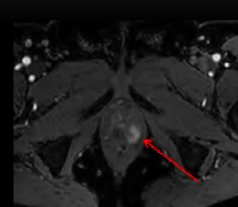
- Tumor angiogenesis causes tumors to have increased enhancement
  - Tumors briskly enhance in first 30-60 seconds after contrast
  - T1 weighted images are taken before and rapidly (every 10-15 seconds) after contrast enhancement in succession up to 3-5 minutes post contrast
  - Degree of vascularity = grade of tumor
  - Can be used to evaluate for effectiveness of treatment

2. Gillian Murphy, Masoom Haider, Sangeet Ghai, and Boraiah Sreeharsha. The expanding role of MRI in prostate cancer. American Journal of Roentgenology 2013 201:6, 1229-1238

DYNAMIC CONTRAST ENHANCED (DCE) MRI

- Tumor angiogenesis causes tumors to have increased enhancement
  - In most cases
- Used only to upgrade lesions seen on ADC (peripheral gland)

EARLY ENHANCEMENT



PI-RADS V 2.1 SCORING

- Utilizes a 5-point scale based on the probability that a combination of mpMRI findings on T2W, DWI, and Dynamic Contrast Enhanced (DCE) images correlate with clinically significant prostate cancer.
- Clinically significant cancer defined via pathology as Gleason score ≥7.
  - Gleason score = degree of dysplastic cells on 1-5 scale seen on pathology
    - Largest group of cells (1-5) + second largest group (1-5) = Gleason score
      - Gleason 4+3 considered high grade/clinically

PI-RADS V.2.1 SCORING

- Assessment Categories:
  - PIRADS 1 – Very low (clinically significant cancer is highly unlikely to be present)
  - PIRADS 2 – Low (clinically significant cancer is unlikely to be present)
  - PIRADS 3 – Intermediate (the presence of clinically significant cancer is equivocal)
  - PIRADS 4 – High (clinically significant cancer is likely to be present)
  - PIRADS 5 – Very high (clinically significant cancer is highly likely to be present)

PI-RADS ASSESSMENT OF DWI

Score	Peripheral Zone or Transition Zone
1	No abnormality (i.e., normal) on ADC and high b-value DWI
2	Indistinct hypointense on ADC
3	Focal mildly/moderately hypointense on ADC and isointense/mildly hyperintense on high b-value DWI.
4	Focal markedly hypointense on ADC and markedly hyperintense on high b-value DWI; <1.5cm in greatest dimension
5	Same as 4 but ≥1.5cm in greatest dimension or definite extraprostatic extension/invasive behavior

PI-RADS ASSESSMENT FOR T2W

2. PI-RADS Assessment for T2W

Score	Peripheral Zone (PZ)
1	Uniform hyperintense signal intensity (normal)
2	Linear or wedge-shaped hypointensity or diffuse mild hypointensity, usually indistinct margin
3	Heterogeneous signal intensity or non-circumscribed, rounded, moderate hypointensity Includes others that do not qualify as 2, 4, or 5
4	Circumscribed, homogenous moderate hypointense focus/mass confined to prostate and <1.5 cm in greatest dimension
5	Same as 4 but ≥1.5cm in greatest dimension or definite extraprostatic extension/invasive behavior

Score	Transition Zone (TZ)
1	Normal appearing TZ (rare) or a round, completely encapsulated nodule. ("typical nodule")
2	A mostly encapsulated nodule OR a homogeneous circumscribed nodule without encapsulation ("atypical nodule") OR a homogeneous mildly hypointense area between nodules
3	Heterogeneous signal intensity with obscured margins Includes others that do not qualify as 2, 4, or 5
4	Lenticular or non-circumscribed, homogeneous, moderately hypointense, and <1.5 cm in greatest dimension
5	Same as 4, but ≥1.5cm in greatest dimension or definite extraprostatic extension/invasive behavior

IMAGE INTERPRETATION: DCE

PI-RADS v2.1

Score	Peripheral Zone (PZ) or Transition Zone (TZ)
(–)	**no early or contemporaneous enhancement; or diffuse multifocal enhancement NOT corresponding to a focal finding on T2W and/or DWI or focal enhancement corresponding to a lesion demonstrating features of BPH on T2WI (including features of extruded BPH in the PZ)**
(+)	**focal, and; earlier than or contemporaneously with enhancement of adjacent normal prostatic tissues, and; corresponds to suspicious finding on T2W and/or DWI**

PI-RADS ASSESSMENT

Peripheral Zone (PZ)

DWI	T2W	DCE	PI-RADS
1	Any*	Any	1
2	Any	Any	2
3	Any	–	3
		+	4
4	Any	Any	4
5	Any	Any	5

* "Any" indicates 1-5

Transition Zone (TZ)

T2W	DWI	DCE	PI-RADS
1	Any*	Any	1
2	≤3	Any	2
	≥4	Any	3
3	≤4	Any	3
	5	Any	4
4	Any	Any	4
5	Any	Any	5

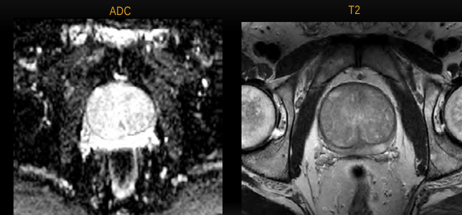
* "Any" indicates 1-5

MIMICS

- Low signal on T2 seen in fibrosis/scarring, stromal BPH, inflammation, infection, treatment, post-biopsy hemorrhage
- Diffusion restriction seen in fibrosis/scarring, dysplasia, stromal BPH
- Increased enhancement rate and total enhancement seen in prostatitis and hypervascular or stromal BPH

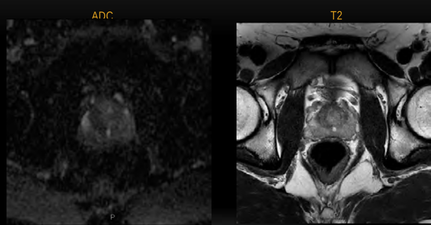
PI-RADS 1: VERY LOW (CLINICALLY SIGNIFICANT CANCER IS HIGHLY UNLIKELY TO BE PRESENT)

ADC T2



No Hypointense Foci on ADC, Enlarged Central Gland Consistent with Benign Prostatic Hypertrophy

PI-RADS 2: LOW (CLINICALLY SIGNIFICANT CANCER IS UNLIKELY TO BE PRESENT)

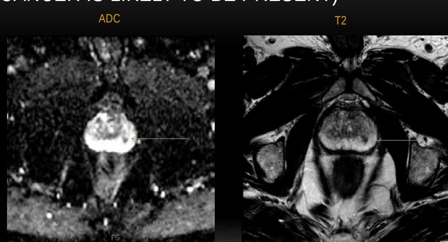


Mild dark T2/ADC signal throughout the prostate which is non-focal or mass-like.

PI-RADS 3: INTERMEDIATE (THE PRESENCE OF CLINICALLY SIGNIFICANT CANCER IS EQUIVOCAL)

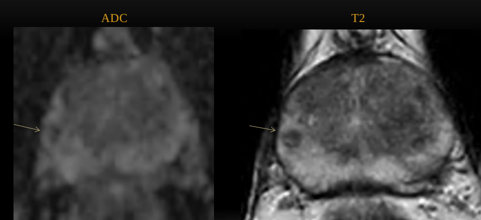
Heterogenous T2 & Mildly hypointense ADC peripheral focus with no early enhancement

PI-RADS 4: HIGH (CLINICALLY SIGNIFICANT CANCER IS LIKELY TO BE PRESENT)



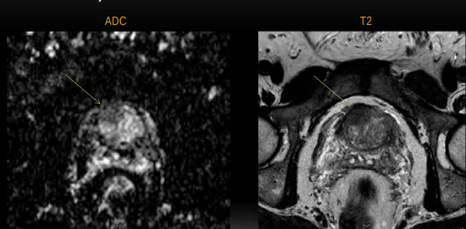
Gleason 4+3; hypointense lesion <1.5 cm

PI-RADS 4: HIGH (CLINICALLY SIGNIFICANT CANCER IS LIKELY TO BE PRESENT)



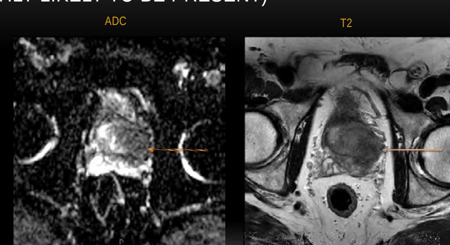
Hypointense peripheral zone lesion < 1.5cm.

PI-RADS 5: VERY HIGH (CLINICALLY SIGNIFICANT CANCER IS HIGHLY LIKELY TO BE PRESENT)



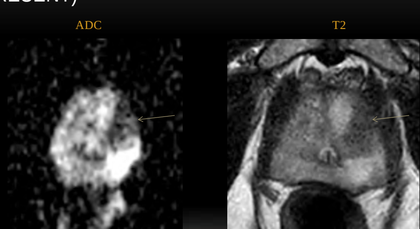
Gleason 4+3; right anterior prostate hypointense lesion >1.5 cm

PI-RADS 5: VERY HIGH (CLINICALLY SIGNIFICANT CANCER IS HIGHLY LIKELY TO BE PRESENT)



Gleason 4+3; left lateral/posterior hypointense lesion >1.5 cm, extracapsular extension into seminal vesicle

PI-RADS 5: VERY HIGH (CLINICALLY SIGNIFICANT CANCER IS HIGHLY LIKELY TO BE PRESENT)



Hypointense transitional zone lesion ≥1.5cm

ASSESSMENT OF T2W

PI-RADS v2.1

Score	Transition Zone (TZ)
1	Normal appearing TZ (rare) or a round, completely encapsulated nodule. (“typical nodule”)
2	A mostly encapsulated nodule OR a homogeneous circumscribed nodule without encapsulation. “atypical nodule”) OR a homogeneous mildly hypointense area between nodules
3	Heterogeneous signal intensity with obscured margins Includes others that do not qualify as 2, 4, or 5
4	Lenticular or non-circumscribed, homogeneous, moderately hypointense, and <1.5 cm in greatest dimension
5	Same as 4, but ≥1.5cm in greatest dimension or definite extraprostatic extension/invasive behavior

IMAGE INTERPRETATION: TRANSITION ZONE (TZ)

T2W score of 2:

A mostly encapsulated nodule

A homogeneous circumscribed nodule without encapsulation

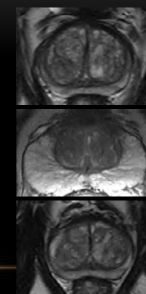
A homogeneous mildly hypointense area between nodules

IMAGE INTERPRETATION: TZ

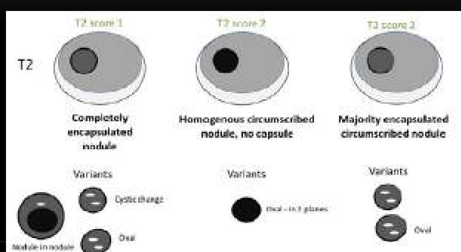
Only score nodules or lesions/regions between nodules that differ from the background TZ.

Findings similar to the background should ***NOT*** be scored.

Typical BPH nodules (i.e., round, completely encapsulated nodules) are now ***NOT*** scored.



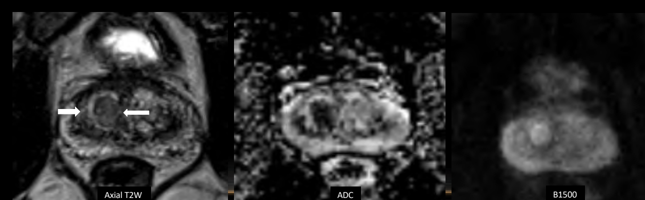
SCHEMATIC DIAGRAM OF FEATURES OF NODULES IN THE TZ AND THEIR CORRESPONDING SCORES



Turkbey et al. Eur Urol 2019

ENCAPSULATED NODULE

- PI-RADS 1



ENCAPSULATED NODULE

- PI-RADS 1

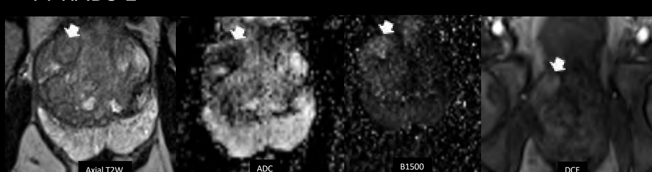


IMAGE INTERPRETATION: TRANSITION ZONE

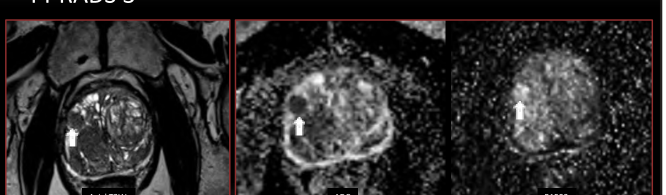
In TZ, ***DWI score of 4 or 5*** now ***elevates*** the overall PI-RADS assessment category from 2 to 3 for lesions receiving a T2W score of 2.

T2W	DWI	DCE	PI-RADS
1	Any*	Any	1
2	≤3	Any	2
	≥4	Any	3
3	≤4	Any	3
	5	Any	4
4	Any	Any	4

The only change in deriving the overall PI-RADS assess ment cate gory, compared to PI-RADS v2, concerns TZ lesions with T 2W score of 2.

ATYPICAL TZ NODULE

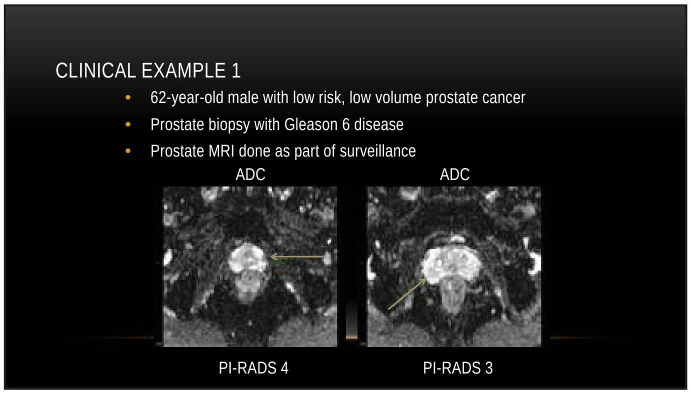
- PI-RADS 3

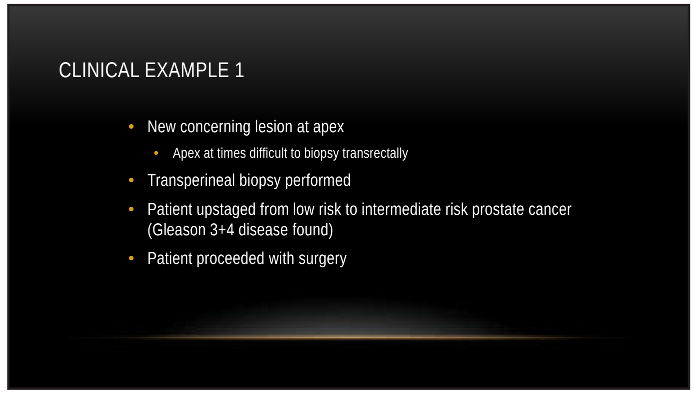


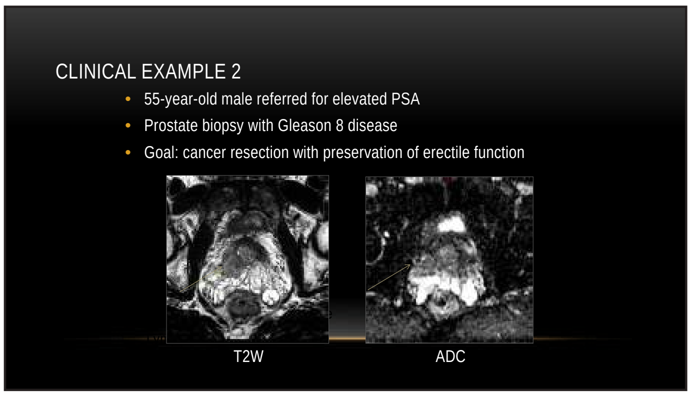
TZ: 2 DWI:4

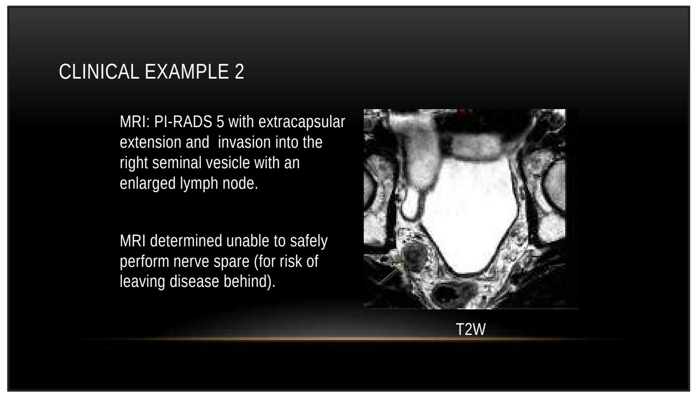
Homogeneous mostly encapsulated nodule

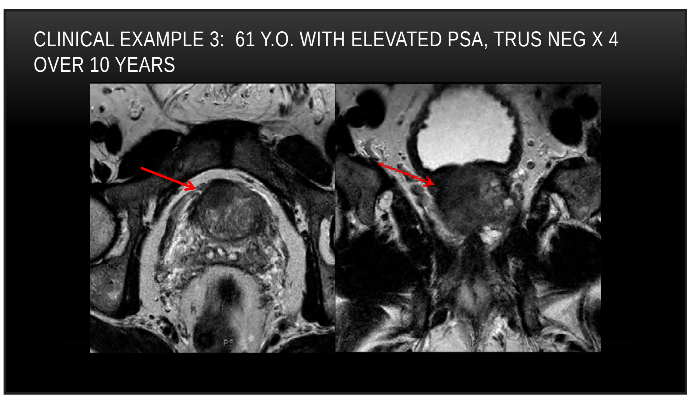
CLINICAL CASES

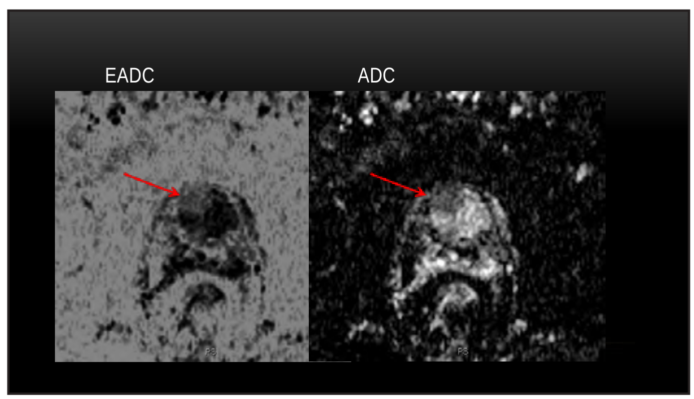

CLINICAL EXAMPLE 1
62-year-old male with low risk, low volume prostate cancer
Prostate biopsy with Gleason 6 disease
Prostate MRI done as part of surveillance
ADC
ADC
PI-RADS 4
PI-RADS 3


CLINICAL EXAMPLE 1
New concerning lesion at apex
Apex at times difficult to biopsy transrectally
Transperineal biopsy performed
Patient upstaged from low risk to intermediate risk prostate cancer (Gleason 3+4 disease found)
Patient proceeded with surgery

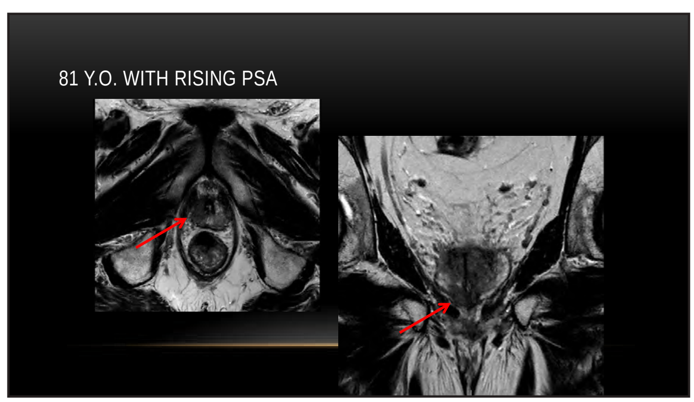

CLINICAL EXAMPLE 2
55-year-old male referred for elevated PSA
Prostate biopsy with Gleason 8 disease
Goal: cancer resection with preservation of erectile function
T2W
ADC


CLINICAL EXAMPLE 2
MRI: PI-RADS 5 with extracapsular extension and invasion into the right seminal vesicle with an enlarged lymph node.
MRI determined unable to safely perform nerve spare (for risk of leaving disease behind).
T2W


CLINICAL EXAMPLE 3: 61 Y.O. WITH ELEVATED PSA, TRUS NEG X 4 OVER 10 YEARS

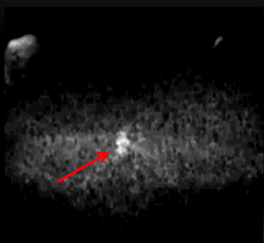

EADC
ADC


PIRADS 5
EARLY CONTRAST: PROSTATECTOMY GLEASON 4+3

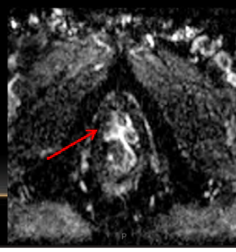

81 Y.O. WITH RISING PSA

PIRADS 5

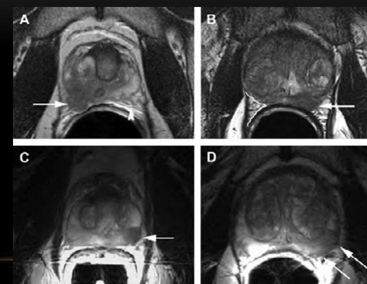
DWI B990



ADC

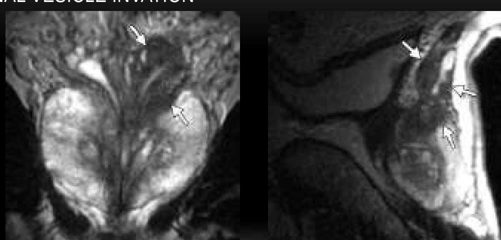


NEUROVASCULAR BUNDLE INVASION



Jung AJ, Westphalen AC. Imaging Prostate CancerRadiol Clin North Am. 2012 Nov;50(6):1043-59. doi: 10.1016/j.rcl.2012.08.001.

SEMINAL VESICLE INVATION



RadioGraphics,
http://pubs.rsna.org/doi/abs/10.1148/rg.313105139

Published in: David Bonekamp; Michael A. Jacobs; Riham El-Khouli; Dan Stoianovici; Katarzyna J. Macura; *RadioGraphics* **2011,** 31, 677-703.

CONCLUSION

- Prostate MRI is beneficial for surveillance and characterization of prostate cancer
- Its use in surveillance is being validated by longitudinal studies
- PI-RADS 2.1 scores lesions in the prostate based on their likelihood to be clinically significant cancer

THANK YOU FOR YOUR ATTENTION

Robert Marks, MD, FSAR
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UC San Diego
SCHOOL OF MEDICINE
Department of Radiology

SELF EVALUATION

Prostate MRI

True/False

1. 1 in 10 men will get prostate cancer in their lifetime.

2. An ADC cutoff value of 700 mm2/s is diagnostic of a high-grade prostate cancer?

3. For a lesion to be PI-RADS 5 in the peripheral zone, it must meet the criteria of PI-ADS 4 AND be greater than 1.5 cm OR have extraprostatic extension.

4. In the transition zone, an atypical nodule is defined as either a mostly encapsulated nodule or a homogenous circumscribed nodule without encapsulation.

5. In order to upgrade a PI-RADS 3 lesion in the transition zone to PI-RADS 4, it must have early contrast enhancement on dynamic post contrast imaging.

Answer Key: 1. F, 2. F, 3. T, 4. T, 5. F

Female Infertility and GYN Cancer Imaging

Robert M. Marks, MD

Objectives

- Understand the causes of female infertility
- Review the imaging findings of causes of female infertility
- Be able to use imaging findings to properly stage endometrial and cervical cancer
- Apply MRI O-RADS for risk stratification of ovarian tumors

Infertility

- Definition:
  - The inability to conceive after 1 year of unprotected intercourse
- The Problem:
  - 6% of married women aged 15 to 44 years in the United States report infertility
  - 12% of women aged 15 to 44 years in the United States have difficulty getting pregnant or carrying a pregnancy to term

What about men???

- In about 35% of couples with infertility, a male factor is identified along with a female factor
- In about 8% of couples with infertility, a male factor is the only identifiable cause
- Not just a female problem….
- This talk is going to focus on imaging of female infertility

Infertility Workup

- Workup is multifactorial with a history, physical, semen samples…
- And of course…imaging!
  - Ultrasound
  - Hysterosalpingogram
  - MRI

Ultrasound

- First line study
- Both Transabdominal and Transvaginal
- Many advantages
  - Readily available, inexpensive, easy to perform, and no radiation
  - Excellent in diagnosing fibroids, endometrial polyps/masses, and the ovaries
  - 3D Ultrasound is highly accurate in diagnosing müllerian duct anomalies and endometrial masses
  - Saline Infused Hysterosonography (SIS), allows for delineation of the endometrium surface and patency of the fallopian tubes

Hysterosalpinogography (HSG)

- Excellent examination for evaluation of the fallopian tubes and intrauterine filling defects
- Saline, or oil, infused via catheter into uterine cavity under fluoroscopy
  - Invasive procedure, uses ionizing radiation, limited scope of findings
- Perform between days 7-12 of menstrual cycle
  - Always confirm negative pregnancy test prior to exam

Magnetic Resonance Imaging (MRI)

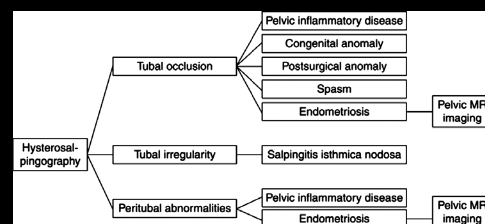
- Excellent examination for:
  - Müllerian Duct Anomalies
  - Uterine abnormalities
    - Adenomyosis
    - Fibroids
    - Endometriomas/Endometriosis
  - Advantages
    - Non-invasive, no radiation, wider field of view than US
  - Disadvantages
    - Expensive

The Break Down

- Female infertility can be broken down into abnormalities of the:
  - Fallopian Tubes and Peritubal area
  - Uterus
  - Cervix
  - Ovaries

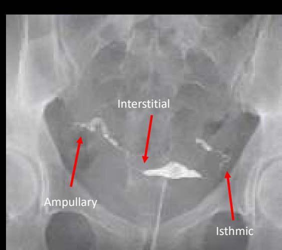
Fallopian Tube Abnormalities

- Most common cause of infertility
  - 30-40% of all cases
- Hysterosalpingography is first line in imaging
  - Optimal detection of:
    - Tubal patency
    - Tubal occlusion
    - Tubal irregularity
    - Peritubal disease



Steinkeler JA, Woodfield CA, Lazarus E, Hillstrom MM. Female infertility: a systematic approach to radiologic imaging and diagnosis. Radiographics. 2009 Sep-Oct;29(5):1353-70. doi: 10.1148/rg.295095047. PMID: 19755600.

Portions of the Fallopian Tube



Normal HSG

27-year-old female with infertility

23-year-old female with infertility

Salpingitis Isthmica Nodosa

32-year-old female with history of tubo-ovarian abscess on the left

Peritubal Adhesions

https://radiologykey.com/tubal-abnormalities/

32-year-old female with infertility

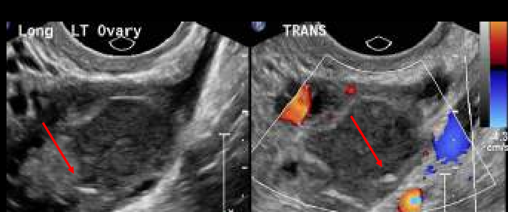
Endometriomas/Endometriosis

- Up to 50% of women with endometriosis are infertile
- 20% of infertile women have endometriosis
- Prescence of endometrial glands and stroma outside of the uterus
- Symptoms vary:
  - Asymptomatic
  - Pelvic pain
  - Infertility

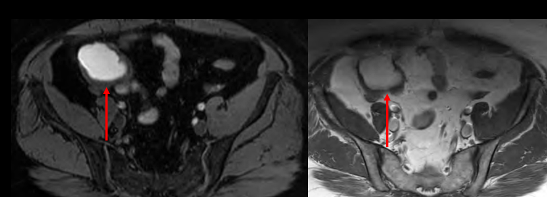
Endometriomas/Endometriosis

- First line imaging is Ultrasound
  - Followed by MRI if necessary
- Ultrasound appearance
  - Adnexal mass with faint or low-level echoes and highly echogenic mural foci
- MR appearance
  - Thick-walled cyst that is T1 Bright with T2 “shading”
  - T2 Dark Spot sign: highly specific for endometrioma
  - Serosal endometrial implants are T1 bright (however sensitivity on MR is low <20%)
    - Laparoscopy is usually indicated for the diagnosis

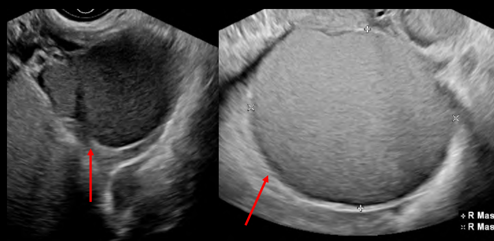
Endometriomas/Endometriosis



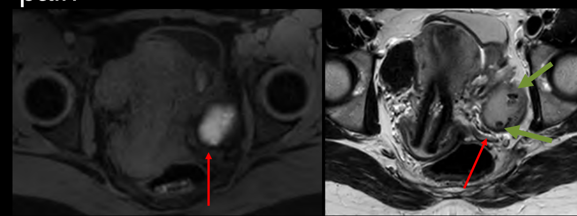
41 y.o. female with pelvic pain



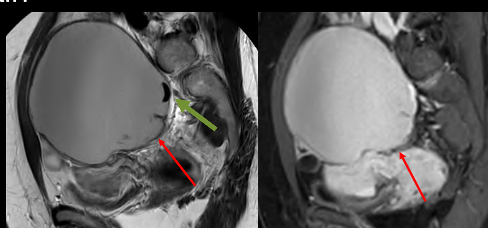
34 y.o. female with infertility and pelvic pain



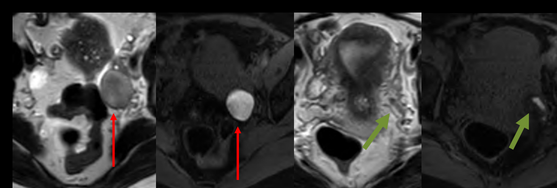
34 y.o. female with infertility and pelvic pain



34 y.o. female with infertility and pelvic pain



43 y.o. female with pelvic pain



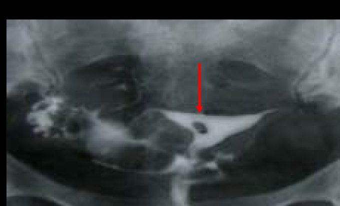
Uterus

- Intrauterine Filling Defects
- Uterine Contour Irregularities
- Müllerian Duct Anomalies

Intrauterine Filling Defects

- HSG, US, and MRI are all useful diagnostic exams
- Synechiae
  - Caused by infection, iatrogenic trauma (D&C, IUD, C-section)
  - Infertility caused by adhesions known as Asherman Syndrome
- Endometrial polyps and submucosal fibroids
  - SIS is excellent in determining number and location
  - Submucosal fibroids
    - Appear as hypoechoic masses that distort the endometrium
  - Polyps
    - Echogenic intravcavitary masses, may be party cystic, and have a vascular stalk

Synechiae

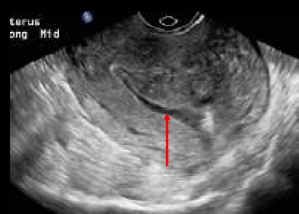


Ahmadi F, Siahbazi S, Akhbari F, Eslami B, Vosough A. Hysterosalpingography finding in intra uterine adhesion (asherman' s syndrome): a pictorial essay. *Int J Fertil Steril*. 2013;7(3):155-160.

Synechiae

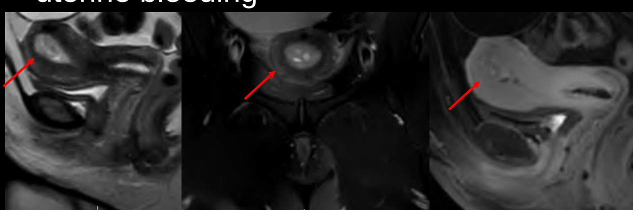
Steinkeler JA, Woodfield CA, Lazarus E, Hillstrom MM. Female infertility: a systematic approach to radiologic imaging and diagnosis. Radiographics. 2009 Sep-Oct;29(5):1353-70. doi: 10.1148/rg.295095047. PMID: 19755600.

39-year-old female with infertility



35-year-old female with infertility

51-year-old female with dysfunctional uterine bleeding



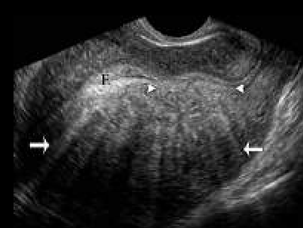
Uterine Contour Abnormalities

- Ultrasound and MRI are the studies of choice
  - Adenomyosis
  - Leiomyomas
  - Müllerian Duct Anomalies

Adenomyosis

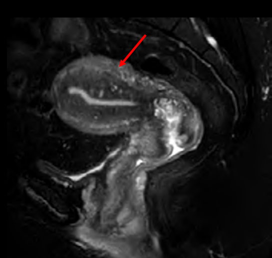
- Ultrasound
  - Globular uterine enlargement
  - Heterogenous myometrial echotexture
  - Indistinct endometrial/myometrial interface
  - Indistinct lesion borders
- MRI
  - Highly sensitive and specific
  - Thickening of junctional zone > 12mm
  - T2 bright "cysts" in junctional zone

Adenomyosis

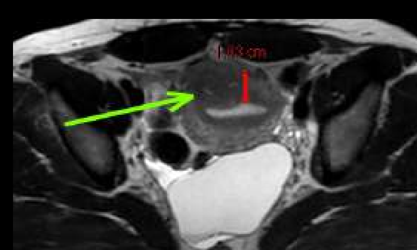


Steinkeler JA, Woodfield CA, Lazarus E, Hillstrom MM. Female infertility: a systematic approach to radiologic imaging and diagnosis. Radiographics. 2009 Sep-Oct;29(5):1353-70. doi: 10.1148/rg.295095047. PMID: 19755600.

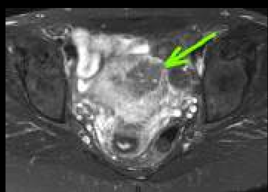
25 y.o. female with infertility

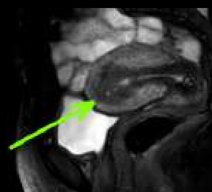


29 y.o. female with abnormal ultrasound



34 y.o. female with pelvic pain





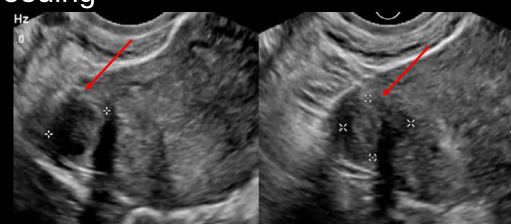
Leiomyomas

- The most common benign mass and most common cause of uterine enlargement in non-pregnant women
- May be submucosal, intramural, subserosal, or pedunculated
- Causes infertility by interfering with embryo implantation when fibroids are submucosal or are numerous
- Women with multiple fibroids have increased risk for early spontaneous fetal loss

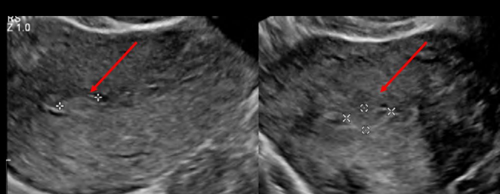
Leiomyomas

- Ultrasound
  - Hypoechoic mass that may be have accompanying acoustic shadow
  - Submucosal fibroids may distort the endometrium
- MRI
  - Focal masses hypointense to myometrium on T2-weighted imaging

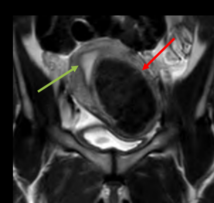
23 y.o. female with dysfunctional uterine bleeding

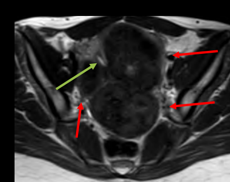


23 y.o. female with dysfunctional uterine bleeding

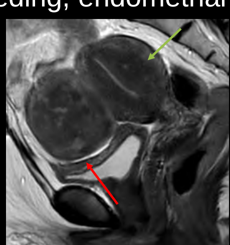


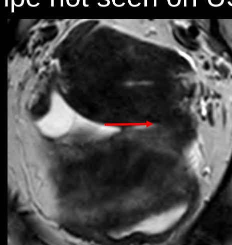
36 y.o. female with dysfunctional uterine bleeding



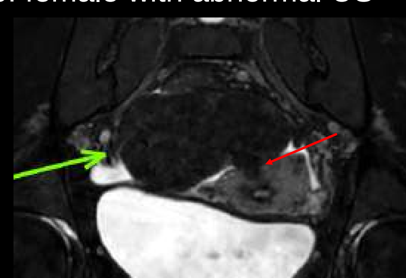


56 y.o. female with dysfunctional uterine bleeding, endometrial stripe not seen on US





37 y.o. female with abnormal US



Müllerian Duct Anomalies

- Müllerian duct anomalies cause alteration in the uterus contours which can cause female infertility
- Present in 1-5% of the general population
- 13-25% of women with müllerian duct anomalies have reproductive problems
  - Spontaneous abortions
  - Prematurity
  - Intrauterine growth retardation
  - Abnormal fetal lie

Müllerian Duct Anomalies

- Embryology
  - In the first 6 weeks, the male and female embryo are indistinguishable
    - Have paired mesonephric (male) and paramesonephric (female) ducts
    - In a female embryo, at 6 weeks, the absence of müllerian-inhibiting factor (which is carried on the Y chromosome), promotes
      - Growth of the paired müllerian-ducts
      - Regression of the wolffian-ducts
    - Interruption of müllerian-duct development leads to aplasia/hypoplasia of vagina, cervix, or uterus

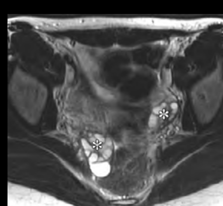
Müllerian Duct Anomalies

- Embryology
  - Müllerian duct growth is associated with fusion of the paired ducts
    - Interruption of fusion leads to
      - Didelphys
      - Bicornuate
  - Between 9-12 weeks gestation the fused müllerian ducts reabsorb the intervening uterovaginal septum
    - Interruption of septum resorption leads to
      - Septate
      - Arcuate
    - By 22 weeks gestation the process is complete

Müllerian Duct Anomalies

- Imaging
  - HSG may show an abnormal shape of the endometrium
    - Cannot reliably differentiate between subtypes of MDAs
  - Ultrasound (especially 3D US) and MRI are excellent at diagnosing the type of MDA
    - Also can easily look for presence of both kidneys

Mayer-Rokitansky-Küster-Hauser syndrome

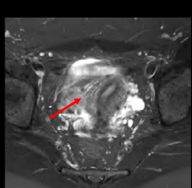


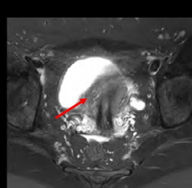
Behr SC, Courtier JL, Qayyum A. Imaging of müllerian duct anomalies. Radiographics. 2012 Oct;32(6):E233-50. doi: 10.1148/rg.326125515. PMID: 23065173.

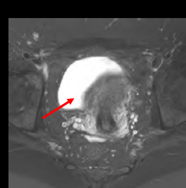
Unicornuate Uterus

- Normal development of one müllerian duct, near complete-to-complete arrested development of other duct
- May have a rudimentary horn with or without endometrium
  - If it has endometrium, can lead to
    - Pelvic pain due to endometriosis
    - Miscarriage, ectopic pregnancy, and uterine rupture
  - High association with renal anomalies (agenesis) on side ipsilateral to rudimentary horn

25 y.o. female with infertility

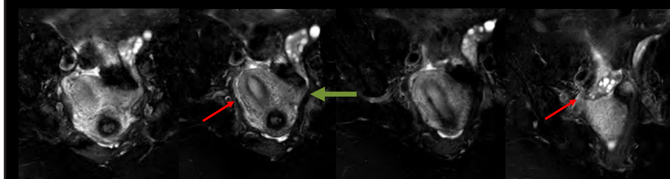






36 y.o. female with infertility

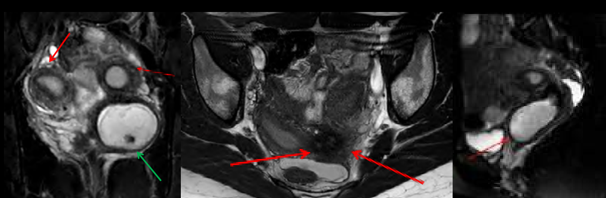
36 y.o. female with infertility



Uterus Didelphys

- Results from failed ductal fusion
- Two widely divergent uterine horns
  - Two cervixes
- 75% will have longitudinal vaginal septum
  - With or without a unilateral horizonal vaginal septum
    - Causing hematometrocolpos
- Can be treated with metroplasty for patients with recurrent spontaneous abortions or preterm labor
  - Benefits of surgery are unclear

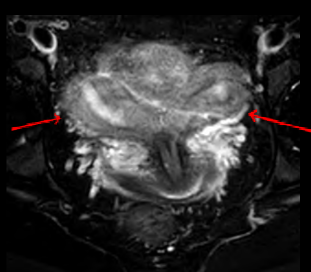
25 y.o. female with infertility



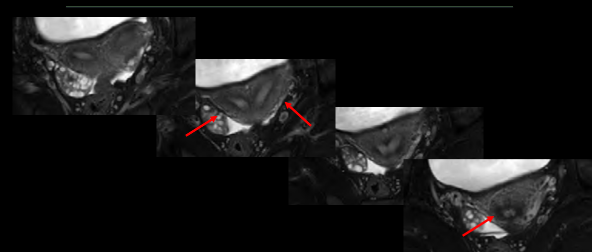
Bicornuate Uterus

- Incomplete fusion of müllerian ducts
  - 10% of MDAs
  - May have two cervices
- Imaging shows two symmetric but widely divergent uterine horns
  - Deep > 1cm fundal cleft
  - Intercornual distance of > 4 cm

19 y.o. female with abnormal ultrasound



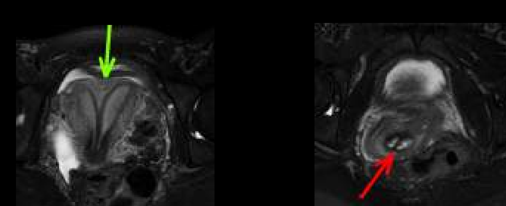
22 y.o. female with abnormal ultrasound



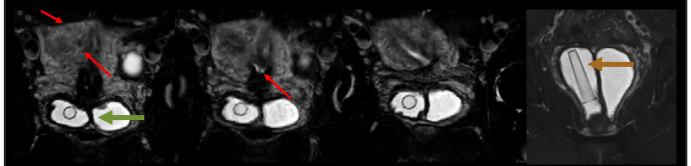
Septate Uterus

- Partial or incomplete resorption of müllerian duct fusion
  - Most common MDA (55%)
  - Two uterine horns
    - Normal convex, flat, or minimally concave fundal contour
    - May have a thin fibrous septum
    - May have a thick muscular septum
- Spontaneous AB rate the highest of all MDAs
  - Rates ranging between 26-94% in literature
  - Septum can be resected

Septate Uterus



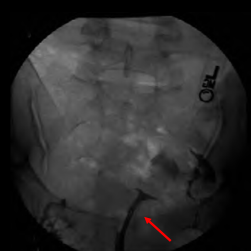
27 y.o. female with infertility and abnormal HSG



Arcuate and DES uterine anomalies

- Arcuate is considered a normal variant
  - Very shallow broad-based impression on fundal contour
  - No effect on fertility
- DES-related uterine anomalies
  - Between 1945-1970 DES was used for prevention of spontaneous abortions
  - Female fetuses exposed to DES are at risk of
    - Hypoplastic uterus with a T-shape, fallopian tube stricturing
      - High risk for SAB, pre-term delivery, ectopic pregnancy
    - Vaginal clear cell carcinoma
    - 1990's DES used for advanced prostate and breast cancer
    - Ely Lilly took it off the market in 1997

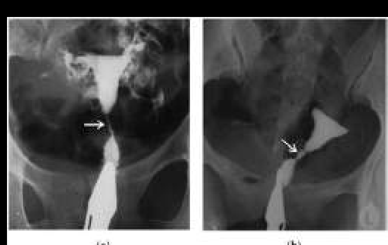
DES exposure



Cervix

- Cervical stenosis defined as narrowing that prevents a 2.5 mm dilator
  - Congenital or secondary to trauma/infection
    - Prior cone biopsy, cryotherapy, biopsy for cervical dysplasia
  - Causes inability of sperm to enter upper genital tract
  - Impediment to fertility treatments

Cervical Stenosis



Zafarani F, Ahmadi F, Shahrzad G. Hysterosalpingographic features of cervical abnormalities: acquired structural anomalies. Br J Radiol. 2015 Aug;88(1052):20150045. doi: 10.1259/bjr.20150045. Epub 2015 May 29. PMID: 26111269; PMCID: PMC4651374.

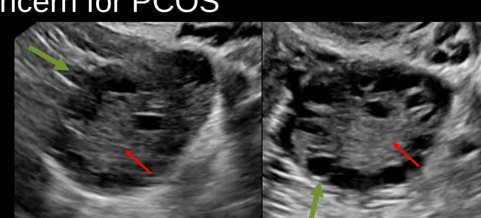
Ovarian Abnormalities

- Ovarian causes of infertility include
  - Non-functional ovaries
  - Premature ovarian failure
  - Gonadal dysgenesis
- Polycystic Ovarian Syndrome
  - Affects 8% of women
  - A common cause of infertility
  - Women have hyperandrogenism
    - Leads to overproduction of luteinizing hormone
      - Incomplete ovulatory cycles

Polycystic Ovarian Syndrome

- Morphologic changes seen in 80% of affected women
  - Ultrasound is best imaging modality
  - Enlarged ovaries, increased echogenicity of ovarian stroma (most sensitive finding)
    - Increased number of small peripheral cysts (at least 12)
  - Ultrasound findings are not diagnostic
    - 20-30% of normal population of women may have ovaries with this appearance
    - Functional disorder

27 y.o. female with pelvic pain and concern for PCOS



In Summary

- Pelvic causes of female infertility include tubal, peritubal, uterine, endometrial, cervical, and ovarian abnormalities
- HSG is a powerful exam for tubal and peri-tubal abnormalities
- Ultrasound is a great first line exam for almost all other anomalies
- MRI is a powerful examination for uterine causes of infertility

And now let's talk about something completely different…..

- GYN Malignancies and MRI

The Big Four

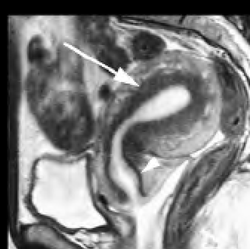
- Normal Anatomy on MRI
- Endometrial carcinoma
- Cervical carcinoma
- Ovarian Cancer

The Uterus

https://my.clevelandclinic.org/health/body/22467-uterus

The Uterus

- T2 weighted imaging
  - Zonal anatomy
- Endometrial Stripe
  - T2 Bright
  - Thickness Varies
    - 5-7 mm = early proliferative phase
    - 7-16 mm = secretory phase



The Uterus

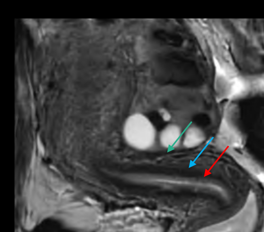
- T2 weighted imaging
  - Zonal anatomy
- Junctional Zone
  - Low signal
  - Up to 12 mm normal
- Disruption of the junctional zone serves as a sensitive marker for myometrial invasion by endometrial carcinoma

The Uterus

- T2 weighted imaging
  - Zonal anatomy
- Myometrium
  - Intermediate signal

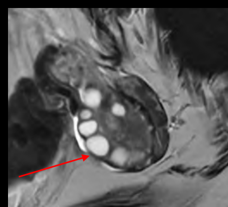
The Cervix

- T2 weighted imaging
  - Zonal anatomy
- Three layers
  - Central hyperintensity = mucus in endocervical canal + endocervix (columnar epi)
  - Low signal fibrous stroma
  - Intermediate signal myometrium



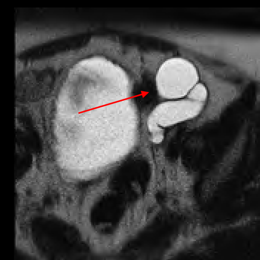
The Ovaries

- T2 weighted imaging
- Follicular activity



The Fallopian Tubes

- T2 weighted imaging
- Typically not seen on MRI due to narrow caliber
- Can be T2 bright in hydrosalpinx



Endometrial Cancer

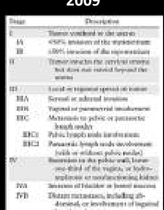
- Most common malignant tumor of female genital tract
- Most cases
  - Early stage
  - 75% occur in postmenopausal women
  - Vaginal bleeding

Endometrial Cancer

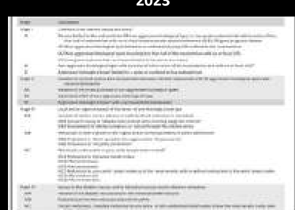
- Risk Factors
  - Increased estrogen exposure
    - Hormonal replacement
  - Obesity
  - Early menarche
  - Late menopause
  - Nulliparity
  - PCOS
  - Hereditary non-polyposis colorectal cancer (Lynch syndrome type 2)

FIGO Changes Over Time

2009



2023



Why the Change?

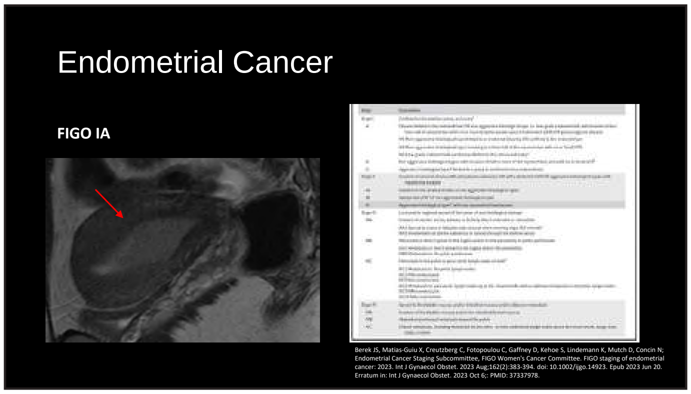
- Since 2009 new information has emerged that better defines pathology and molecular findings of endometrial carcinoma
- New treatments, clinical trails, and survival data that correlate with pathologic and surgical findings

Endometrial Cancer

Berek JS, Matias-Guiu X, Creutzberg C, Fotopoulou C, Gaffney D, Kehoe S, Lindemann K, Mutch D, Concin N; Endometrial Cancer Staging Subcommittee, FIGO Women's Cancer Committee. FIGO staging of endometrial cancer: 2023. Int J Gynaecol Obstet. 2023 Aug;162(2):383-394. doi: 10.1002/ijgo.14923. Epub 2023 Jun 20. Erratum in: Int J Gynaecol Obstet. 2023 Oct 6;: PMID: 37337978.

Endometrial Cancer

- Two main types
- Type 1 (80-95%) of cases
  - Estrogen dependent
  - Younger patients
  - Early-stage diagnosis with vaginal bleeding
  - Grade 1-2: endometrioid adenocarcinoma
- Type 2 (10-15%) of cases
  - Postmenopausal women
  - Advanced stage 60%
  - Includes grade 3 endometrioid adenocarcinomas
  - Other rare etiologies: clear cell carcinoma, undifferentiated serous carcinoma, and carcinosarcoma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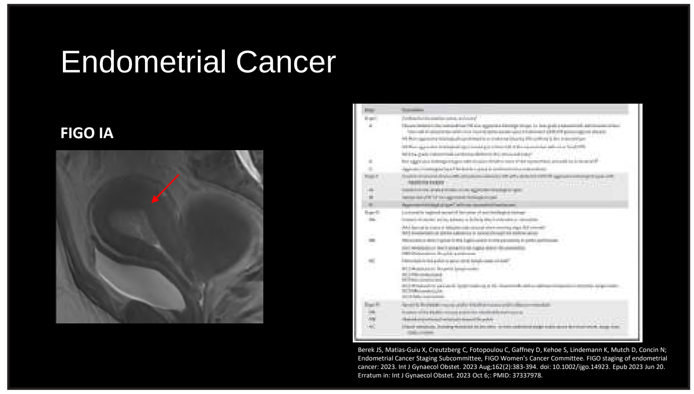
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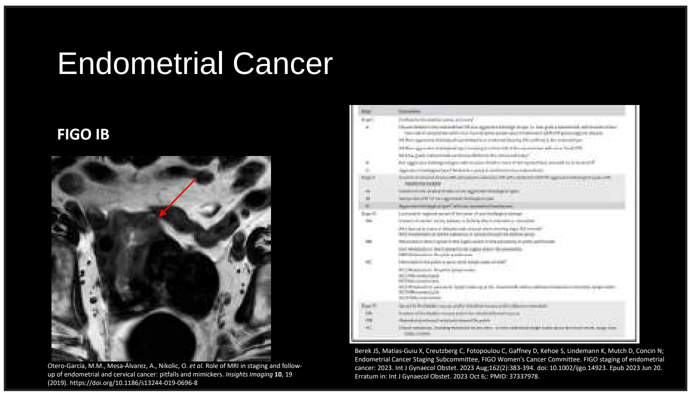
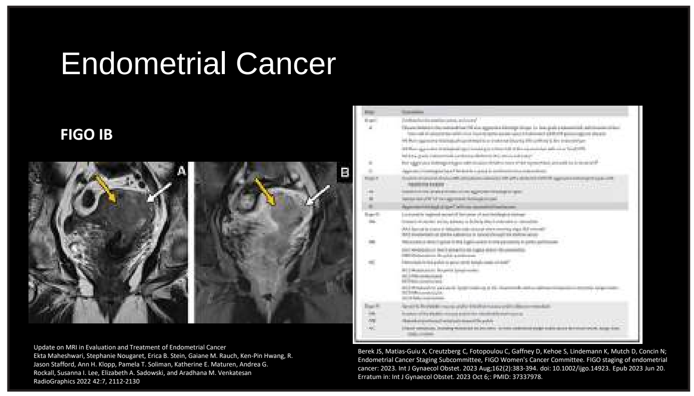
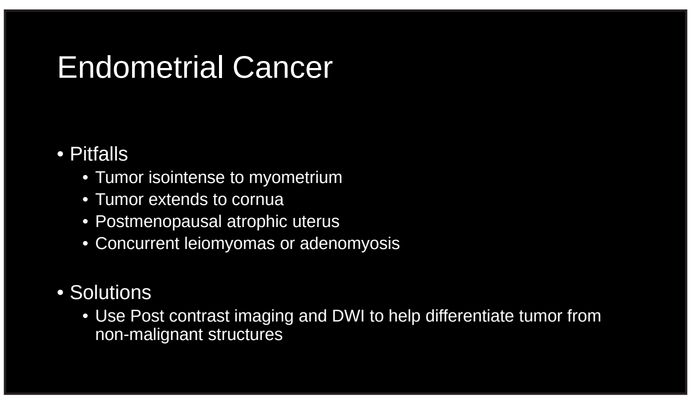
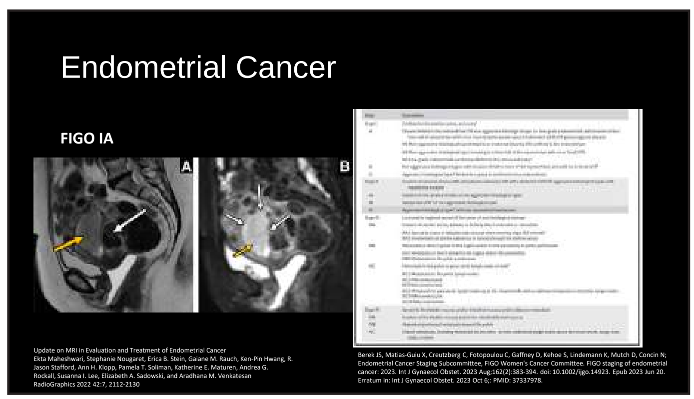

Endometrial Cancer
FIGO IB
Otero-García, M.M., Mesa-Álvarez, A., Nikolic, O. et al. Role of MRI in staging and follow-up of endometrial and cervical cancer: pitfalls and mimickers. Insights Imaging 10, 19 (2019). https://doi.org/10.1186/s13244-019-0696-8
Berek JS, Matias-Guiu X, Creutzberg C, Fotopoulou C, Gaffney D, Kehoe S, Lindemann K, Mutch D, Concin N; Endometrial Cancer Staging Subcommittee, FIGO Women's Cancer Committee. FIGO staging of endometrial cancer: 2023. Int J Gynaecol Obstet. 2023 Aug;162(2):383-394. doi: 10.1002/ijgo.14923. Epub 2023 Jun 20. Erratum in: Int J Gynaecol Obstet. 2023 Oct 6;: PMID: 37337978.


Endometrial Cancer
FIGO IB
A
B
Update on MRI in Evaluation and Treatment of Endometrial Cancer
Ekta Maheshwari, Stephanie Nougaret, Erica B. Stein, Gaiane M. Rauch, Ken-Pin Hwang, R. Jason Stafford, Ann H. Klopp, Pamela T. Soliman, Katherine E. Maturen, Andrea G. Rockall, Susanna I. Lee, Elizabeth A. Sadowski, and Aradhana M. Venkatesan
RadioGraphics 2022 42:7, 2112-2130
Berek JS, Matias-Guiu X, Creutzberg C, Fotopoulou C, Gaffney D, Kehoe S, Lindemann K, Mutch D, Concin N; Endometrial Cancer Staging Subcommittee, FIGO Women's Cancer Committee. FIGO staging of endometrial cancer: 2023. Int J Gynaecol Obstet. 2023 Aug;162(2):383-394. doi: 10.1002/ijgo.14923. Epub 2023 Jun 20. Erratum in: Int J Gynaecol Obstet. 2023 Oct 6;: PMID: 37337978.


Endometrial Cancer
• Pitfalls
• Tumor isointense to myometrium
• Tumor extends to cornua
• Postmenopausal atrophic uterus
• Concurrent leiomyomas or adenomyosis
• Solutions
• Use Post contrast imaging and DWI to help differentiate tumor from non-malignant structures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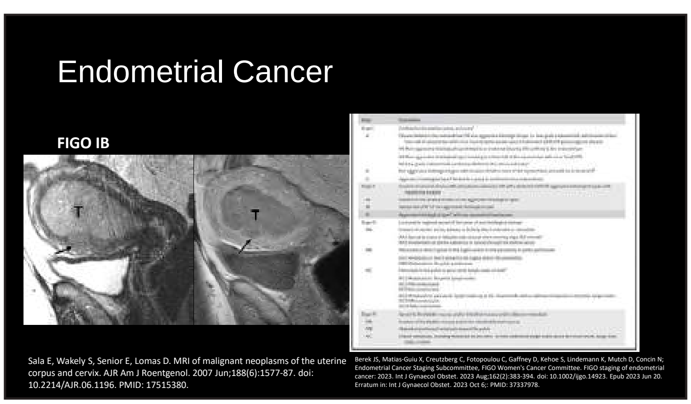
Endometrial Cancer
FIGO IB
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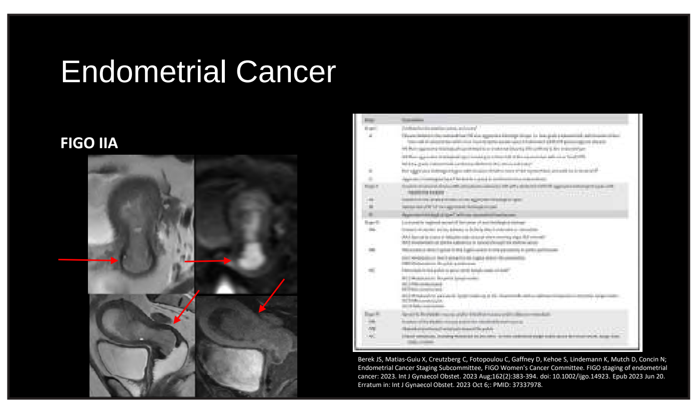
Sala E, Wakely S, Senior E, Lomas D. MRI of malignant neoplasms of the uterine corpus and cervix. AJR Am J Roentgenol. 2007 Jun;188(6):1577-87. doi: 10.2214/AJR.06.1196. PMID: 17515380.
Berek JS, Matias-Guiu X, Creutzberg C, Fotopoulou C, Gaffney D, Kehoe S, Lindemann K, Mutch D, Concin N; Endometrial Cancer Staging Subcommittee, FIGO Women's Cancer Committee. FIGO staging of endometrial cancer: 2023. Int J Gynaecol Obstet. 2023 Aug;162(2):383-394. doi: 10.1002/ijgo.14923. Epub 2023 Jun 20. Erratum in: Int J Gynaecol Obstet. 2023 Oct 6;: PMID: 37337978.


Endometrial Cancer
FIGO IIA
Berek JS, Matias-Guiu X, Creutzberg C, Fotopoulou C, Gaffney D, Kehoe S, Lindemann K, Mutch D, Concin N; Endometrial Cancer Staging Subcommittee, FIGO Women's Cancer Committee. FIGO staging of endometrial cancer: 2023. Int J Gynaecol Obstet. 2023 Aug;162(2):383-394. doi: 10.1002/ijgo.14923. Epub 2023 Jun 20. Erratum in: Int J Gynaecol Obstet. 2023 Oct 6;: PMID: 37337978.

Cervical Cancer

- 4th most common cancer in women worldwide
- 99% of cases are associated with the human papilloma virus
  - HIV increases risk 6-fold
- Primary prevention is vaccination against HPV
  - Secondary prevention is screen testing for HPV DNA and early treatment of precancerous lesions

Cervical Cancer

- May be clinically silent
- May present with:
  - Pelvic pain
  - Abnormal bleeding
  - Dyspareunia

Cervical Cancer

- World Health Organization Classification
- Epithelial Tumors
  - Squamous 70-80% of cases
  - Adenocarcinoma 20-25% of cases
  - Other
    - Adenosquamous
    - Neuroendocrine

FIGO Staging for Cervical Cancer

Table 1
2018 International Federation of Gynecology and Obstetrics staging classification of cervical cancer

Stage	Description
I	Carcinoma is strictly confined to the cervix (extension to uterine corpus should be disregarded)
IA	Invasive carcinoma that can be diagnosed only by microscopy with a maximum depth of invasion <5 mm
IA1	Measured stromal invasion <3 mm in depth
IA2	Measured stromal invasion ≥3 and <5 mm in depth
IB	Invasive carcinoma with measured deepest invasion ≥5 mm; lesion limited to the cervix uteri with size measured by maximum tumor diameter
IB1	Invasive carcinoma ≥5 mm depth of stromal invasion and <2 cm in greatest dimension
IB2	Invasive carcinoma ≥2 and ≤4 cm in greatest dimension
IB3	Invasive carcinoma >4 cm in greatest dimension
II	The carcinoma invades beyond the uterus, but has not extended into the lower third of the vagina or to the pelvic wall
IIA	Involvement limited to the upper two-thirds of the vagina without parametrial involvement
IIA1	Invasive carcinoma ≤4 cm in greatest dimension
IIA2	Invasive carcinoma >4 cm in greatest dimension
IIB	With parametrial involvement but not up to the pelvic wall
III	The carcinoma involves the lower third of the vagina and/or extends to the pelvic wall and/or causes hydronephrosis or nonfunctioning kidney and/or involves pelvic and/or para-aortic lymph nodes
IIIA	The carcinoma involves the lower third of the vagina, with no extension to the pelvic wall
IIIB	Extension to the pelvic wall and/or hydronephrosis or nonfunctioning kidney (unless known to be due to another cause)
IIIC	Involvement of pelvic and/or para-aortic lymph nodes (including micrometastases), irrespective of tumor size and extent
IIIC1	Pelvic lymph node metastasis only
IIIC2	Para-aortic lymph node metastasis
IV	The carcinoma has extended beyond the true pelvis or has involved (biopsy proven) the mucosa of the bladder or rectum.
IVA	Spread to adjacent pelvic organs
IVB	Spread to distant organs

Taemee Pak, Elizabeth A. Sadowski, Krupa Patel-Lippmann, MR Imaging in Cervical Cancer: Initial Staging and Treatment, Radiologic Clinics of North America, Volume 61, Issue 4, 2023, Pages 639-649,

Cervical Cancer

IB1 = 1.4 cm

Salib MY, Russell JHB, Stewart VR, Sudderuddin SA, Barwick TD, Rockall AG, Bharwani N. 2018 FIGO Staging Classification for Cervical Cancer: Added Benefits of Imaging. Radiographics. 2020 Oct;40(6):1807-1822. doi: 10.1148/rg.2020200013. Epub 2020 Sep 18. PMID: 32946322.

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Cervical Cancer

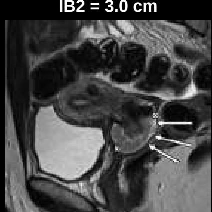
IB2 = 3.0 cm

Salib MY, Russell JHB, Stewart VR, Sudderuddin SA, Barwick TD, Rockall AG, Bharwani N. 2018 FIGO Staging Classification for Cervical Cancer: Added Benefits of Imaging. Radiographics. 2020 Oct;40(6):1807-1822. doi: 10.1148/rg.2020200013. Epub 2020 Sep 18. PMID: 32946322.

https://radiologyassistant.nl/abdomen/unsorted/mr-in-cervical-cancer-1

Cervical Cancer

IB2 = 3.0 cm



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https://radiologyassistant.nl/abdomen/unsorted/mr-in-cervical-cancer-1

Cervical Cancer

IIA = 3.0 cm

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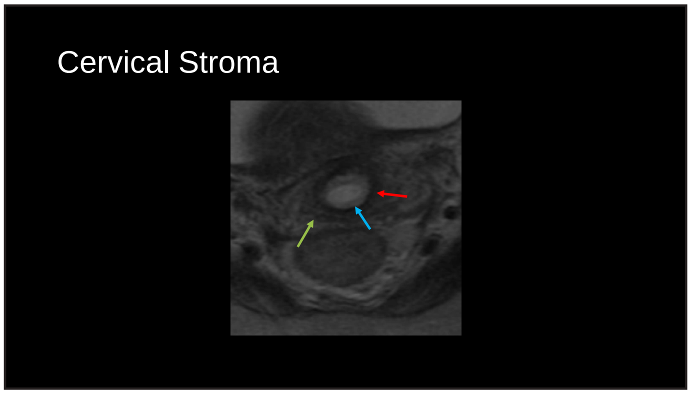
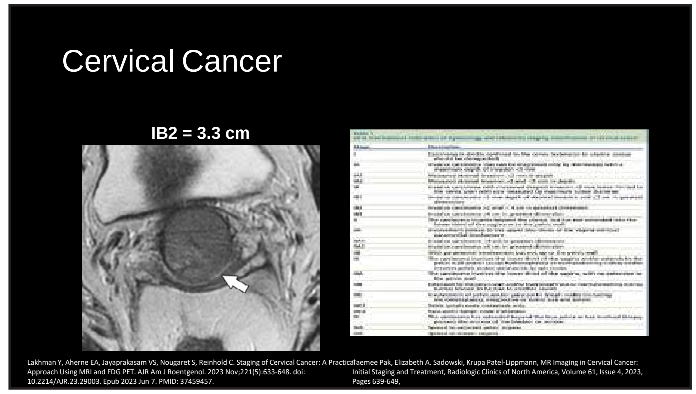

Cervical Stroma


Cervical Cancer
IB2 = 3.3 cm
Lakhman Y, Aherne EA, Jayaprakasam VS, Nougaret S, Reinhold C. Staging of Cervical Cancer: A Practical Approach Using MRI and FDG PET. AJR Am J Roentgenol. 2023 Nov;221(5):633-648. doi: 10.2214/AJR.23.29003. Epub 2023 Jun 7. PMID: 37459457.
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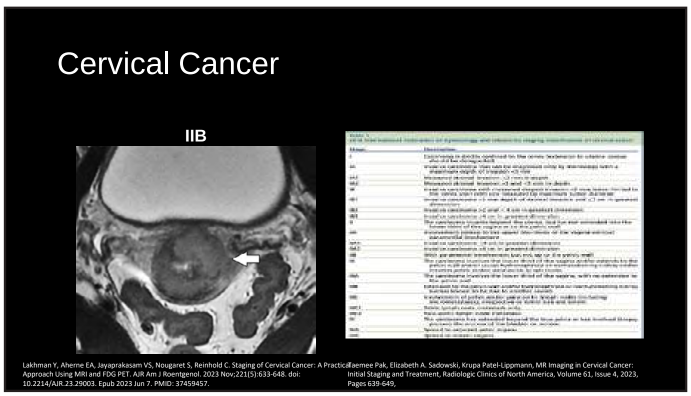
Cervical Cancer
IIB
Lakhman Y, Aherne EA, Jayaprakasam VS, Nougaret S, Reinhold C. Staging of Cervical Cancer: A Practical Approach Using MRI and FDG PET. AJR Am J Roentgenol. 2023 Nov;221(5):633-648. doi: 10.2214/AJR.23.29003. Epub 2023 Jun 7. PMID: 37459457.
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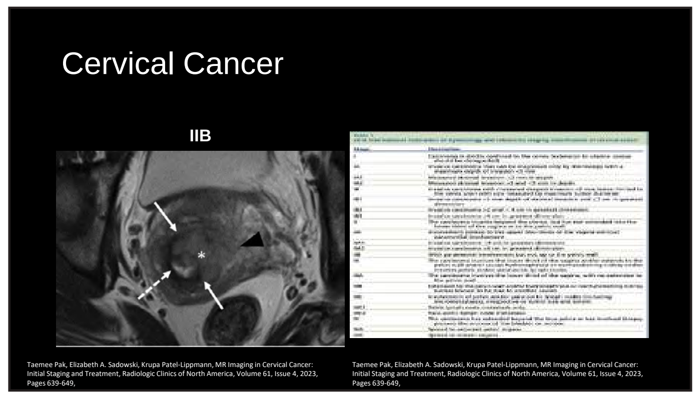
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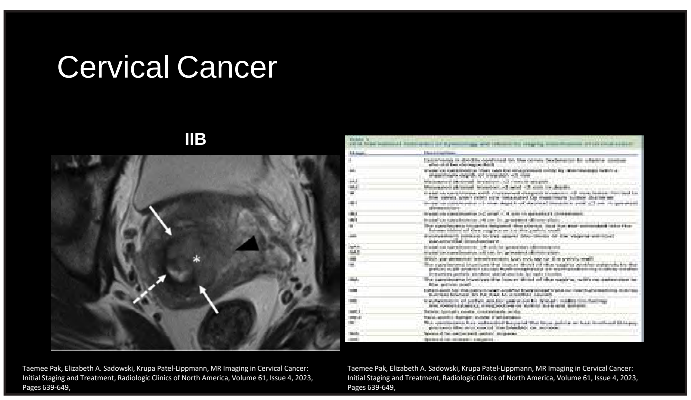
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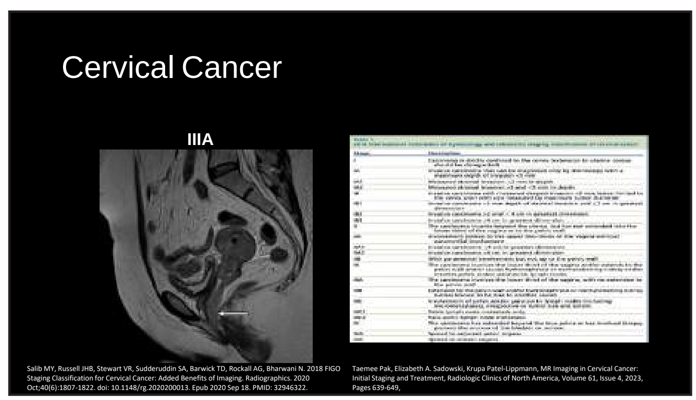
Cervical Cancer
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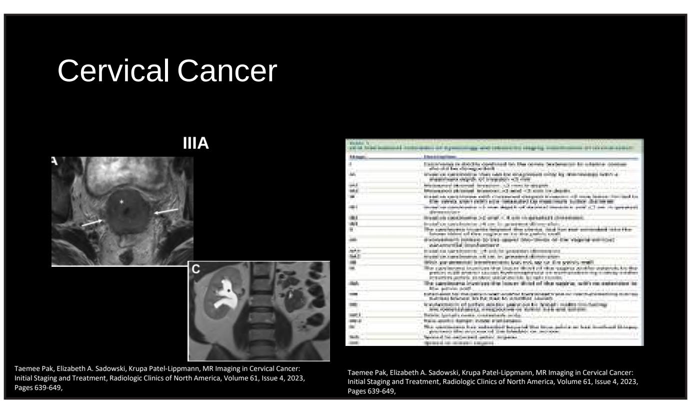
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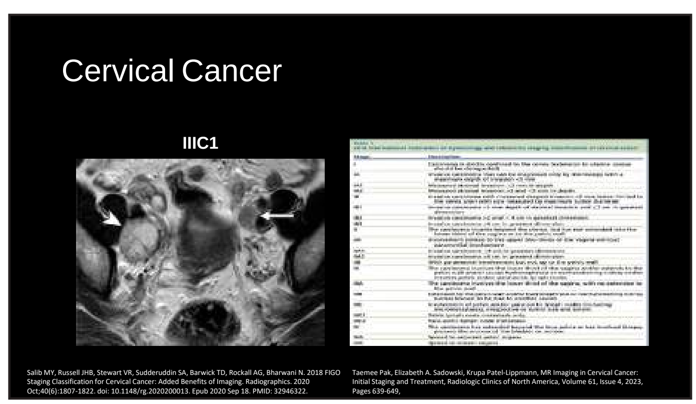
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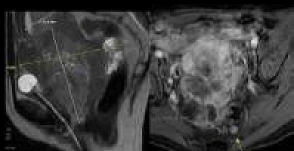
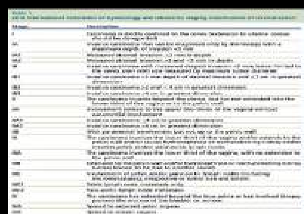
Cervical Cancer

IVA





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Ovarian Cancer

- Ovarian carcinoma is the second most common gynecologic malignancy
- Fifth leading cause of cancer death in females
- Four main categories:
  - Epithelial cell – cells lining the ovary
  - Germ cell – cells used to form eggs
  - Sex cord–stromal – cells that secrete hormones of connective structures
  - Metastases

Ovarian Cancer

- Although US is first line in imaging
  - PPV 7-50% when imaging is indeterminate or worrisome for malignancy
- MRI
  - PPV 71%
  - NPV 98%
- On MRI, the presence of enhancing tissue is primary driver of risk stratification
  - Without it, risk of malignancy is close to 0%

ACR O-RADS

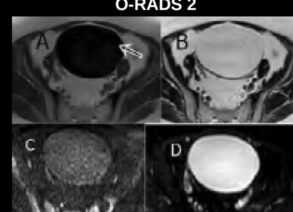
Sadowski EA, Thomassin-Naggara I, Rockall A, Maturen KE, Forstner R, Jha P, Nougaret S, Siegelman ES, Reinhold C. O-RADS MRI Risk Stratification System: Guide for Assessing Adnexal Lesions from the ACR O-RADS Committee. Radiology. 2022 Apr;303(1):35-47. doi: 10.1148/radiol.204371. Epub 2022 Jan 18. Erratum in: Radiology. 2023 Jul;308(1):e239017. PMID: 35040672; PMCID: PMC8962917.

ACR O-RADS

- Mission: risk stratification system is to improve communication between radiologists and referring physicians
  - women with benign lesions or borderline tumors can avoid unnecessary or over-extensive surgery
  - women with potential malignancy are promptly referred for oncologic surgical evaluation.

Ovarian Tumors

O-RADS 2



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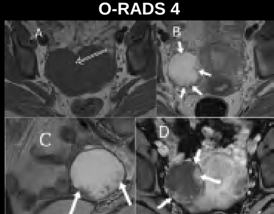
Ovarian Tumors

O-RADS 4



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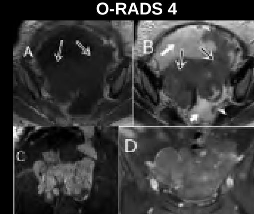
Ovarian Tumors

O-RADS 4



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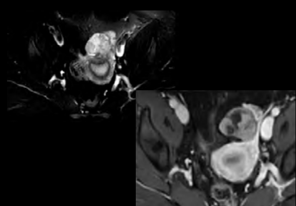
Ovarian Tumors

O-RADS 4 – Micropapillary Borderline Tumor



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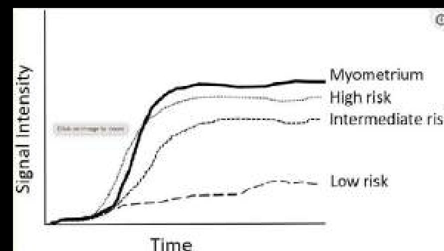
ACR O-RADS



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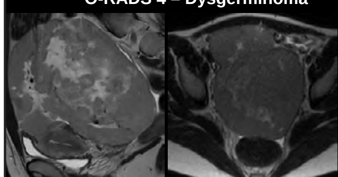
Ovarian Tumors

O-RADS 4 – Dysgerminoma



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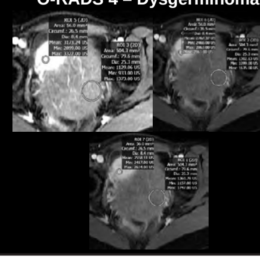
Ovarian Tumors

O-RADS 4 – Dysgerminoma



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Ovarian Tumors

O-RADS 4 – Dysgerminoma

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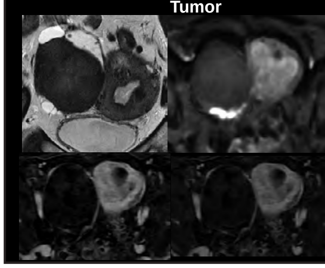
Ovarian Tumors

O-RADS 4 – Serous Borderline Tumor



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In summary

- For Endometrial and Cervical Cancer
  - Accurate evaluation of the tumor and where it is going will allow for proper FIGO staging
  - Allow for proper medical and surgical treatment
- For Ovarian Tumors
  - ACR O-RADS is a risk stratification system for ovarian tumors to help avoid unnecessary treatment and surgery for benign tumors and to help patients with worrisome features get appropriate treatment

SELF EVALUATION

Female Infertility and GYN Cancer Imaging

1. What percentage of cases of infertility have a male factor identified as well as a female factor?

a. 10%
b. 35%
c. 65%
d. 85%

2. In endometriomas, “T2 shading” refers to what?

a. The T2 dark spots
b. A crescendo effect from blood products on T2 weighted imaging
c. T2 rim of dark signal
d. T2 signal is less bright than the signal of the lesion on T1

3. Which Müllerian duct anomaly has the highest rate of infertility?

a. Unicornuate uterus
b. Uterus Didelphys
c. Septate Uterus
d. Bicornuate Uterus

4. T/F - High grade Type 2 endometrial carcinomas are more common than Type 1 cancers.

5. T/F - Invasion of the cervical stroma in cervical cancer makes the FIGO stage IIB.

6. T/F - According to O-RADS, you can only score an ovarian lesion ORADS-5 if dynamic contrast enhancement (DCE) is part of the MRI study.

Answer Key: 1. B, 2. D, 3. C, 4. F, 5. T, 6. F

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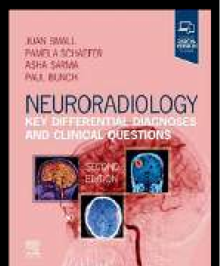
Incidental Findings in the Head and Neck

Disclosures

- Financial relationships:
  - Medical advisor, Guerbet
  - Author royalties, Elsevier
  - Research funding, GE HealthCare



Objectives

- To illustrate incidentally encountered “don’t miss” imaging findings and important diagnoses
- To emphasize relevant anatomy and practical tips for refining image interpretation
- To discuss associated work-up and treatment considerations

Format

- Review real-life patient examples with head and neck findings
  - **Unrelated** to clinical indication
  - Related but **outside focus of exam**

Format

- Four themes
  - Normal variants
  - Sinonasal opacification
  - Middle ear and mastoid opacification
  - Mass in the neck

Case Examples

Theme #1

Normal variants

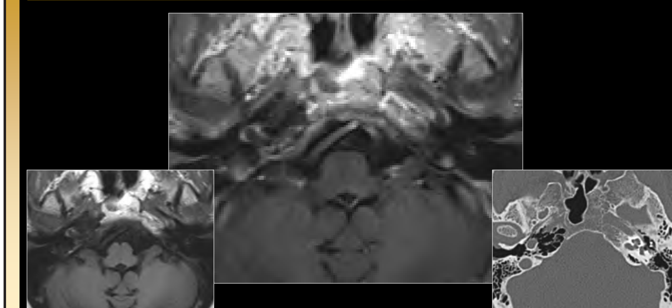
Principle

Don't mistake normal variants for pathology.

56-year-old male with recently diagnosed lung cancer.

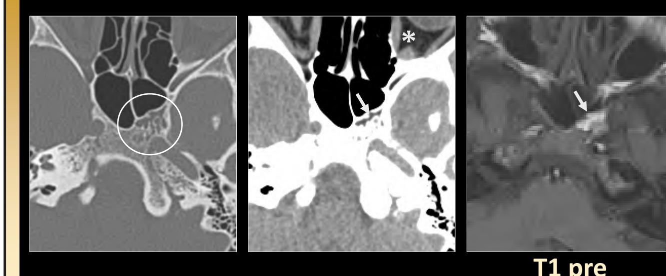
Brain MRI

Asymmetric Pneumatization

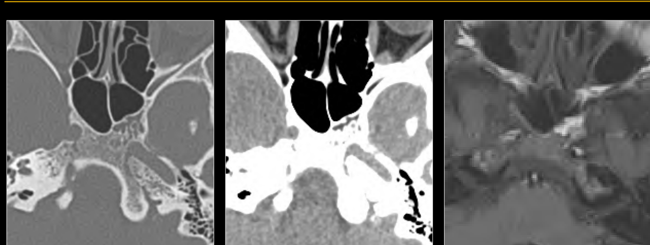


36-year-old female with headache.

Head CT



Benign Marrow Variant



"Arrested pneumatization"

"Benign medullary variant"

Theme #2

Sinonasal opacification

Principles

Inflammation is common, and tumors are rare.

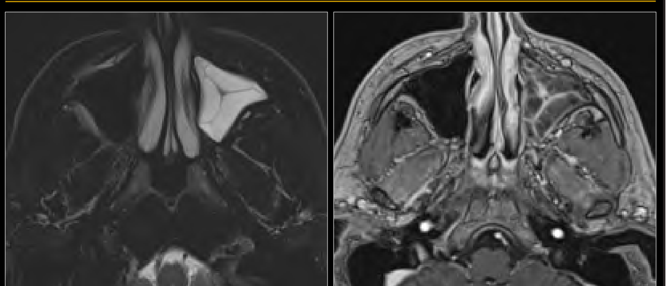
Tumors are often malignant and not to be missed.

Sinonasal Inflammation

- Mucosal thickening
- Retention cyst
- Polyp
- Mucocele

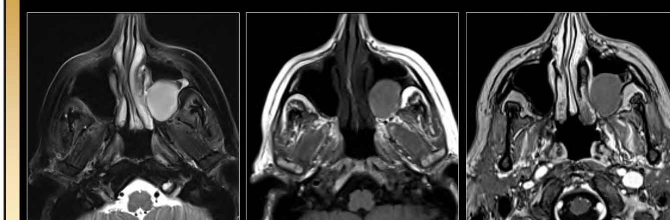
Focus on **enhancement**

Mucosal Thickening



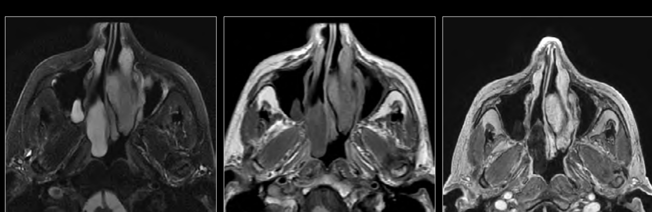
T2 FS T1 C+

Retention Cyst



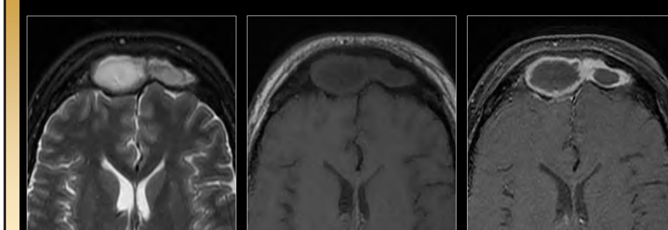
T2 FS T1 pre T1 C+

Polyp



T2 FS T1 pre T1 C+

Mucocele



T2 FS T1 pre T1 C+

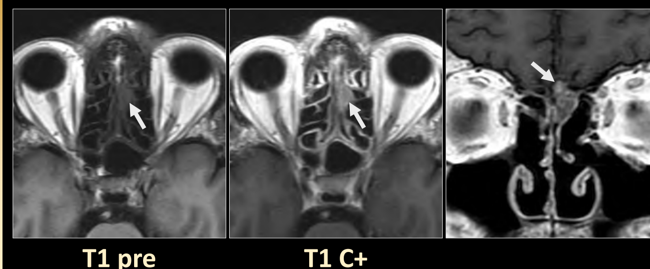
Principle

Solid enhancement is worrisome and should prompt ENT consultation.

68-year-old male for vestibular schwannoma follow-up.

Temporal Bone MRI

Temporal Bone MRI

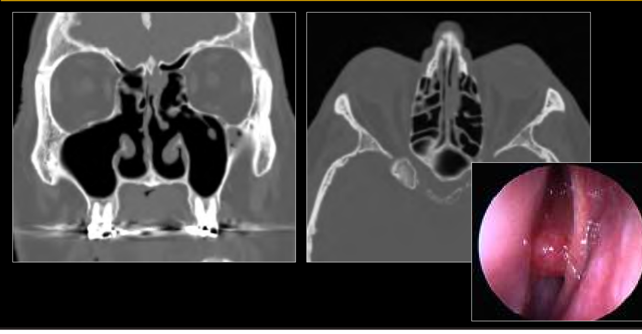


Esthesioneuroblastoma

Arise in the **superior nasal cavity**.

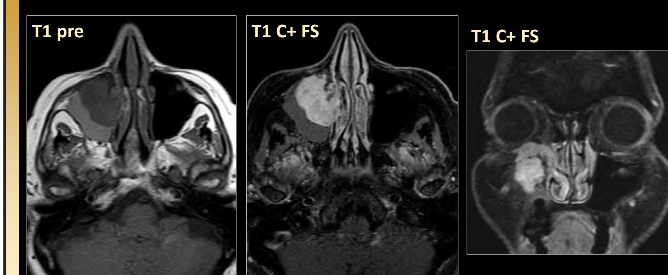
Bunch PM, Kelly HR. In: *Neuroradiology: Spectrum and Evolution of Disease*, 2018;331-338.

Esthesioneuroblastoma



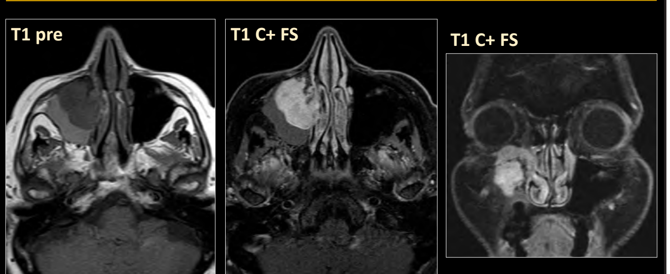
80-year-old female with face pain and diplopia.

Brain and Orbits MRI



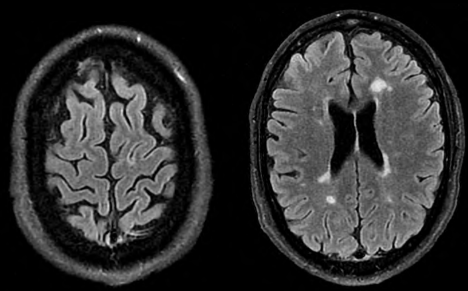
"Opacification of the right maxillary sinus. Could represent mucocele."

Squamous Cell Carcinoma

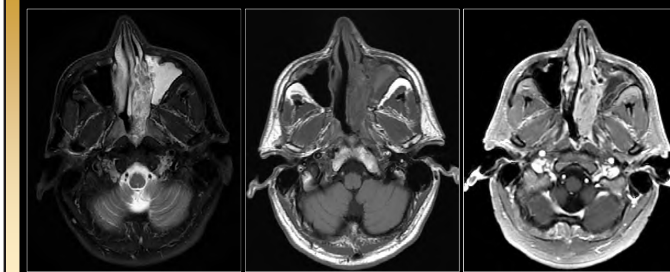


50-year-old male with multiple sclerosis.

Brain MRI

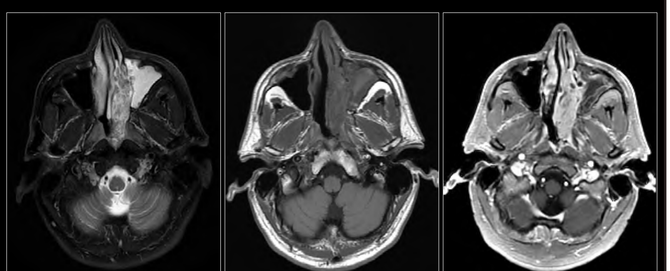


Brain MRI



T2 FS T1 pre T1 C+

Inverted Papilloma

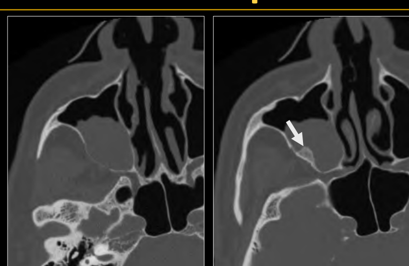


T2 FS T1 pre T1 C+

Companion Case

66-year-old male with fall from bed.

Inverted Papilloma

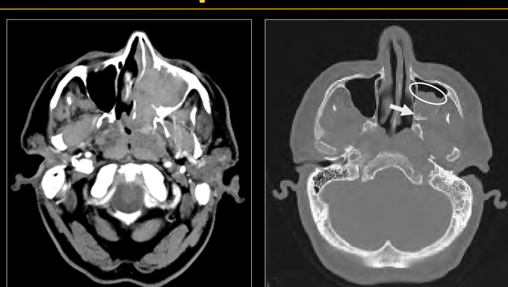


Focal hyperostosis suggests diagnosis and correlates with site of attachment

Companion Case #2

63-year-old male with biopsy-proven sinonasal squamous cell carcinoma.

Companion Case



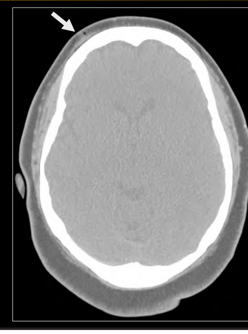
Where does this arise? Head CT from 2017

Principle

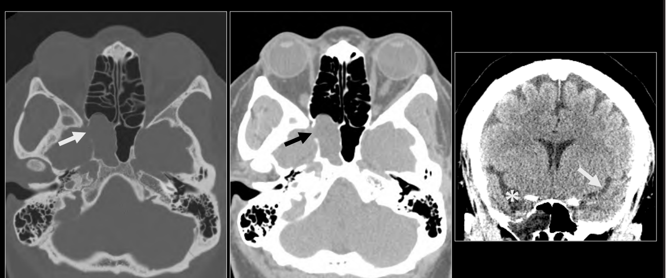
Occasionally, it's neither inflammation nor neoplasm.

41-year-old female
with syncope.

Head CT

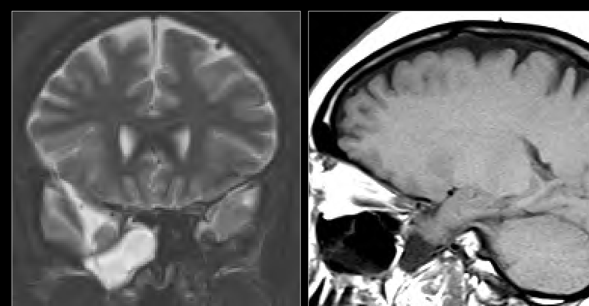


Head CT



Could this be a cephalocele?

Cephalocele



Companion Examples

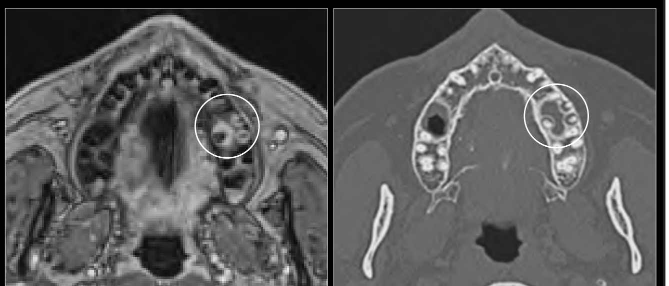
Principle

Look at the teeth!

53-year-old male follow-up for
anaplastic meningioma.

Brain MRI

Odontogenic Sinusitis



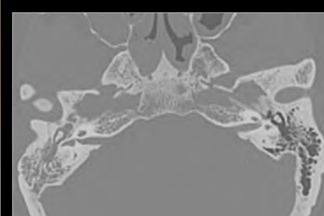
Theme #3

Middle ear and mastoid opacification

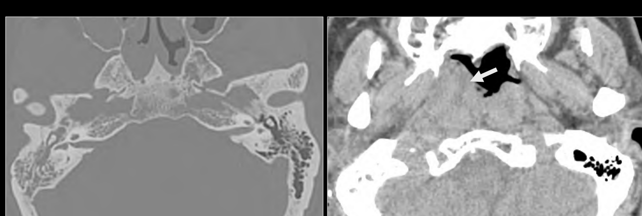
Conventional Teaching

"Unilateral mastoid effusion in an adult should prompt assessment of the nasopharynx."

Head CT



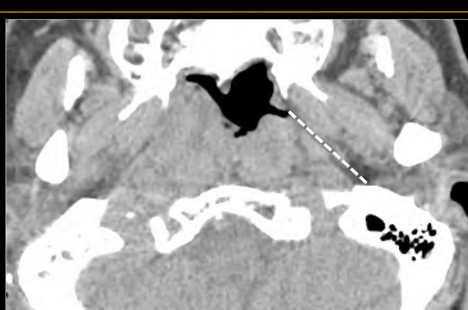
Nasopharyngeal Carcinoma



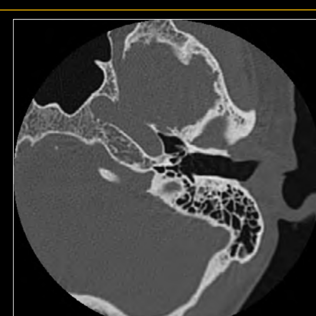
Principle

Unilateral mastoid effusion in an adult should prompt evaluation of the Eustachian tube.

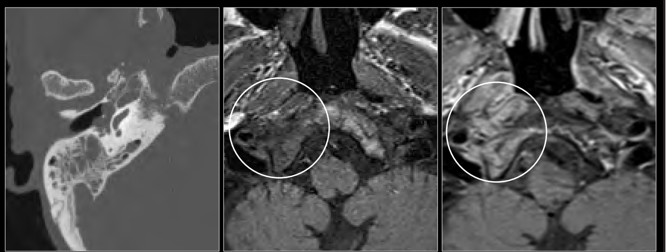
Eustachian Tube Evaluation



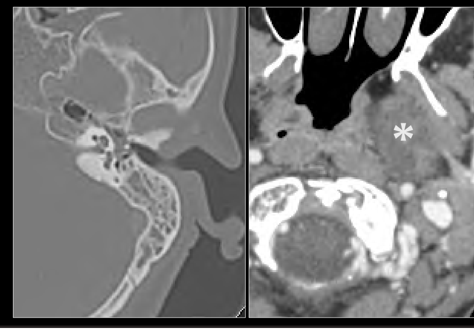
Eustachian Tube Evaluation



Eustachian Tube Obstruction



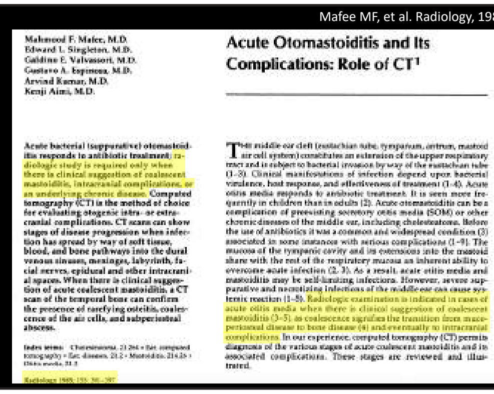
Eustachian Tube Obstruction



Principle

Middle ear and mastoid opacification *does not equal* mastoiditis.

Mafee MF, et al. Radiology, 1985;155:391-397.



Mahmood F. Mafee, M.D.
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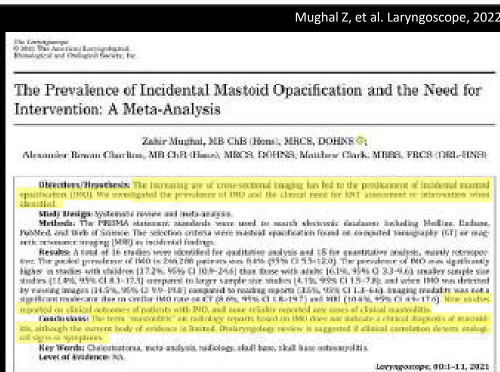
Gustavo A. Espinosa, M.D.
Arvind Kumar, M.D.
Kenji Aimi, M.D.

Acute Otomastoiditis and Its Complications: Role of CT[1]

Acute bacterial (suppurative) otomastoiditis responds to antibiotic treatment; radiologic study is required only when there is clinical suggestion of coalescent mastoiditis, intracranial complications, or an underlying chronic disease. Computed tomography (CT) is the method of choice for evaluating otogenic intra- or extracranial complications. CT scans can show stages of disease progression when infection has spread by way of soft tissue, blood, and bone pathways into the dural venous sinuses, meninges, labyrinth, facial nerves, epidural and other intracranial spaces. When there is clinical suggestion of acute coalescent mastoiditis, a CT scan of the temporal bone can confirm the presence of rarefying osteitis, coalescence of the air cells, and subperiosteal abscess.

The middle ear cleft (eustachian tube, tympanum, antrum, mastoid air cell system) constitutes an extension of the upper respiratory tract and is subject to bacterial invasion by way of the eustachian tube (1–3). Clinical manifestations of infection depend upon bacterial virulence, host response, and effectiveness of treatment (1–4). Acute otitis media responds to antibiotic treatment. It is seen more frequently in children than in adults (2). Acute otomastoiditis can be a complication of preexisting secretory otitis media (SOM) or other chronic diseases of the middle ear, including cholesteatoma. Before the use of antibiotics it was a common and widespread condition (3) associated in some instances with serious complications (1–9). The mucosa of the tympanic cavity and its extensions into the mastoid share with the rest of the respiratory mucosa an inherent ability to overcome acute infection (2, 3). As a result, acute otitis media and mastoiditis may be self-limiting infections. However, severe suppurative and necrotizing infections of the middle ear can cause systemic reaction (1–5). Radiologic examination is indicated in cases of acute otitis media when there is clinical suggestion of coalescent mastoiditis (3–5), as coalescence signifies the transition from mucoperiosteal disease to bone disease (4) and eventually to intracranial complications. In our experience, computed tomography (CT) permits diagnosis of the various stages of acute coalescent mastoiditis and its associated complications. These stages are reviewed and illustrated.

Mughal Z, et al. Laryngoscope, 2022;132:422-432.



The Prevalence of Incidental Mastoid Opacification and the Need for Intervention: A Meta-Analysis

Zahir Mughal, MB ChB (Hons), MRCS, DOHNS;
Alexander Rowan Charlton, MB ChB (Hons), MRCS, DOHNS; Matthew Clark, MBBS, FRCS (ORL-HNS)

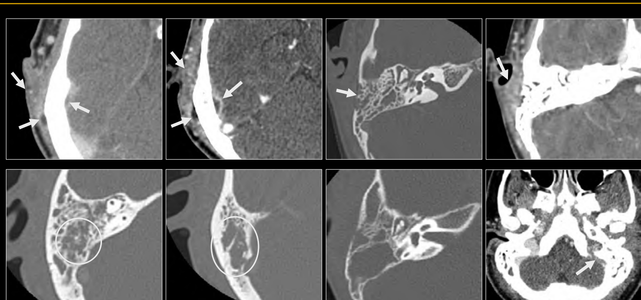
Laryngoscope, 00:1–11, 2021

Mastoiditis

When to worry about (oto)mastoiditis?

1. Referring physicians are worried.
2. Evidence of complications.

Mastoiditis Complications



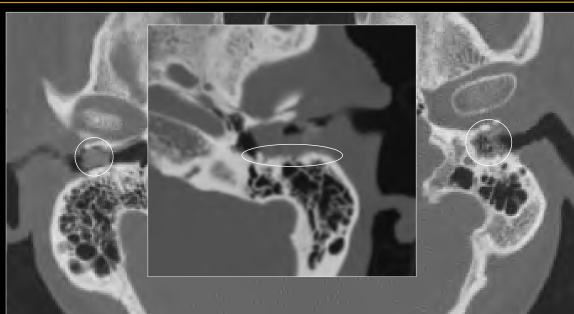
Additional Tip

Consider cholesteatoma in the presence of osseous erosion.

38-year-old female
with seizure.

Head CT

External Auditory Canal Cholesteatoma



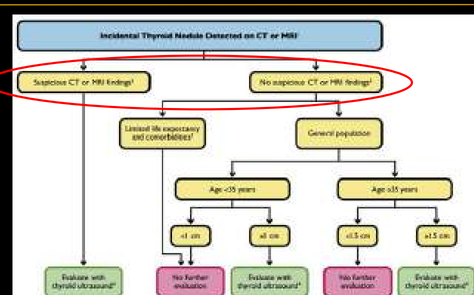
Theme #4

Mass in the neck

Principle

When rules exist,
follow the rules...

Incidental Thyroid Nodule

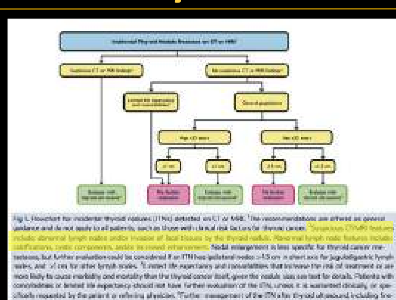


Hoang JK, et al. J Am Coll Radiol, 2015; 12:143-150.

Incidental Thyroid Nodule

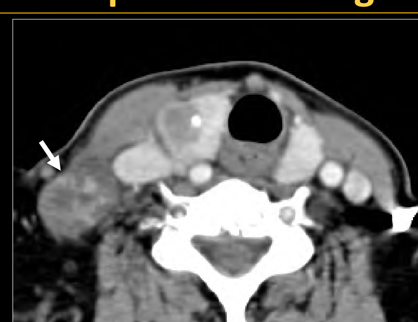
Suspicious findings:

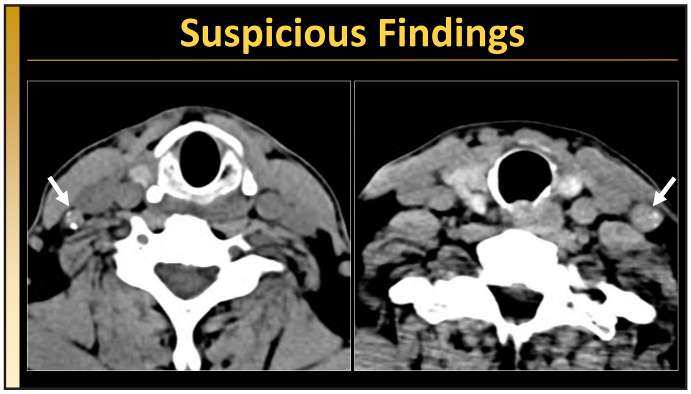
1. Abnormal lymph nodes (calcification, cystic change, enhancement)
2. Invasion of local tissues by nodule

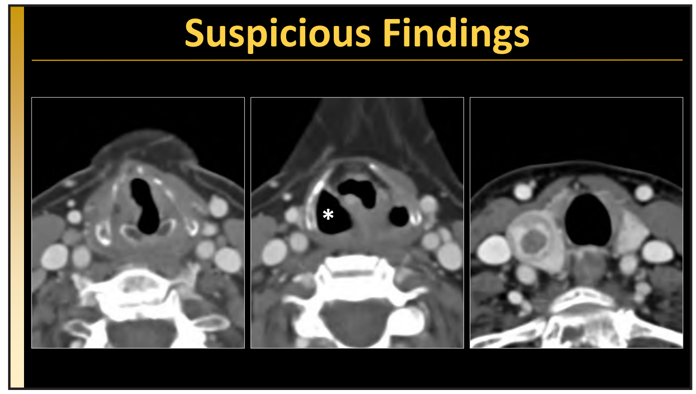


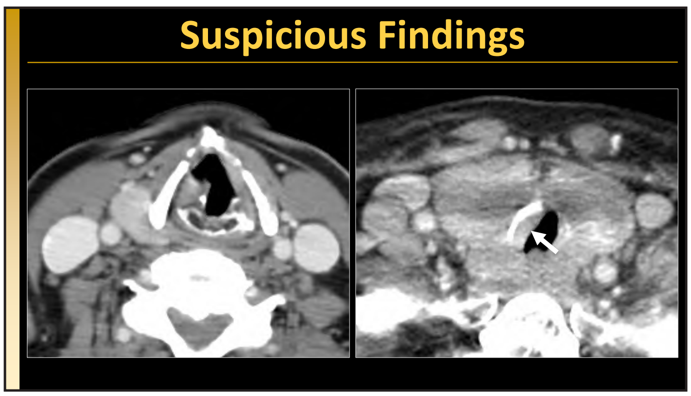
Hoang JK, et al. J Am Coll Radiol, 2015; 12:143-150.

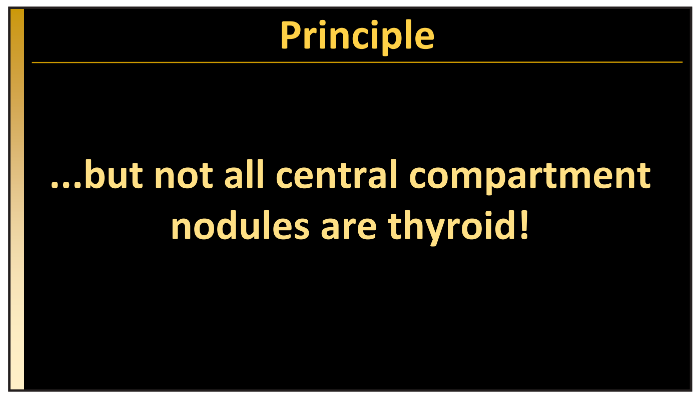
Suspicious Findings



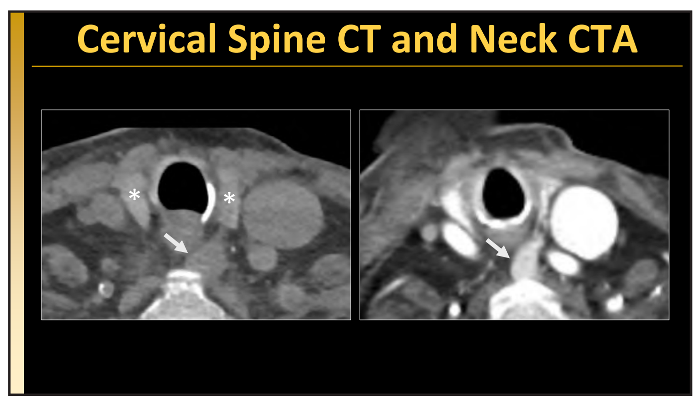

Suspicious Findings

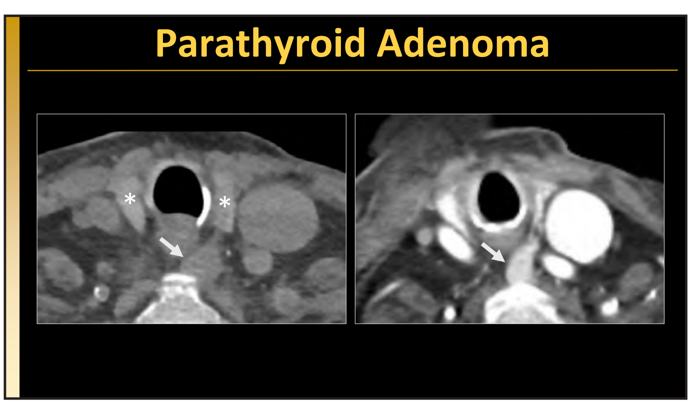

Suspicious Findings
*

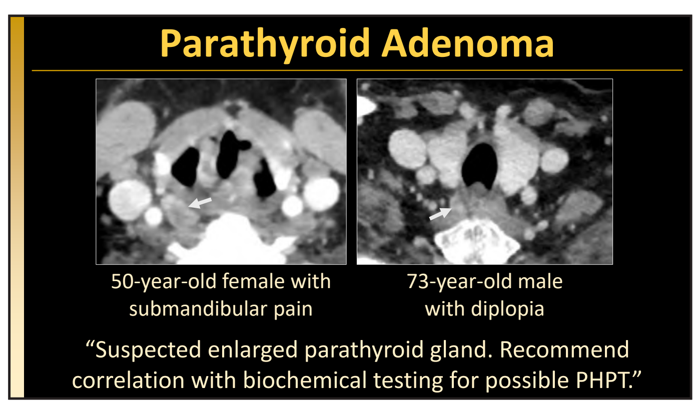

Suspicious Findings


Principle
...but not all central compartment nodules are thyroid!


85-year-old
female trauma patient.

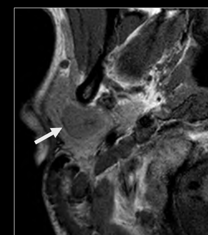

Cervical Spine CT and Neck CTA
*
*


Parathyroid Adenoma
*
*


Parathyroid Adenoma
50-year-old female with submandibular pain
73-year-old male with diplopia
"Suspected enlarged parathyroid gland. Recommend correlation with biochemical testing for possible PHPT."

58-year-old female with altered mental status.

Brain MRI

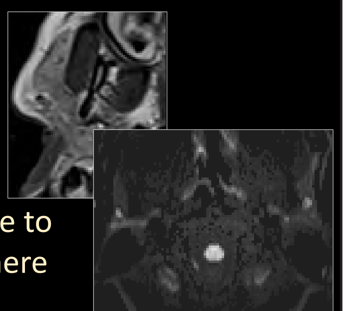


Is it a lymph node?

If not, best for ENT to see.

Intraparotid Lymph Nodes

- Superficial lobe
- Partially embedded, surrounded by fat
- Low diffusivity
- Compare appearance to lymph nodes elsewhere

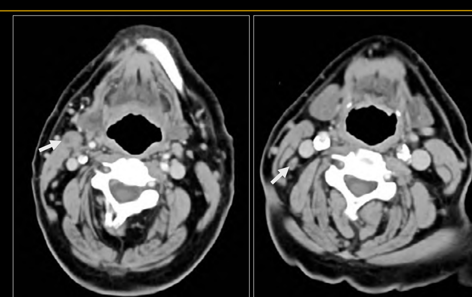


Principle

Beware heterogeneous lymph nodes

63-year-old male with weakness and slurred speech.

Head and Neck CTA



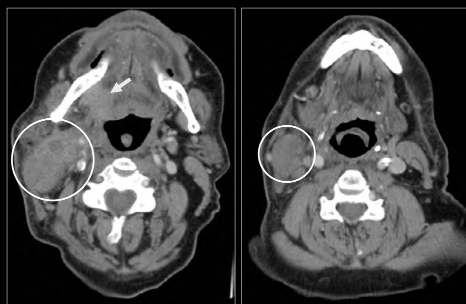
"Heterogeneous lymph nodes, likely reactive."

Head and Neck CTA

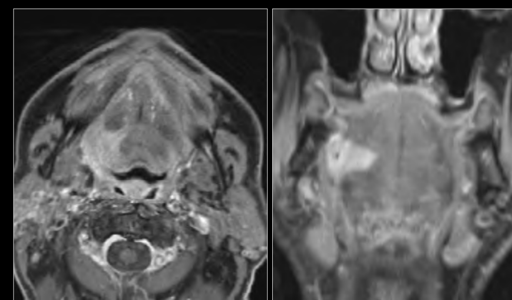
6 weeks later

Neck CT performed for palpable abnormality

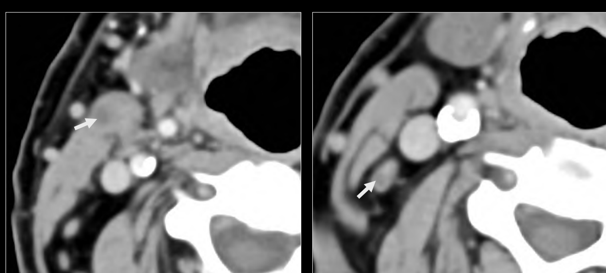
Neck CT



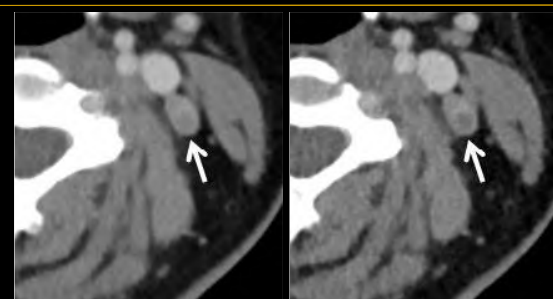
Neck MRI



Node Heterogeneity



Slice Thickness



3.0 mm | 1.5 mm

Take Home Points

- Familiarity with normal variants
- Identify sinonasal neoplasms
  - Solid enhancement
  - Superior nasal cavity opacification
- Mastoid opacification ≠ mastoiditis
  - Look along Eustachian tube
  - Look for erosion

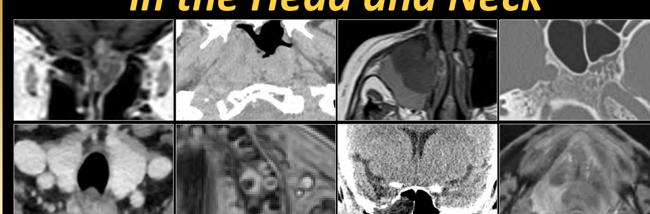
Take Home Points

- More to incidental thyroid nodules than nodule size and patient age
- Don’t forget the parathyroid glands
  - Hypoattenuating on noncontrast CT
  - Enhancement different from lymph nodes

Take Home Points

- Overlap in imaging appearance of benign and malignant parotid tumors
  - Not a lymph node? ENT consultation
- Heterogeneous lymph nodes concerning for metastasis
  - Squamous cell carcinoma
  - Papillary thyroid carcinoma

Incidental Findings in the Head and Neck



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Paul M. Bunch, MD

SELF EVALUATION

Incidental Findings in the Head and Neck

1. T/F - Solid enhancement in the sinonasal cavity is most consistent with an infectious or inflammatory process:

2. Esthesioneuroblastoma most commonly arises in the:

a. Maxillary sinus
b. Frontal sinus
c. Superior nasal cavity
d. Nasopharynx

3. T/F - Middle ear and mastoid opacification is indicative of otomastoiditis.

4. T/F - To determine the next step in evaluation of an incidental thyroid nodule detected on CT or MRI, the radiologist need only consider the patient’s age and the thyroid nodule size.

5. The most appropriate next step in the evaluation of a patient suspected to have an incidentally detected parathyroid adenoma is:

a. Parathyroid CT
b. Ultrasound
c. Biopsy
d. Laboratory testing

Answer Key: 1. F, 2. C, 3. F, 4. F, 5, D

Wake Forest™ School of Medicine

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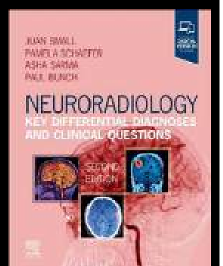
Primary Hyperparathyroidism and Parathyroid CT

Disclosures

- Financial relationships:
  - Medical advisor, Guerbet
  - Author royalties, Elsevier
  - Research funding, GE HealthCare



Objectives

- Describe role and rationale of imaging
- Summarize relevant anatomy, embryology, and operative considerations
- Define what the surgeon wants to know
- Apply practical approach to parathyroid CT

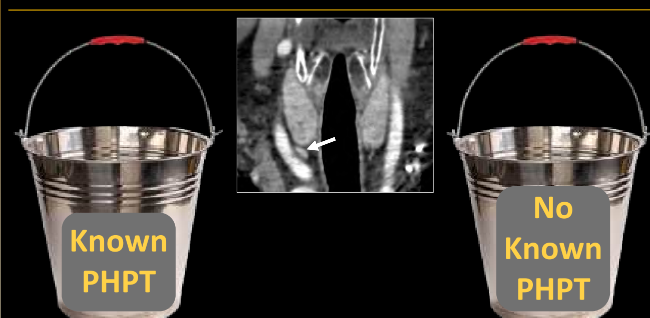
Outline

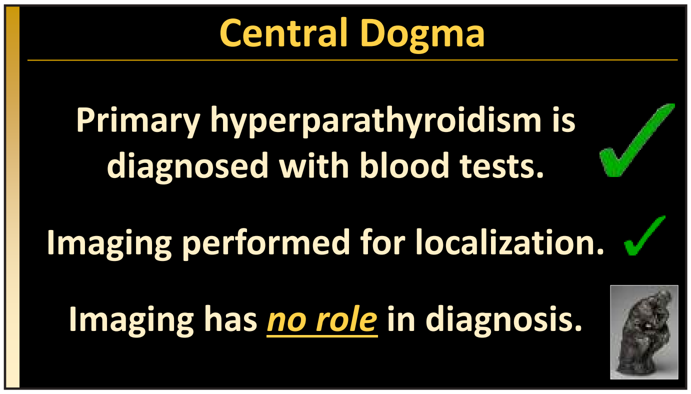
- Background
- Operative Strategies
- Currently Accepted Imaging Role and Rationale
- Anatomy and Embryology
- Imaging Techniques (Parathyroid CT)
- Imaging Interpretation (Pearls and Pitfalls)
- Surgeon Wants to Know
- Summary

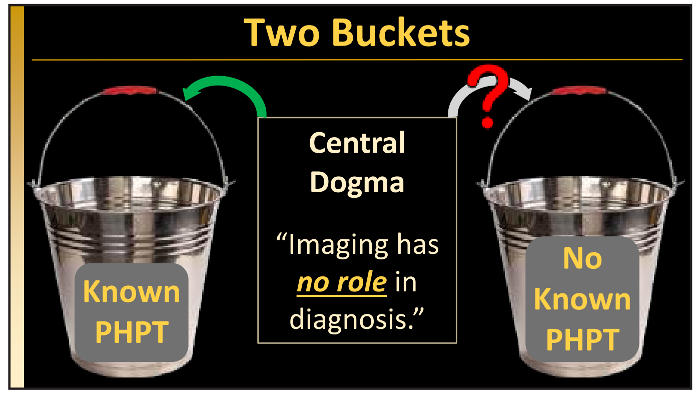
Big Picture

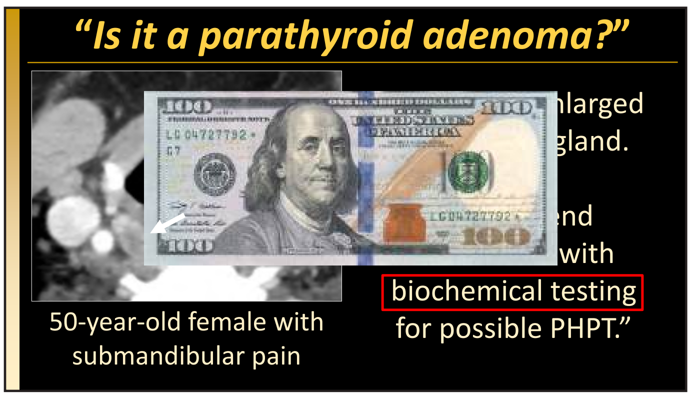
"Is it a parathyroid adenoma?"

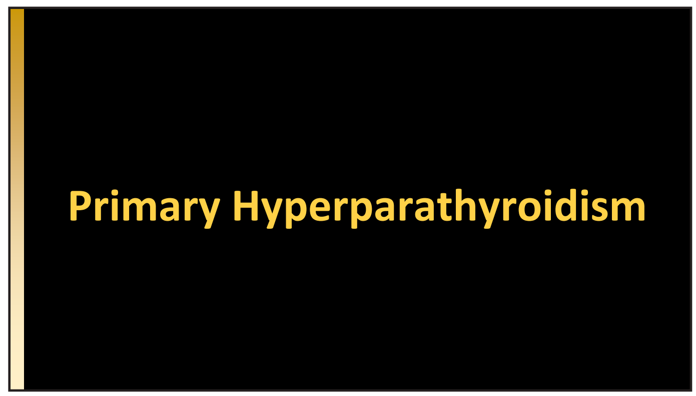
Two Buckets

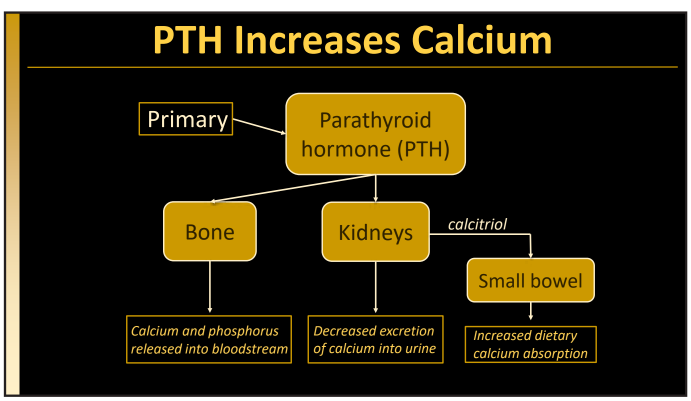


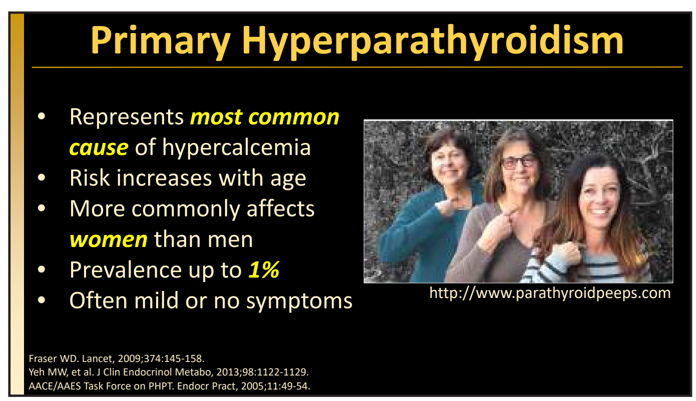

Central Dogma
Primary hyperparathyroidism is diagnosed with blood tests.
Imaging performed for localization.
Imaging has no role in diagnosis.

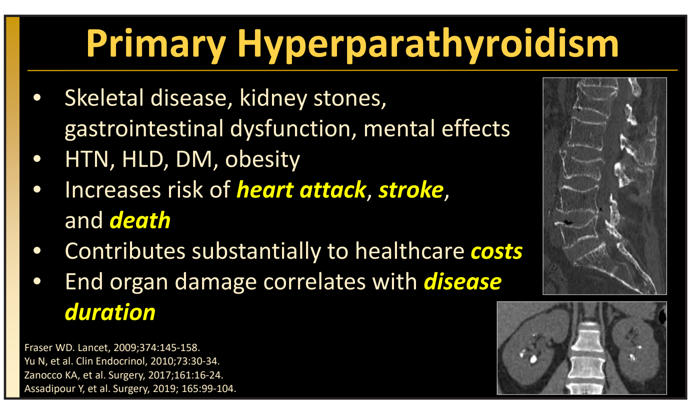

Two Buckets
Known PHPT
Central Dogma
"Imaging has no role in diagnosis."
No Known PHPT

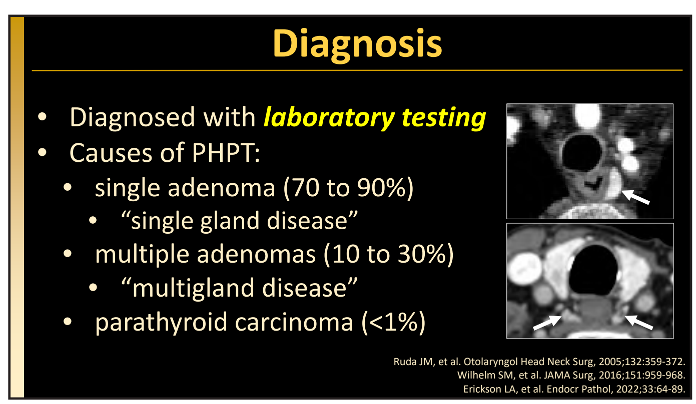

"Is it a parathyroid adenoma?"
nlarged
gland.
nd
with
biochemical testing
for possible PHPT."
50-year-old female with submandibular pain


Primary Hyperparathyroidism


PTH Increases Calcium
Primary
Parathyroid hormone (PTH)
Bone
Kidneys
calcitriol
Small bowel
Calcium and phosphorus released into bloodstream
Decreased excretion of calcium into urine
Increased dietary calcium absorption


Primary Hyperparathyroidism
Represents most common cause of hypercalcemia
Risk increases with age
More commonly affects women than men
Prevalence up to 1%
Often mild or no symptoms
http://www.parathyroidpeeps.com
Fraser WD. Lancet, 2009;374:145-158.
Yeh MW, et al. J Clin Endocrinol Metabo, 2013;98:1122-1129.
AACE/AAES Task Force on PHPT. Endocr Pract, 2005;11:49-54.


Primary Hyperparathyroidism
Skeletal disease, kidney stones, gastrointestinal dysfunction, mental effects
HTN, HLD, DM, obesity
Increases risk of heart attack, stroke, and death
Contributes substantially to healthcare costs
End organ damage correlates with disease duration
Fraser WD. Lancet, 2009;374:145-158.
Yu N, et al. Clin Endocrinol, 2010;73:30-34.
Zanocco KA, et al. Surgery, 2017;161:16-24.
Assadipour Y, et al. Surgery, 2019; 165:99-104.


Diagnosis
Diagnosed with laboratory testing
Causes of PHPT:
single adenoma (70 to 90%)
"single gland disease"
multiple adenomas (10 to 30%)
"multigland disease"
parathyroid carcinoma (<1%)
Ruda JM, et al. Otolaryngol Head Neck Surg, 2005;132:359-372.
Wilhelm SM, et al. JAMA Surg, 2016;151:959-968.
Erickson LA, et al. Endocr Pathol, 2022;33:64-89.

Overview of 2022 WHO Classification

Endocrine Pathology (2022) 33:64–89
https://doi.org/10.1007/s12022-022-09709-1

Overview of the 2022 WHO Classification of Parathyroid Tumors

Lori A. Erickson[1] · Ozgur Mete[2,3] · C. Christofer Juhlin[4,5] · Aurel Perren[6] · Anthony J. Gill[7,8,9]

Accepted: 29 January 2022 / Published online: 17 February 2022
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Erickson LA, et al. Endocr Pathol, 2022;33:64-89.

Treatment

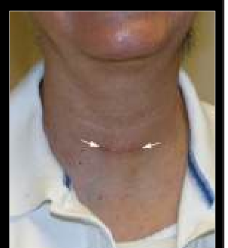
- Surgical ***removal*** of abnormal parathyroid tissue is ***only cure***
- Two accepted strategies for operative management:
  - Bilateral neck exploration (BNE)
  - Minimally invasive parathyroidectomy (MIP)

Courtesy of Gregory W. Randolph, MD

Wilhelm SM, et al. JAMA Surg, 2016;151:959-968.

Bilateral Neck Exploration

- Original operation
- Examination of ***all*** parathyroid glands; diseased glands removed
- Large incision
- Both recurrent laryngeal nerves at risk
- Excellent long-term cure rates (>95%)
- Low morbidity in experienced hands



https://www.uclahealth.org/endocrine-center/scar-gallery

Siperstein AE, et al. In Surgery of the Thyroid and Parathyroid Glands, 2013;567-579.
Wilhelm SM, et al. JAMA Surg, 2016;151:959-968.

Minimally Invasive Parathyroidectomy

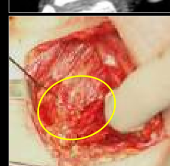
- Preferred operation, ***when appropriate***
- Requires confident and precise preoperative localization of a **single adenoma**
- Removes only ***affected gland*** +/- ioPTH
- Demonstrated ***benefits*** relative to BNE:
  - Shorter operating time
  - Shorter length of stay
  - Lower cost
  - Smaller incision → improved cosmesis
- Equivalent cure rates in experienced hands

https://www.uclahealth.org/endocrine-center/scar-gallery

Perrier ND and Parangi S., et al. In Surgery of the Thyroid and Parathyroid Glands, 2013;580-589.
Bunch PM and Kelly HR. JAMA Otolaryngol Head Neck Surg, 2018;144:929-937.

Accepted Imaging Role and Rationale

- Goal of imaging is ***localization*** – not diagnosis
- Localization of **single adenoma** facilitates **MIP**
- Localization of multigland disease aids BNE
- If imaging is non-localizing, BNE will be necessary



Courtesy of Gregory W. Randolph, MD

Bunch PM and Kelly HR. JAMA Otolaryngol Head Neck Surg, 2018;144:929-937.

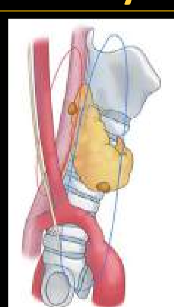
Anatomy and Embryology

Anatomy and Embryology

4 glands +/-

Superior derive from ***fourth*** pharyngeal pouch

Typically (~***80%***) along posterosuperior aspect of thyroid

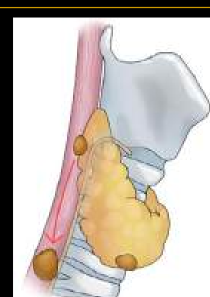


Inferior derive from ***third*** pharyngeal pouch

More variable position; ~50% within 1 cm of thyroid lower pole

Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.

Superior (Posterior) or Inferior (Anterior) Gland?

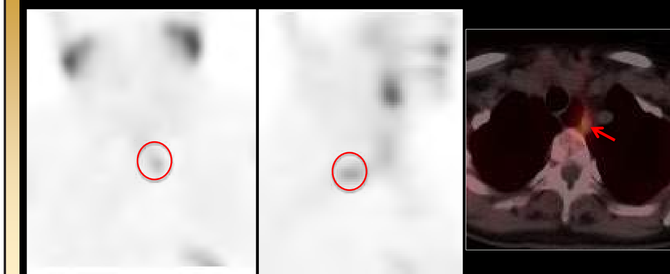


Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.

Illustrative Case

76-year-old female with primary hyperparathyroidism.

Illustrative Case



Illustrative Case

PREOPERATIVE DIAGNOSIS:
Primary hyperparathyroidism.

POSTOPERATIVE DIAGNOSIS:
Primary hyperparathyroidism.

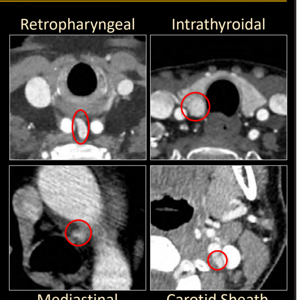
PROCEDURE PERFORMED:
Parathyroidectomy, left inferior.

INDICATION AND CONSENT:
The patient is a pleasant female with a history of primary hyperthyroidism secondary to a left inferior parathyroid adenoma identified on sestamibi scan. She had biochemical evidence of primary hyperparathyroidism, with a calcium as high as 10.9. Recommendation was made for operative intervention. Risks, benefits, and alternatives of procedure were discussed. Informed consent was obtained to proceed.

Illustrative Case

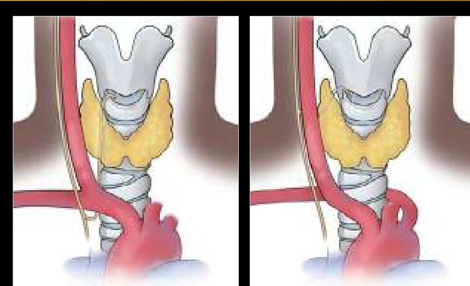
Ectopic Glands

- Up to ***16%*** of glands
- More commonly inferior
- May alter operative plan and approach



Kuzminski SJ, et al. Magn Reson Imaging Clin N Am, 2018;26:151-166.
Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.

Recurrent Laryngeal Nerve



Operative injury to NRLN ***up to 13%***

Toniato A, et al. World J Surg, 2014;28:659-661.
Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.

Localization Techniques

Imaging Modalities

- Widely Used
  - Ultrasound
  - Sestamibi
  - Parathyroid CT
  - Selective venous sampling +/- catheter angiography
- Emerging
  - Elastography
  - PET
  - 4D MRI

Ordered after definitive diagnosis

Personal Opinions

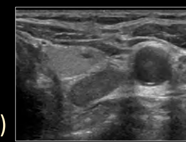
All imaging modalities have value

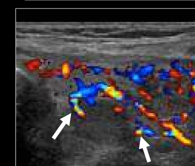
No single best technique for all situations

Combination of techniques often appropriate

Ultrasound

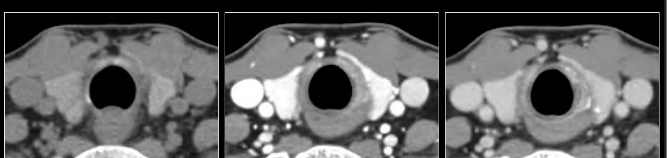
- Widely available (surgeon's office)
- Optimal modality for assessing concurrent thyroid pathology
- Good overall sensitivity (76%); PPV (93%)
- Less sensitive for:
  - mediastinal, retropharyngeal, and retroclavicular lesions
  - mildly enlarged glands
  - multigland disease (16-35%)





Cheung K, et al. Ann Surg Oncol, 2012;19(2):577-583.

Parathyroid CT

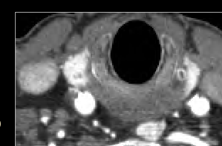


Noncontrast **Arterial** **Venous**

Hoang JK, et al. Otolaryngol Head Neck Surg, 2016;155(6):956-960.

Parathyroid CT

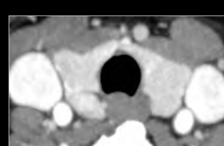
- Advantages
  - Spatial and anatomic detail
  - Short image acquisition times
  - Sensitivity 77-92%; PPV 87-95%
  - Relative sensitivity for MGD (43-67%)
  - Superior performance in several challenging clinical situations

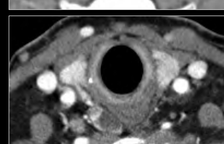


Bunch PM and Kelly HR. JAMA Otolaryngol Head Neck Surg, 2018;144:929-937.

Parathyroid CT

- Disadvantages
  - time-intensive interpretation
  - performance relatively dependent on radiologist experience
  - need for iodinated contrast media
  - ionizing radiation





Bunch PM and Kelly HR. JAMA Otolaryngol Head Neck Surg, 2018;144:929-937.
Hoang JK, et al. AJR Am J Roentgenol, 2015;204(5):W579-585.

Approach to Parathyroid Imaging

- Provide detailed and accurate '***roadmap***'
- "Where is the abnormal tissue located?"
- Use relevant surgical landmarks
- Limited differential diagnosis
- Small lesions with variable location and number
- High quality images ***absolute necessity***

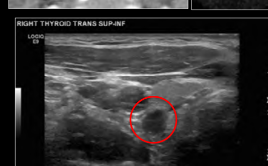


Image Acquisition

Coverage	Maxilla to carina for all phases (I-, arterial, venous)
Injection	350 mgI/mL x 90 mL @ 4mL/sec followed by 40 mL saline flush
Arterial phase	30 sec after start of I+ injection
Venous phase	60 sec after start of I+ injection

	DECT*
kVp	80/140
mA	250-445 mA
Pitch	0.516:1
Rotation time	0.5 s
Detector coverage	40 mm
Helical thickness	2.5 mm
Interval	2.5 mm
CTDIvol (per phase)	11 – 24 mGy

*GE Revolution Apex

Axial – 0.63 mm (all phases)
Coronal – 2 mm (I- and arterial)
Sagittal – 2 mm (arterial)

Image Acquisition

- Other tips
  - inject right arm
  - shoulders low
  - coach not to move or swallow

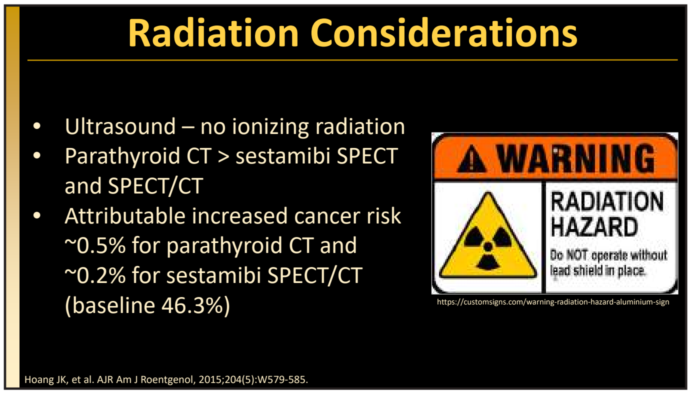
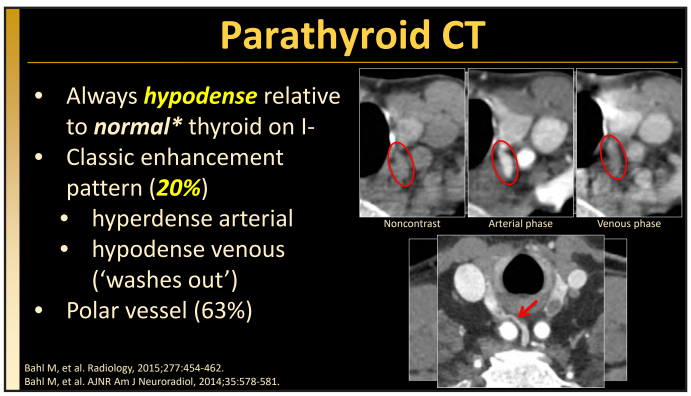
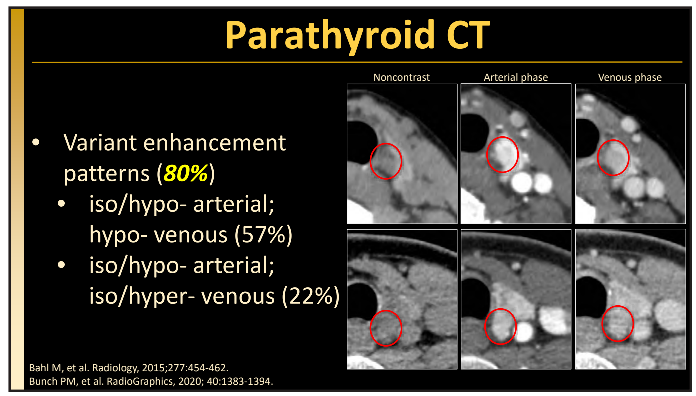
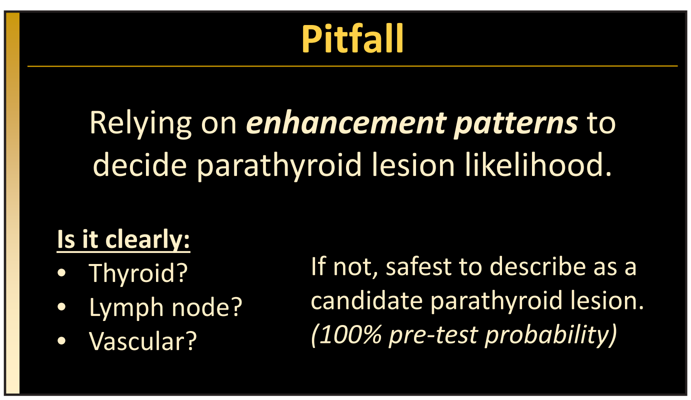

Radiation Considerations
• Ultrasound – no ionizing radiation
• Parathyroid CT > sestamibi SPECT and SPECT/CT
• Attributable increased cancer risk ~0.5% for parathyroid CT and ~0.2% for sestamibi SPECT/CT (baseline 46.3%)
WARNING
RADIATION HAZARD
Do NOT operate without lead shield in place.
https://customsigns.com/warning-radiation-hazard-aluminium-sign
Hoang JK, et al. AJR Am J Roentgenol, 2015;204(5):W579-585.


Image Interpretation

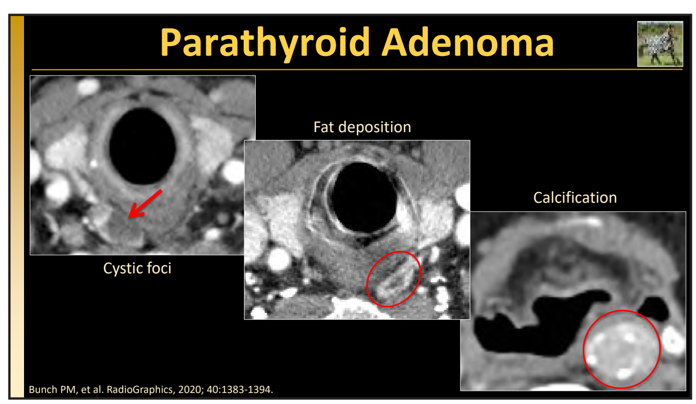

Parathyroid CT
• Always hypodense relative to normal* thyroid on I-
• Classic enhancement pattern (20%)
• hyperdense arterial
• hypodense venous ('washes out')
• Polar vessel (63%)
Noncontrast
Arterial phase
Venous phase
Bahl M, et al. Radiology, 2015;277:454-462.
Bahl M, et al. AJNR Am J Neuroradiol, 2014;35:578-581.


Parathyroid CT
• Variant enhancement patterns (80%)
• iso/hypo- arterial; hypo- venous (57%)
• iso/hypo- arterial; iso/hyper- venous (22%)
Noncontrast
Arterial phase
Venous phase
Bahl M, et al. Radiology, 2015;277:454-462.
Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.


Pitfall
Relying on enhancement patterns to decide parathyroid lesion likelihood.
Is it clearly:
• Thyroid?
• Lymph node?
• Vascular?
If not, safest to describe as a candidate parathyroid lesion. (100% pre-test probability)


Horse or Zebra?
Known PHPT

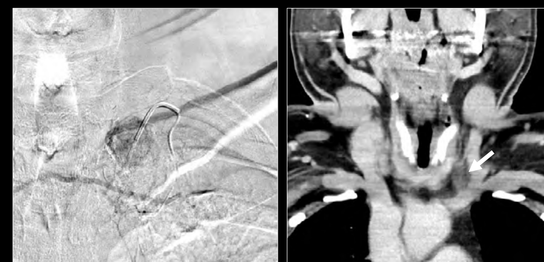

Horse or Disguised Horse?
Known PHPT


Parathyroid Adenoma
Cystic foci
Fat deposition
Calcification
Bunch PM, et al. RadioGraphics, 2020; 40:1383-1394.

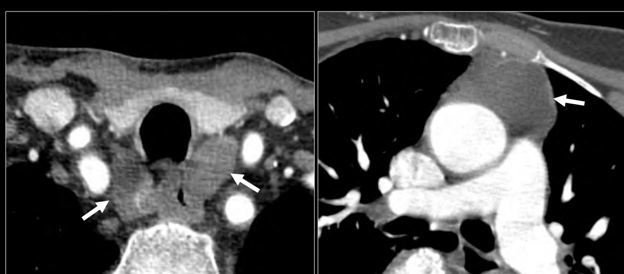
Illustrative Case

62-year-old female with primary hyperparathyroidism

Illustrative Case



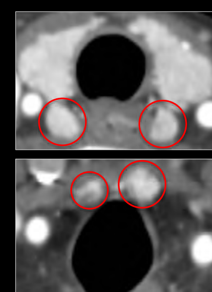
Additional Case Examples



Cases courtesy of Hillary R. Kelly, MD

Multiglandular disease

- Multiple parathyroid lesions
- No parathyroid lesions (88% specific)
- Smaller lesions (<7 mm; 79% specific)
- Requires BNE



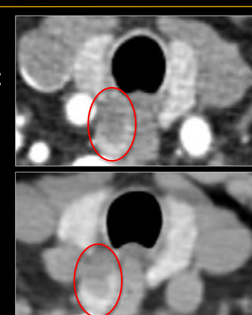
Sho S, et al. AJNR Am J Neuroradiol, 2016;37:2323-2327.

Parathyroid Carcinoma

- Difficult to diagnose preoperatively
- Markedly elevated PTH
- Young age
- Parathyroid calcifications

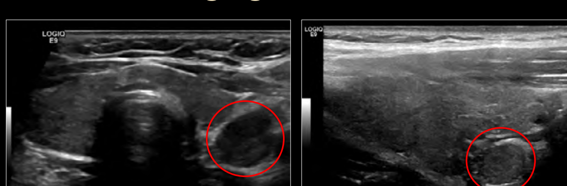
Thyroid

- Exophytic thyroid nodules potential parathyroid mimic
  - Variable enhancement
  - Scrutinize I- phase
- Assess for concurrent thyroid pathology



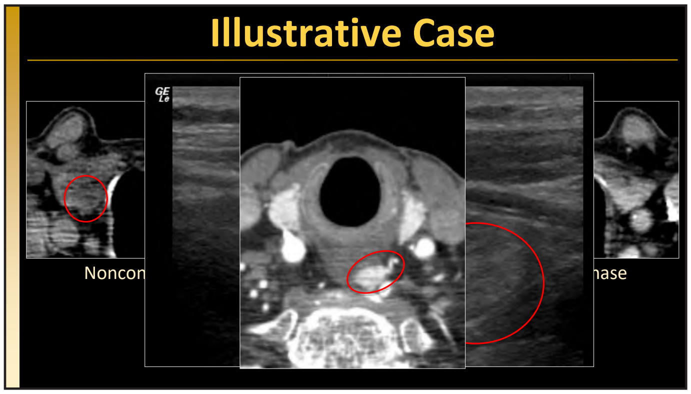
Pearl

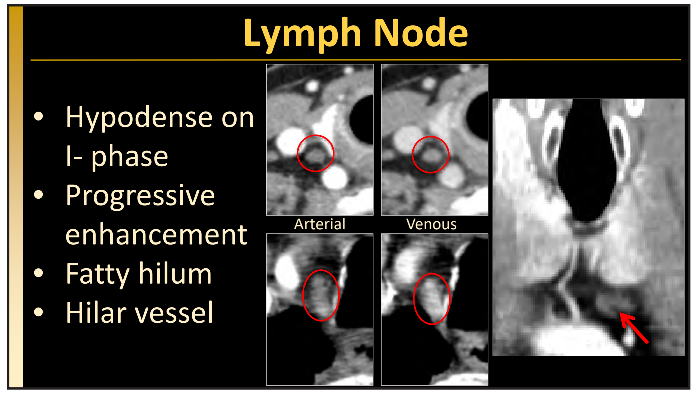
Use ***all*** imaging modalities available

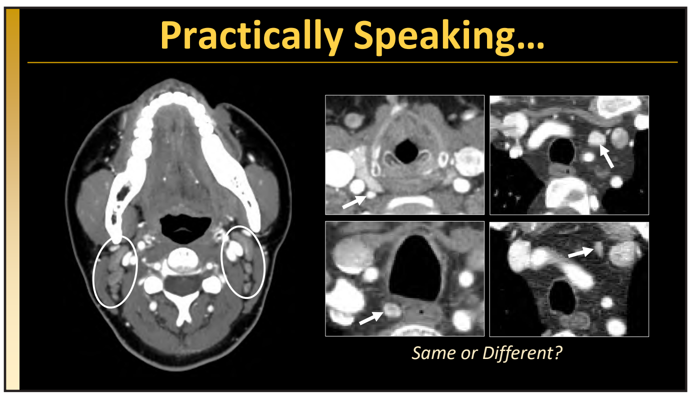


Illustrative Case

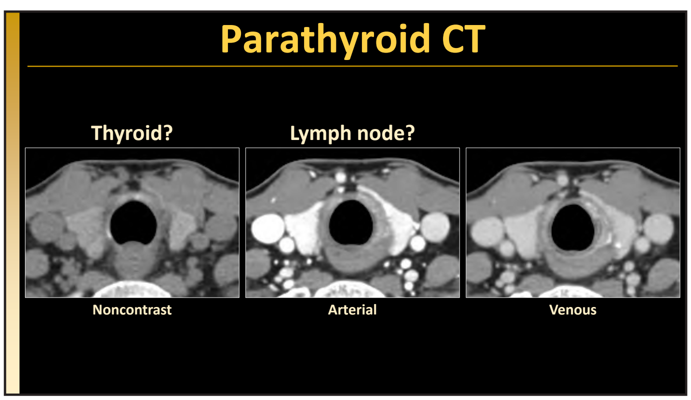
82-year-old male with primary hyperparathyroidism.

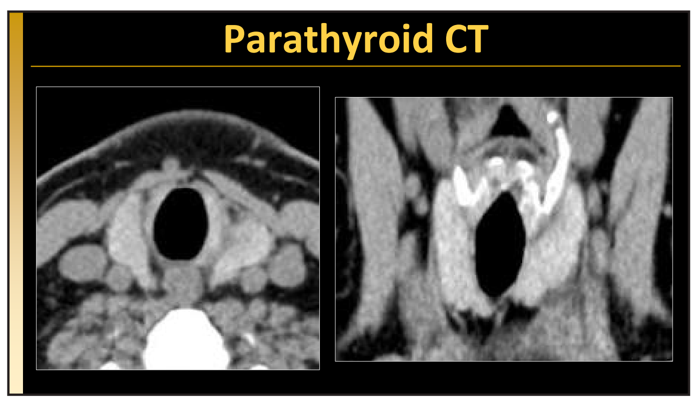

Illustrative Case
Noncon
hase

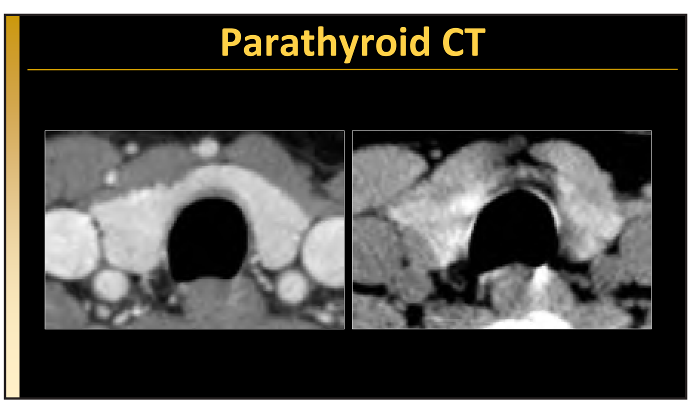

Lymph Node
• Hypodense on I- phase
• Progressive enhancement
• Fatty hilum
• Hilar vessel
Arterial
Venous

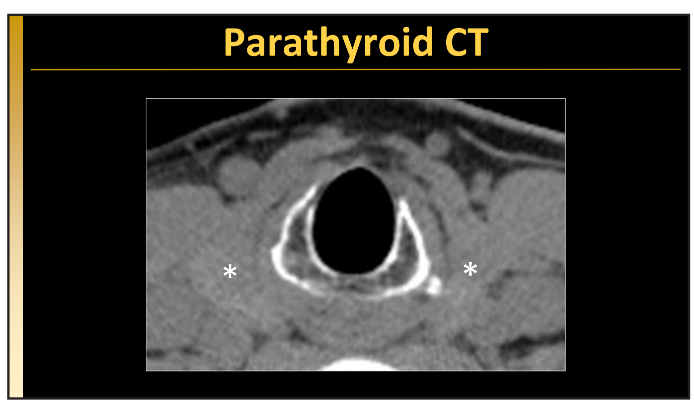

Practically Speaking…
Same or Different?

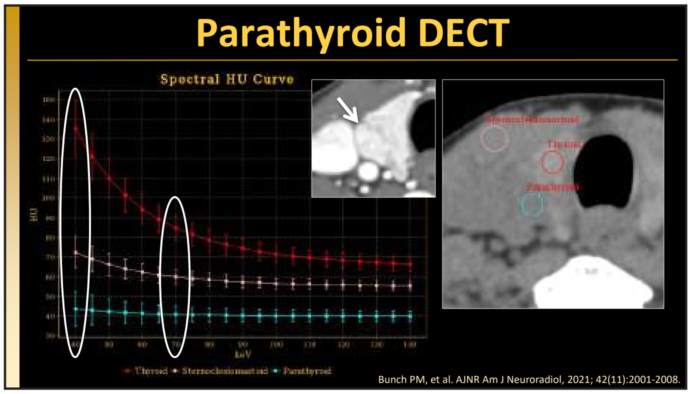

Approach

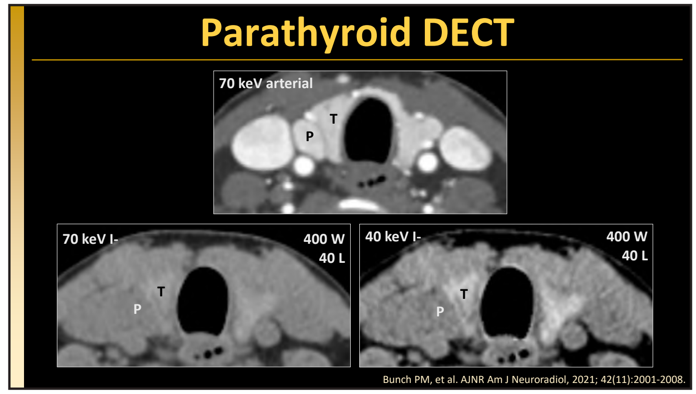

Parathyroid CT
Thyroid?
Lymph node?
Noncontrast
Arterial
Venous

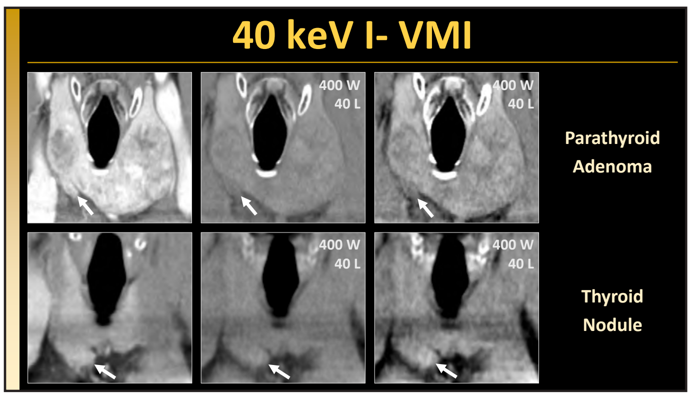

Parathyroid CT

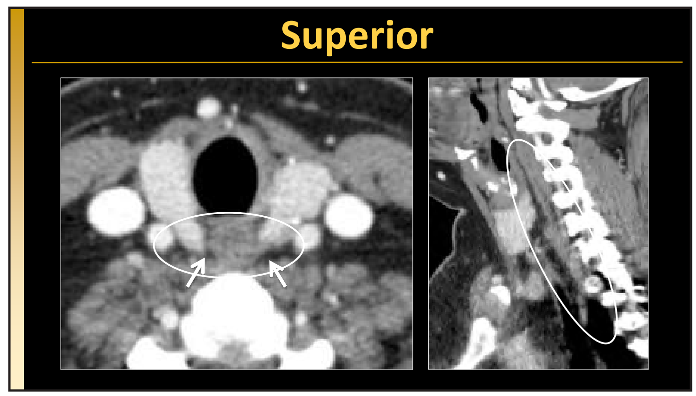

Parathyroid CT

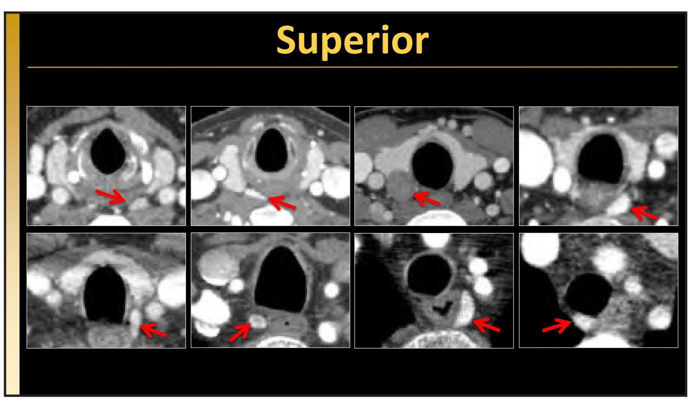

Parathyroid CT
*
*

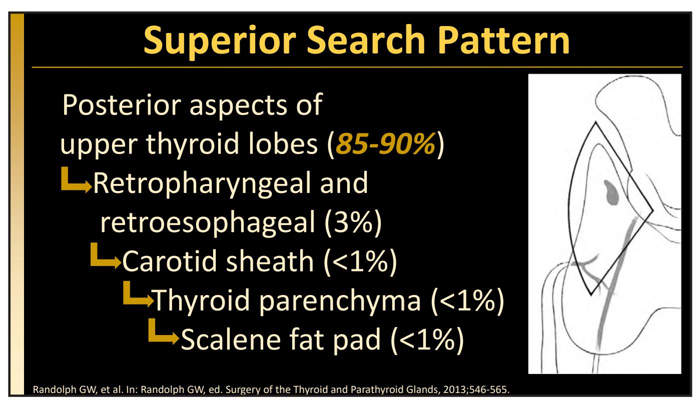

Parathyroid DECT
Spectral HU Curve
Bunch PM, et al. AJNR Am J Neuroradiol, 2021; 42(11):2001-2008.

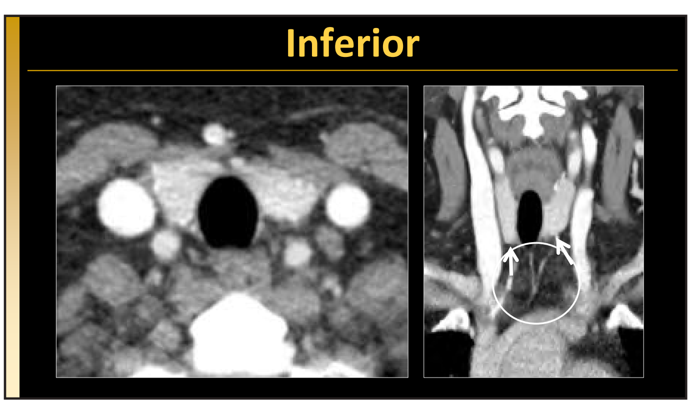

Parathyroid DECT
70 keV arterial
70 keV I-
400 W
40 L
40 keV I-
400 W
40 L
Bunch PM, et al. AJNR Am J Neuroradiol, 2021; 42(11):2001-2008.

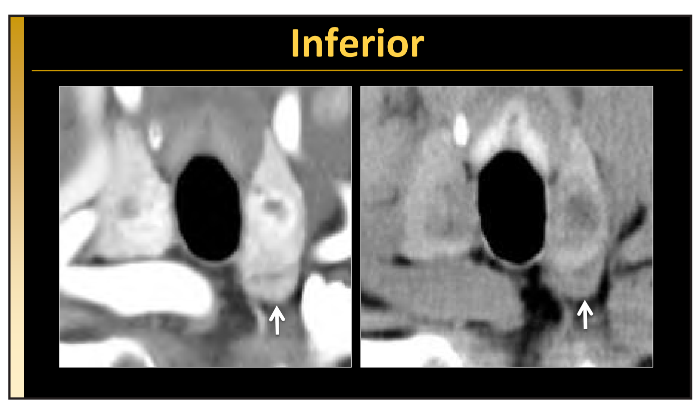

40 keV I- VMI
400 W
40 L
Parathyroid Adenoma
Thyroid Nodule


Superior

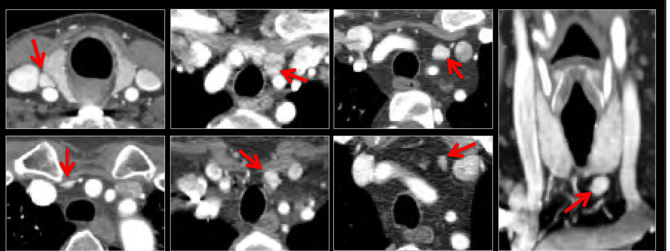

Superior


Superior Search Pattern
Posterior aspects of upper thyroid lobes (85-90%)
Retropharyngeal and retroesophageal (3%)
Carotid sheath (<1%)
Thyroid parenchyma (<1%)
Scalene fat pad (<1%)
Randolph GW, et al. In: Randolph GW, ed. Surgery of the Thyroid and Parathyroid Glands, 2013;546-565.


Inferior


Inferior

Inferior



Inferior Search Pattern

Lower thyroid lobe (***50-60%***)
↳ Thyrothymic ligament (***25%***)
↳ Mediastinum (3%)
↳ Carotid sheath (<1%)
↳ Thyroid parenchyma (<1%)

Randolph GW, et al. In: Randolph GW, ed. Surgery of the Thyroid and Parathyroid Glands, 2013;546-565.

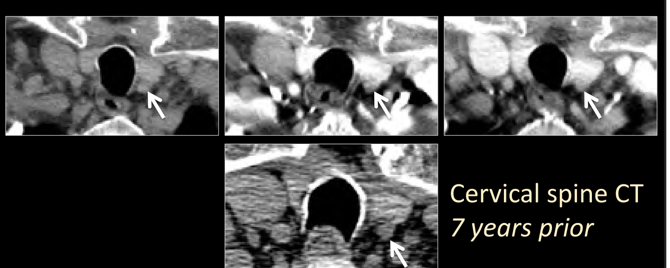
Pearl

Review ***old imaging***

Illustrative Case

81-year-old male with primary hyperparathyroidism.

Illustrative Case

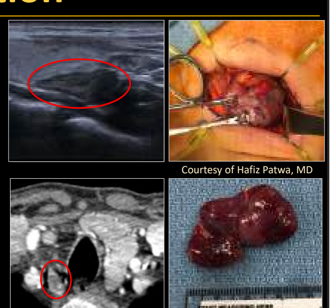


Cervical spine CT
7 years prior

What the Surgeon Wants to Know

To plan the operation

- Candidate lesions
  - Number
  - Size
  - Location (*be specific!*)
  - What you think

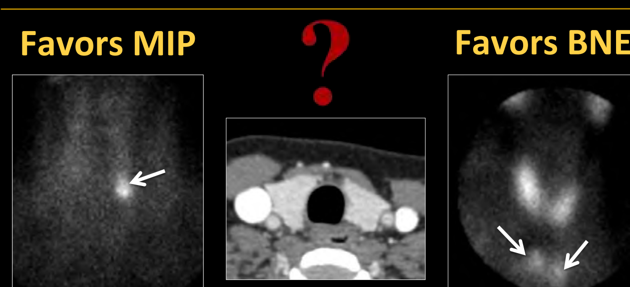


Courtesy of Hafiz Patwa, MD

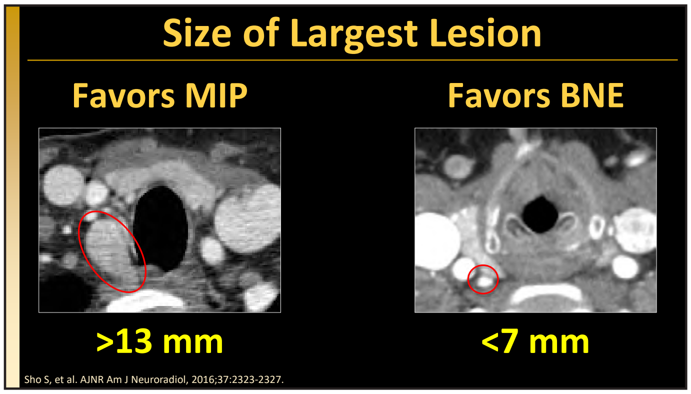
Courtesy of Reese Randle, MD

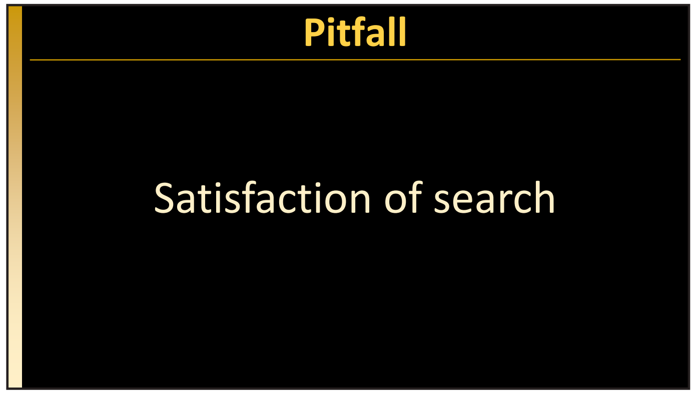
Number

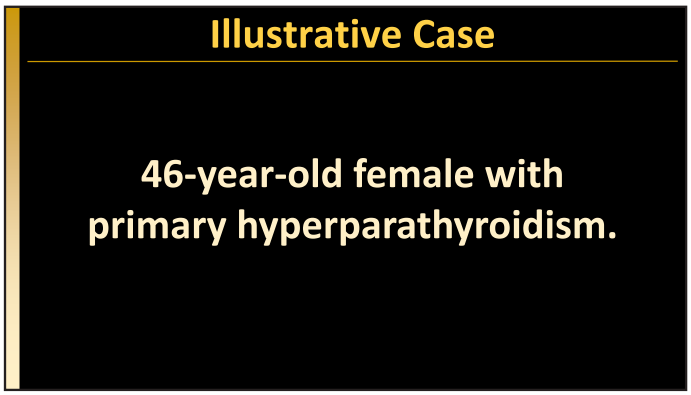
Favors MIP ? **Favors BNE**

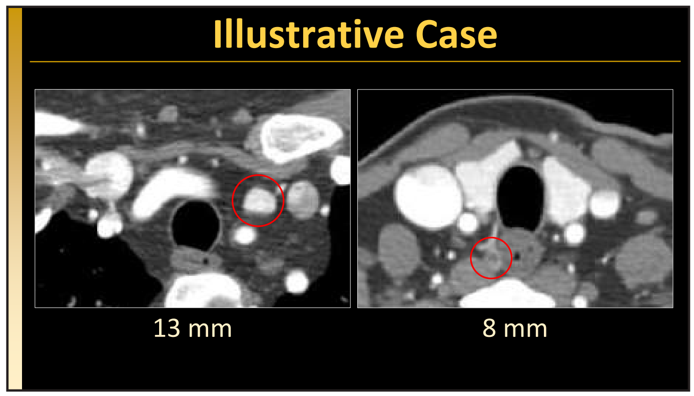


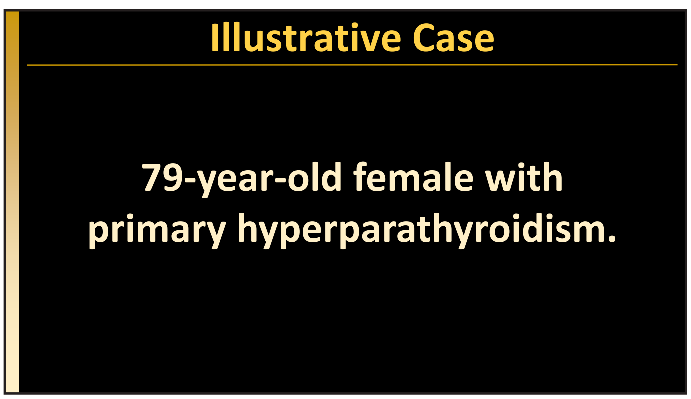
Sho S, et al. AJNR Am J Neuroradiol, 2016;37:2323-2327.

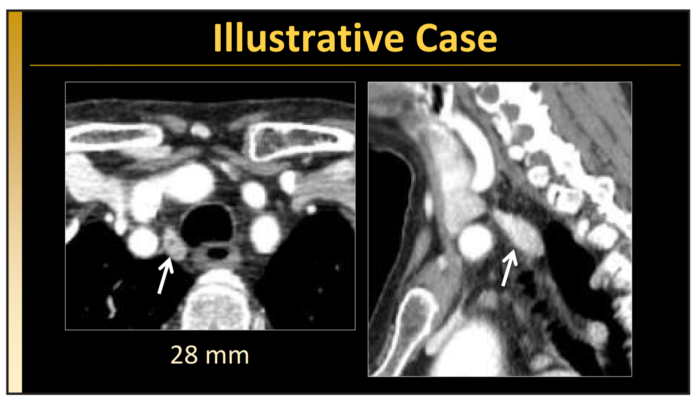

Size of Largest Lesion
Favors MIP
Favors BNE
>13 mm
<7 mm
Sho S, et al. AJNR Am J Neuroradiol, 2016;37:2323-2327.

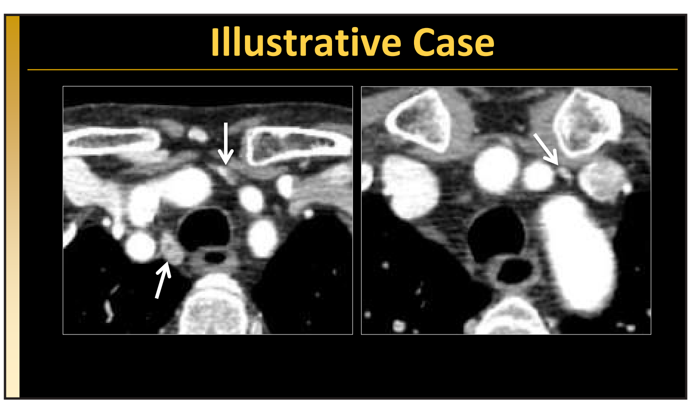

Pitfall
Satisfaction of search

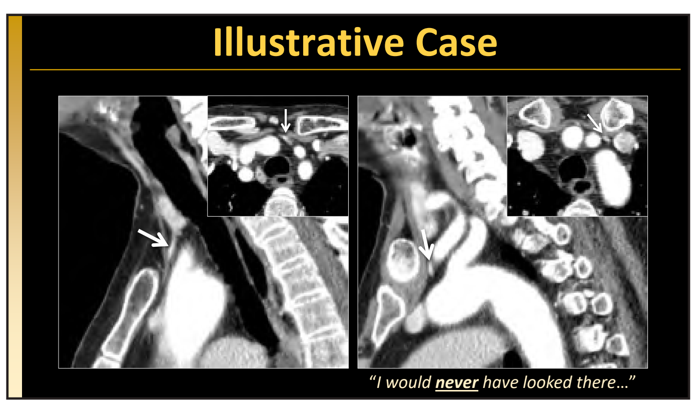

Illustrative Case
46-year-old female with
primary hyperparathyroidism.


Illustrative Case
13 mm
8 mm


Illustrative Case
79-year-old female with
primary hyperparathyroidism.


Illustrative Case
28 mm


Illustrative Case

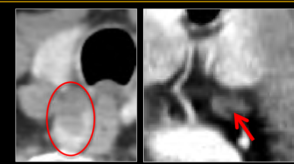

Illustrative Case
"I would never have looked there…"

Location

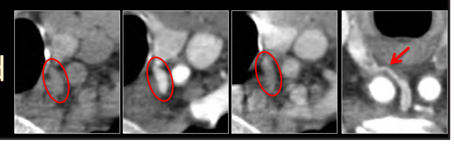
- Preferred landmarks
  - Tracheoesophageal groove (AP, depth)
  - Cricoid cartilage (SI, height)
  - Thyroid gland (upper pole, lower pole, isthmus)
  - Suprasternal notch

Radiologist Opinion

- Thyroid
- Lymph node
- Vascular

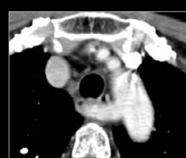


- Parathyroid

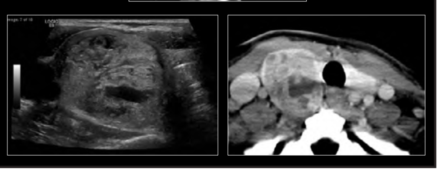


Have your surgeon's back!

- Nonrecurrent laryngeal nerve



- Thyroid pathology



Surgeon Wants to Know	Why Important
Number of Candidate Lesions	Single lesion favors adenoma; none and multiple favor MGD
Size of Candidate Lesions	Larger favors adenoma; smaller (<7 mm, even if single) favors MGD based upon 4D CT data
Lesion Location	Facilitates planning of incision and operative approach; be specific and describe with respect to relevant surgical landmarks
Opinion and Confidence Level of What Lesions Represent	If high and low confidence lesions, surgeon may start with MIP with plan for conversion to BNE if ioPTH does not drop appropriately
Ectopic or Supernumerary Parathyroid Tissue	Implications for operative plan and approach
Concurrent Thyroid Pathology	May require further preoperative workup and possible concurrent resection of suspicious or malignant nodules
Arterial Anomalies Associated with 'Nonrecurrent' LN	Increased operative risk to the nerve

Summary

- PHPT associated with morbidity and costs
- Biochemical diagnosis
- Surgical cure
- Role of imaging is ***preoperative localization***
- Knowledge of embryology and anatomy maximizes localization success
- Leverage strengths of all imaging modalities to maximize patient access to curative minimally invasive surgery

Pearls and Pitfalls

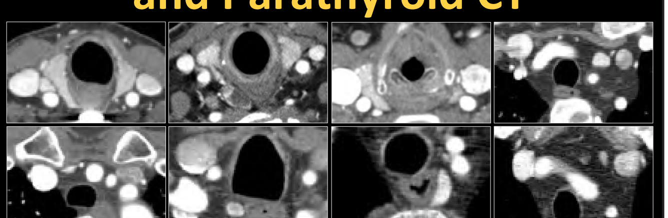
Pearls:

- Start with I- phase (low keV VMI if DECT)
- Correlate with other modalities when available
- Old films

Pitfalls:

- Assuming low in neck = inferior gland
- Enhancement pattern fixation
- Satisfaction of search

Primary Hyperparathyroidism and Parathyroid CT



Wake Forest School of Medicine

Paul M. Bunch, MD

SELF EVALUATION

Primary Hyperparathyroidism and Parathyroid CT

1. The most common cause of hypercalcemia is:

a. Primary hyperparathyroidism
b. Sarcoid
c. Thiazide diuretics
d. Paget's disease

2. The diagnosis of primary hyperparathyroidism is made by:

a. History and physical examination
b. Blood tests
c. Imaging
d. Biopsy

3. T/F - Superior and inferior parathyroid glands are differentiated based on their relative superior or inferior position in the neck.

4. The frequency of multigland disease as the cause of primary hyperparathyroidism most closely approaches:

a. 1 to 5%
b. 5 to 10%
c. 10 to 30%
d. 30 to 50%

5. T/F - Patients with primary hyperparathyroidism and non-localizing imaging studies are not candidates for parathyroidectomy.

Answer Key: 1. A, 2. B, 3. F, 4. C, 5. F