
Photon Counting CT: Overview and Clinical Applications in Neuroradiology (Head and Neck)

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Disclosures: No Financial conflicts



Acknowledgments

- Dr. Zanoni
- Dr. Matsuura



Learning Objectives

- Highlight technical properties of PCD-CT and its impact on clinical images.
- Explore how the advantages of PCD-CT could be translated into potential clinical applications in neuroradiology (head and neck imaging).
- Recognize the limitations of current PCD-CT technology.
- Discuss emerging applications of PCD-CT and the anticipated impact on future clinical practices.

Introduction

- PCD-CT has significantly advanced CT technology. It directly converts x-ray photons into electric signals, while conventional systems rely on indirect conversion.
 - Smaller detector Pixels
 - Elimination of electronic noise
 - Intrinsic spectral sensitivity
 - Equal contribution of lower energy quanta

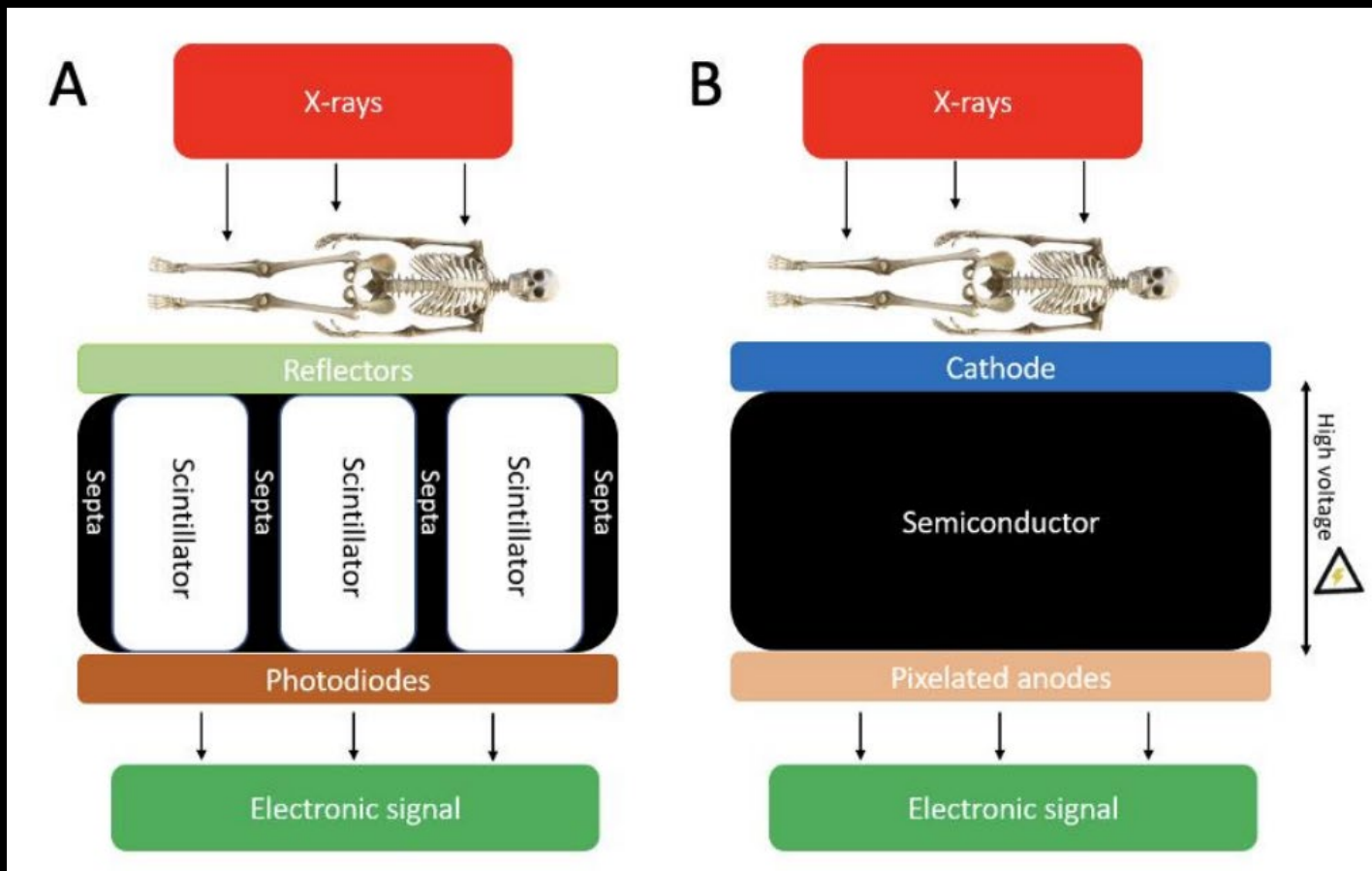
Introduction

- The new detectors allow detection of individual x-ray photon with measurement of its energy, improving spatial resolution, beam-hardening artifact reduction, optimized spectral imaging, and greater temporal resolution.
- Specific applications in neuroimaging include temporal bone evaluation, head and neck CT angiography (CTA) for evaluation of atherosclerosis and stent assessment, spinal CTA , and dynamic CT myelography for detection of cerebrospinal fluid (CSF) leak.

Photon-counting detector CT (PCD-CT)

Technical Properties

Basic schematic overview of EID-CT and PCD-CT



A. EIDs convert incoming photons to visible light, which travels to a photodiode layer and is converted into electric signal, allowing for total energy measurement. Reflective septa divide scintillator elements to prevent leakage but create “dead space” that lowers efficiency.

B. PCDs create an electron-hole pair when a photon strikes the semiconductor material of the detector juxtaposed between a cathode and an anode. The x-ray produces a cloud of positive and negative charges that travel in the electric field, thereby generating an electric signal that can be measured for each photon.

Unique properties of PCD-CT and impact on CT images for clinical practice

Photon-Counting Detector Property	Impact on Clinical Images
A. Direct conversion of X-ray coincidence to signal that is proportional to photon energy	- Increased iodine signal as there is no down weighting of lower energy photons - Ability to obtain multi-energy information with a single X-ray tube voltage: virtual monoenergetic images, virtual non-contrast, virtual non-calcium, and iodine maps routinely available
B. Smaller detector pixel size	- Improved spatial resolution
C. Reflective septae are not required for each detector element, which contributes to geometric dose inefficiency with conventional energy-integrated detectors	- Radiation dose reduction improved spatial resolution
B and C	- Ultra-high spatial resolution does not require attenuating filters that increase radiation dose - Ultra-high spatial resolution no longer has a radiation dose penalty and can be performed in larger body regions
D. Elimination of electronic noise	- Only quantum noise is present
E. Shaping of the X-ray beam with tin filters, energy thresholds, and tube potential selection	- Reduction of metal and blooming artifact - Reduced radiation dose

Photon-counting detector CT (PCD-CT)

Clinical Applications in Neuroradiology

PCD-CT - Clinical Applications in Neuroradiology

- Temporal bone imaging
- Sinus imaging
- Vascular imaging of the head and neck
- Spectral imaging for tumor characterization and reperfusion imaging after intra-arterial therapy for acute stroke.

PCD-CT - Clinical Applications in Neuroradiology

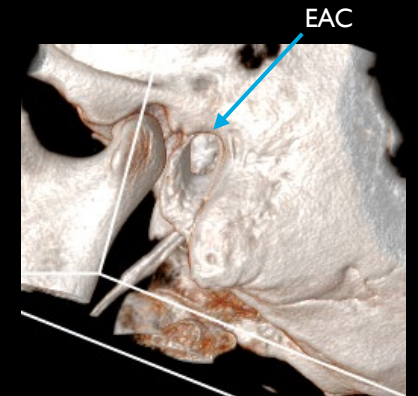
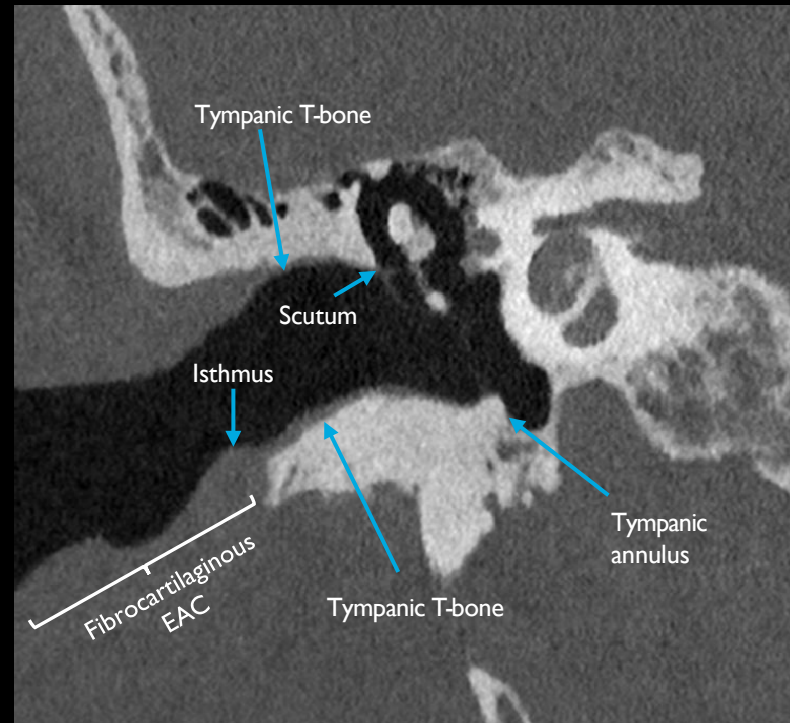
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PCD-CT - Temporal bone imaging

- With higher spatial resolution in comparison with EID-CT, visualization of the very fine anatomic structures is improved.
- Images show sharper delineation of the temporal bone anatomy, including the auditory ossicles, modiolus, vestibular aqueduct and semicircular canals.
- Artifact reduction also improves visualization of the cochlear implants as well as stapes protheses or total ossicular replacements.

External Ear

- Osseous-cartilaginous structure.
- Auricle to the tympanic membrane
- Most of the lesions are diagnosed clinically
- Extent of disease, complications and surgical planning.
- CT typically the first study of choice. MRI have a complementary role.



External Ear

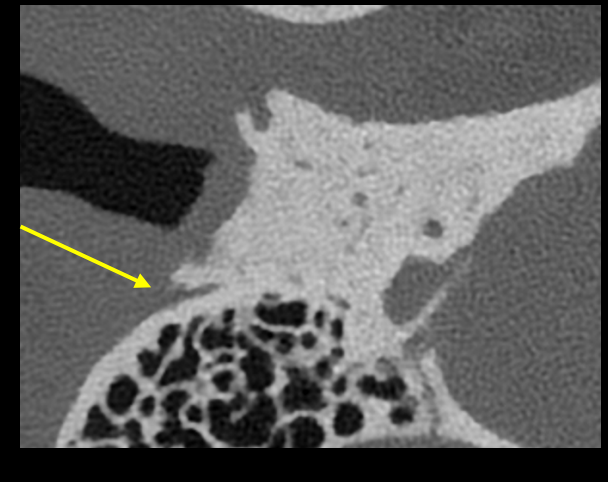
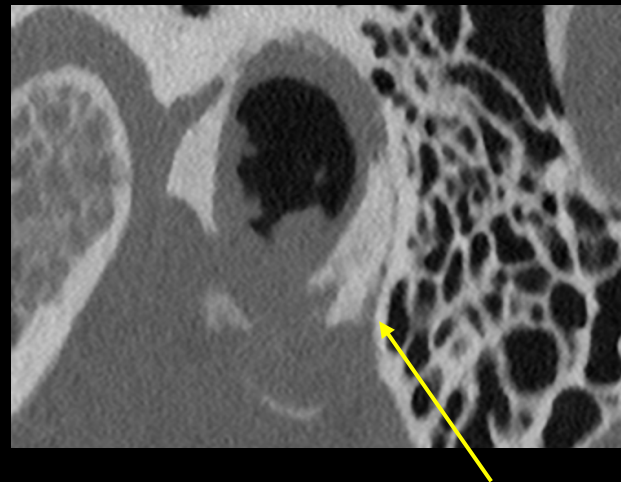
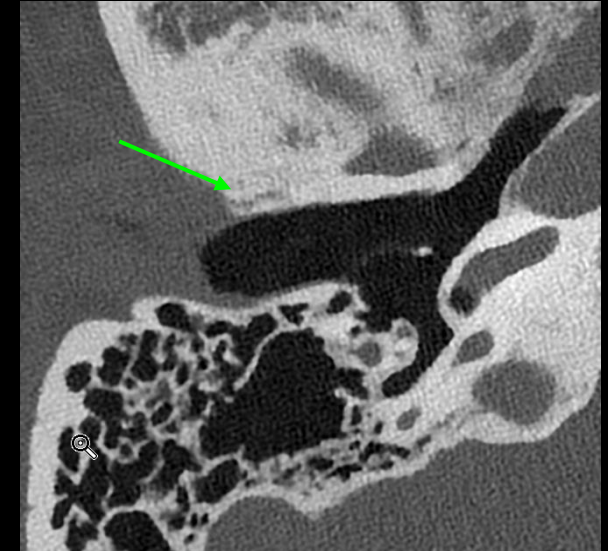
Intrinsic fissures: May mimic fractures lines. Knowledge is important to avoid mistakes.

Tympanosquamosal fissure:

- Anterior to EAC.
- Continues medially as petrotympanic and petrosquamous fissures.

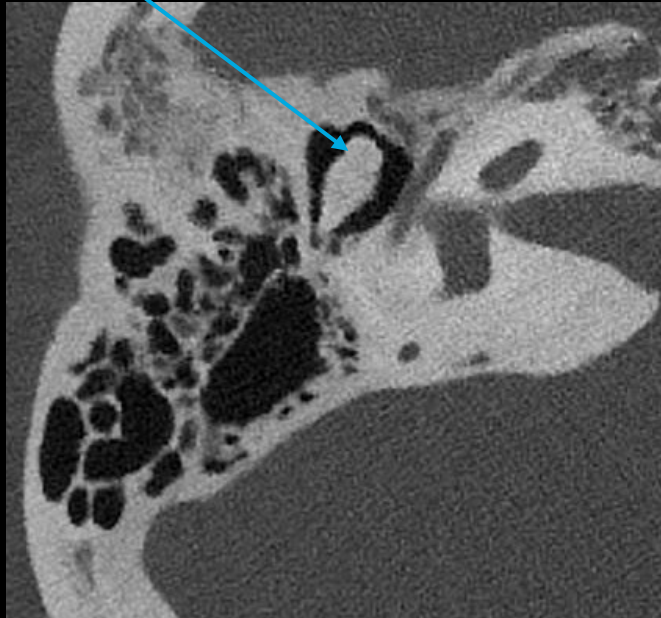
Tympanomastoid fissure:

- Posterior to EAC.
- The auricular branch of CN X (Arnold's nerve) emerges from this fissure to supply the external tympanic membrane and EAC.
- The Arnold's nerve is one of the potential origins of **glomus jugulare tumors** along with the tympanic branch of the glossopharyngeal nerve (nerve of Jacobson) and paraganglia within the wall of the jugular bulb.

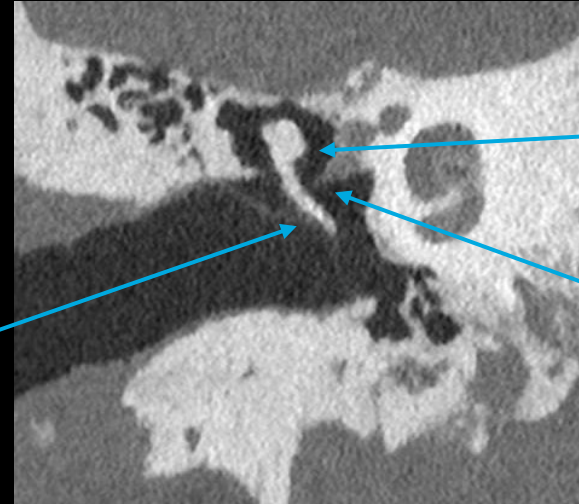


Middle Ear (Ossicles)

Head of Malleus



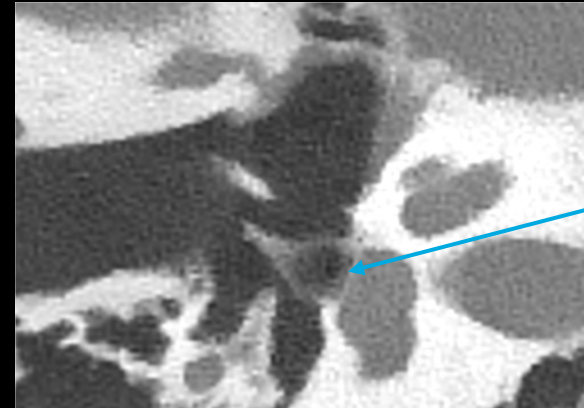
Manubrium



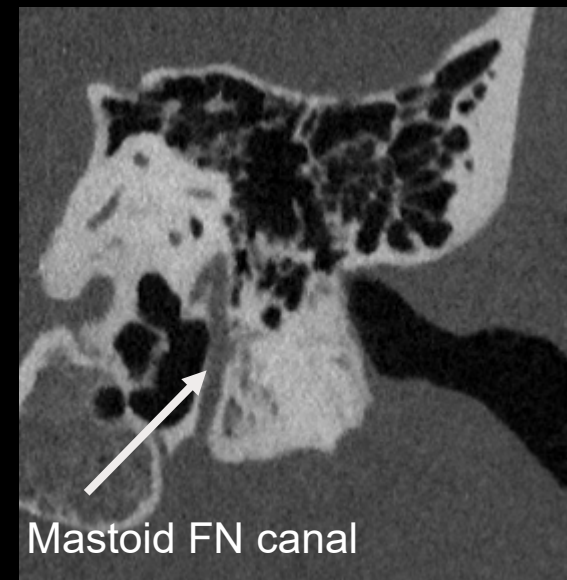
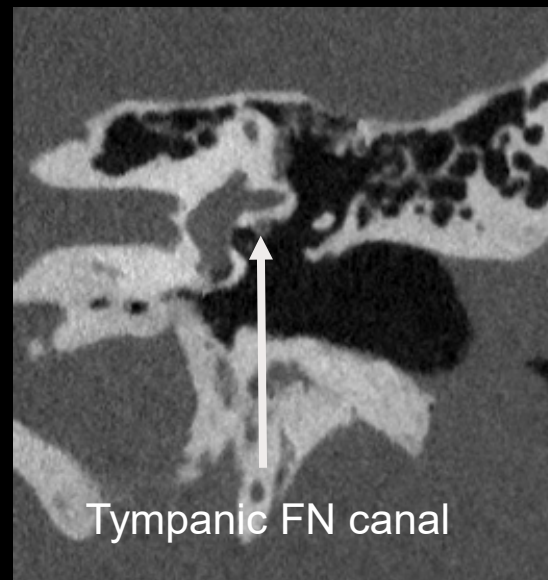
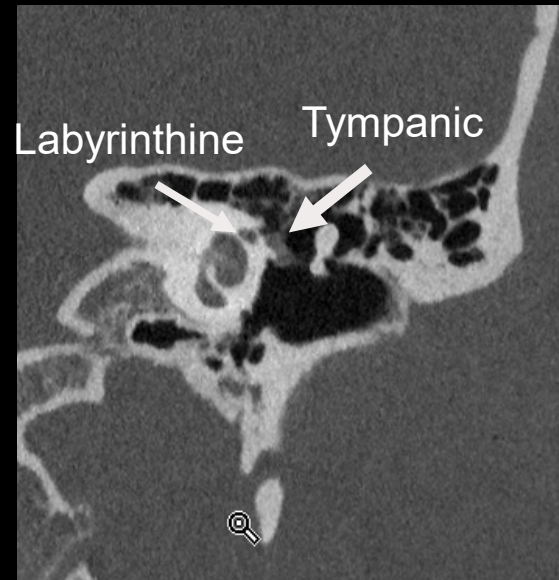
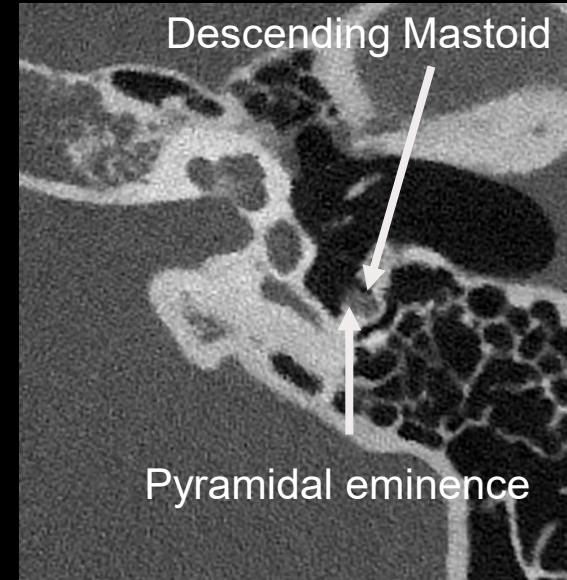
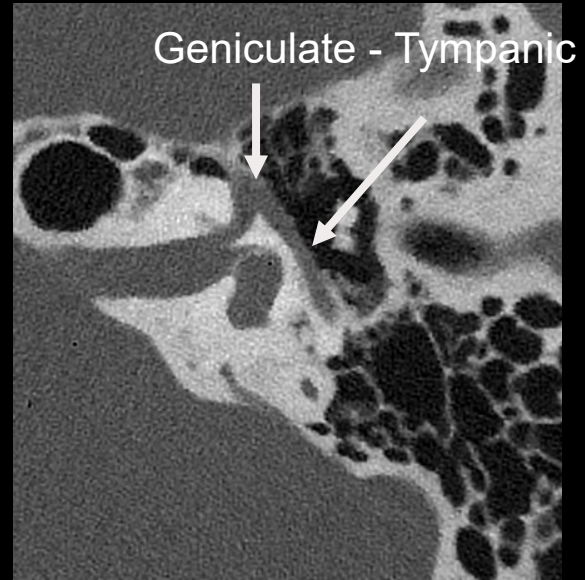
Head of the Malleus

Tensor tympani muscle

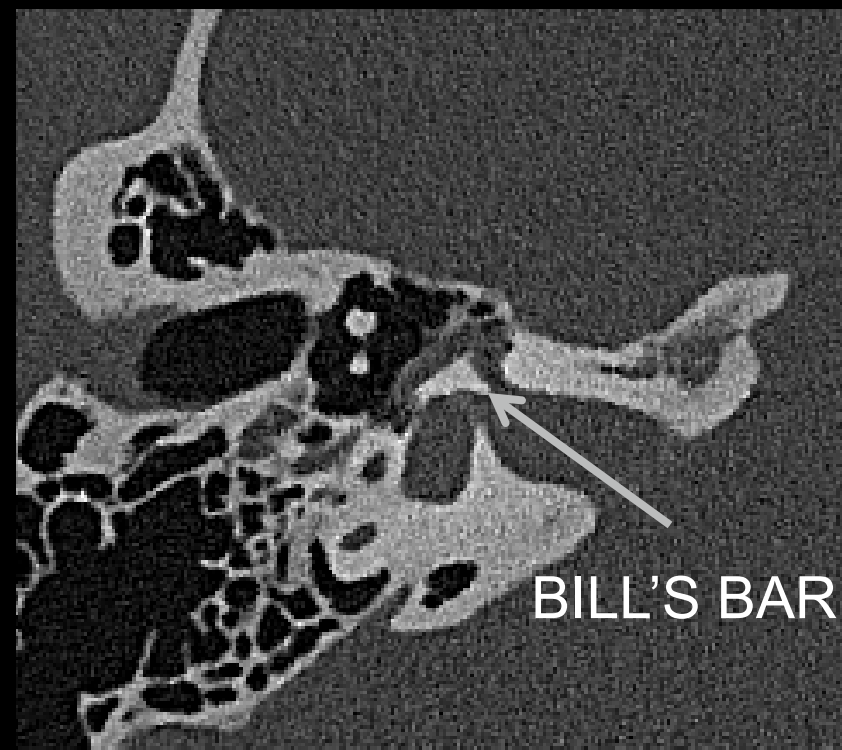
Body Incus



Stapes Footplate

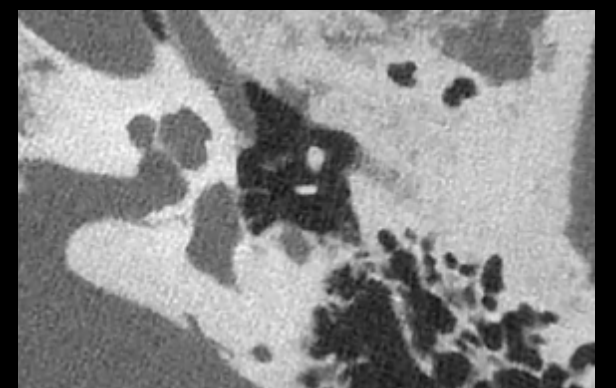
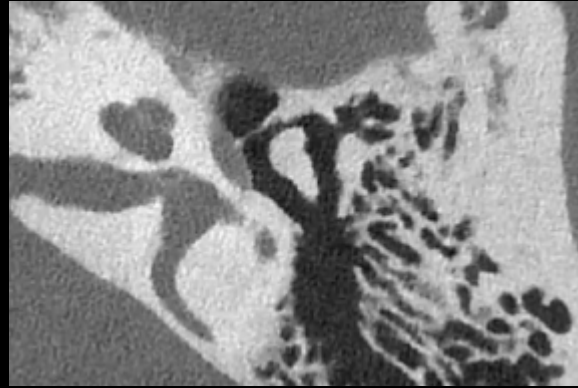
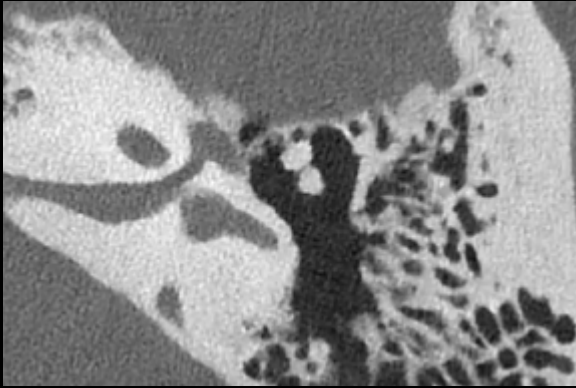


Inner ear

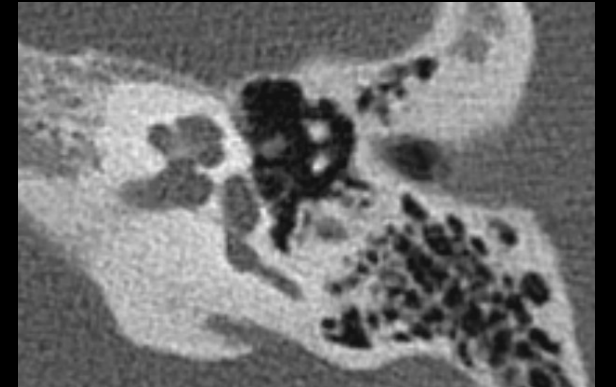
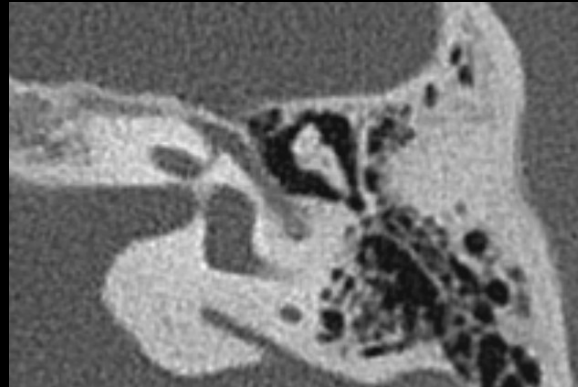
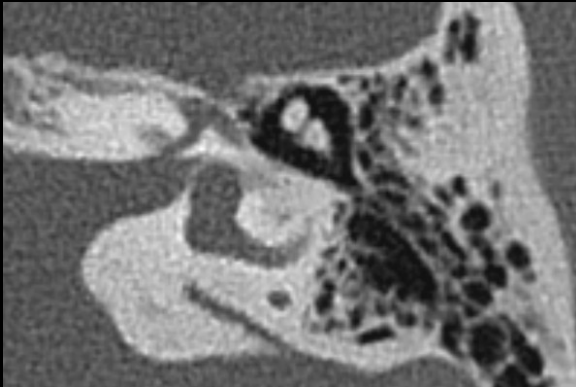


Comparison

PCCT

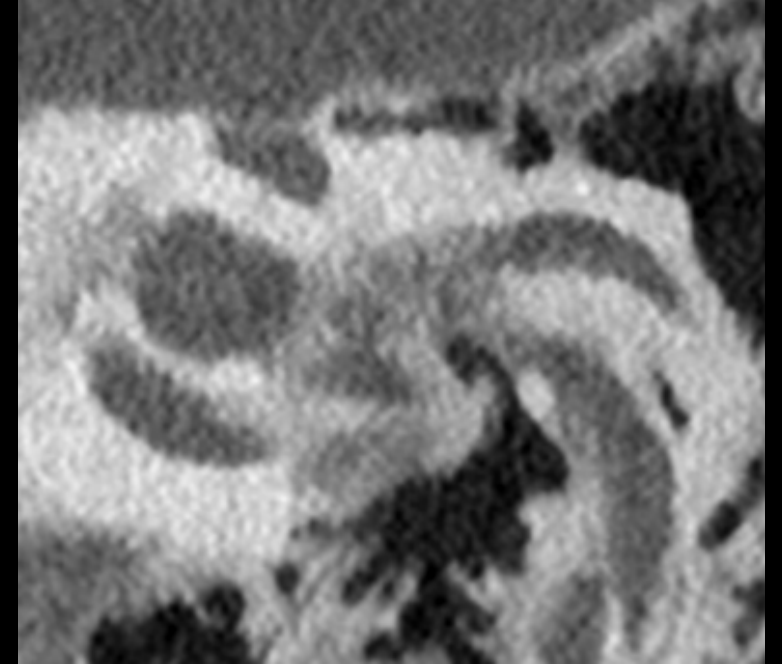
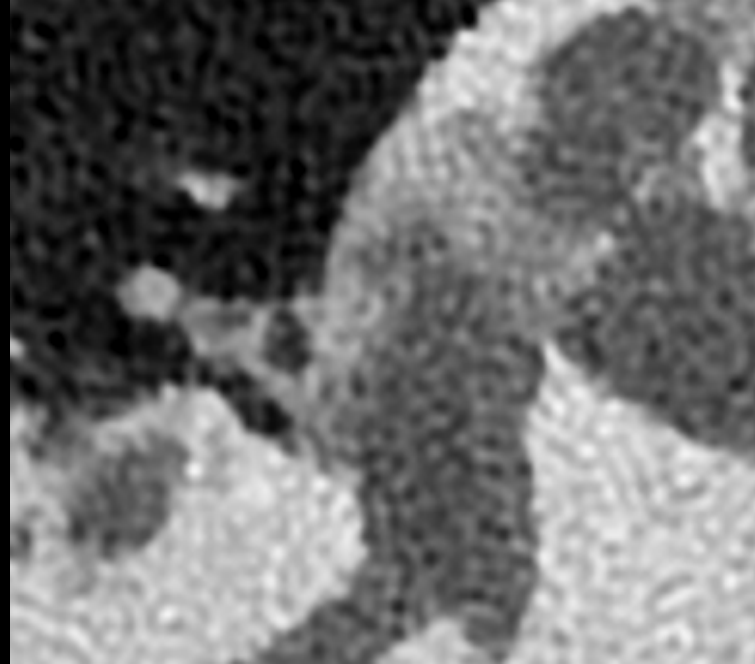
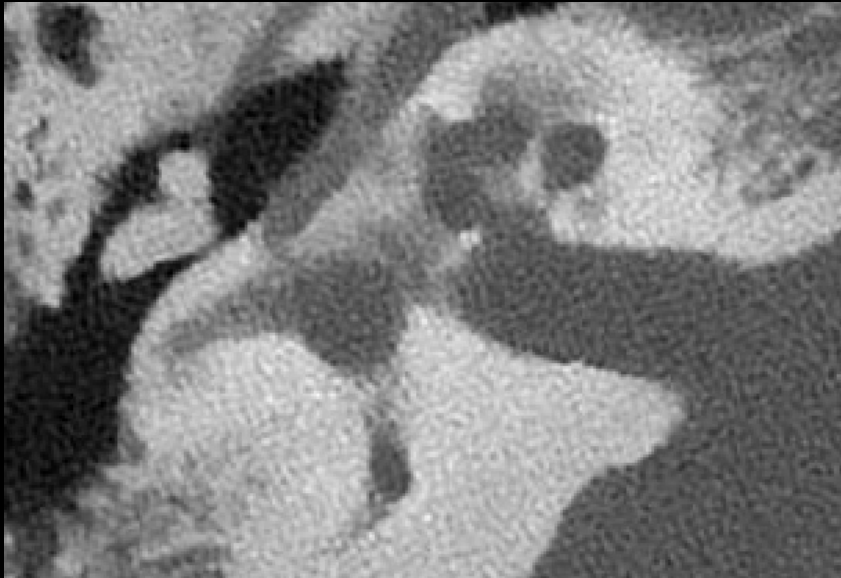
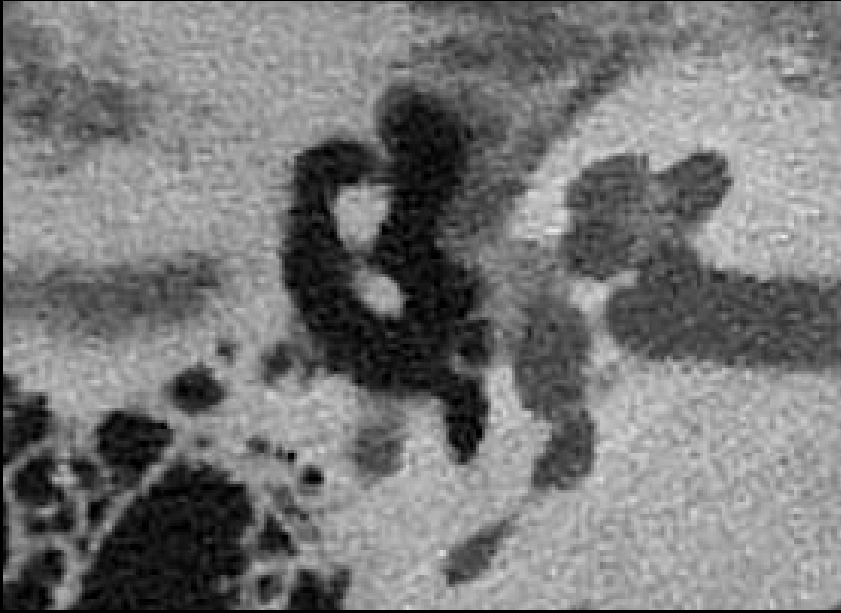


EID-CT

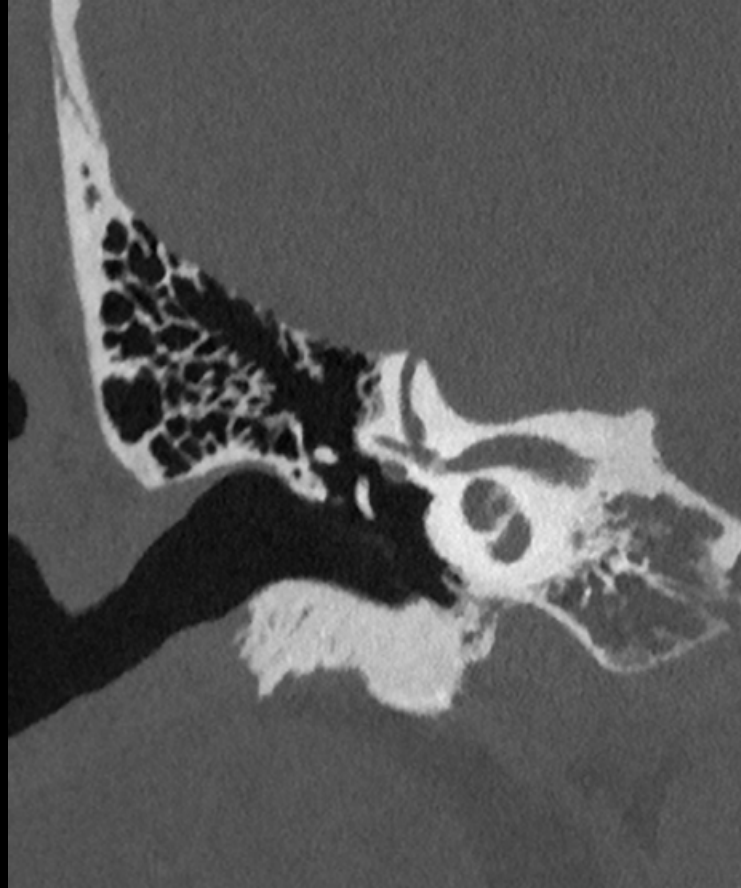


IOWA

Otosclerosis



Superior Semicircular canal dehiscence



A New Frontier in Temporal Bone Imaging: Photon-Counting Detector CT Demonstrates Superior Visualization of Critical Anatomic Structures at Reduced Radiation Dose

J.C. Benson, K. Rajendran, J.I. Lane, F.E. Diehn, N.M. Weber, J.E. Thorne, N.B. Larson, J.G. Fletcher, C.H. McCollough, and S. Leng

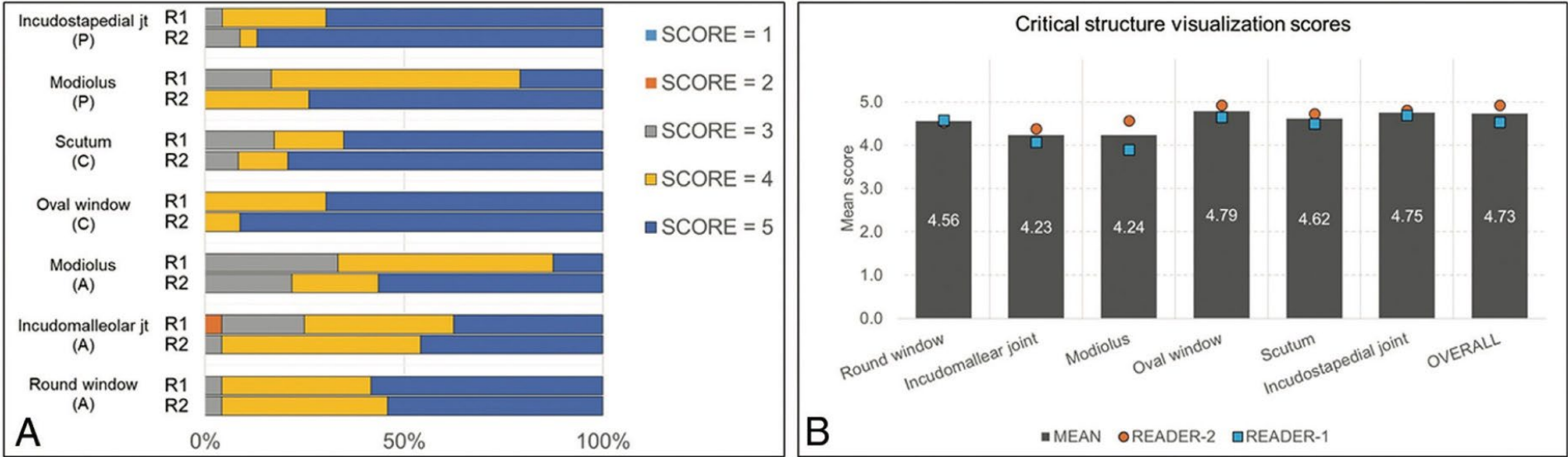
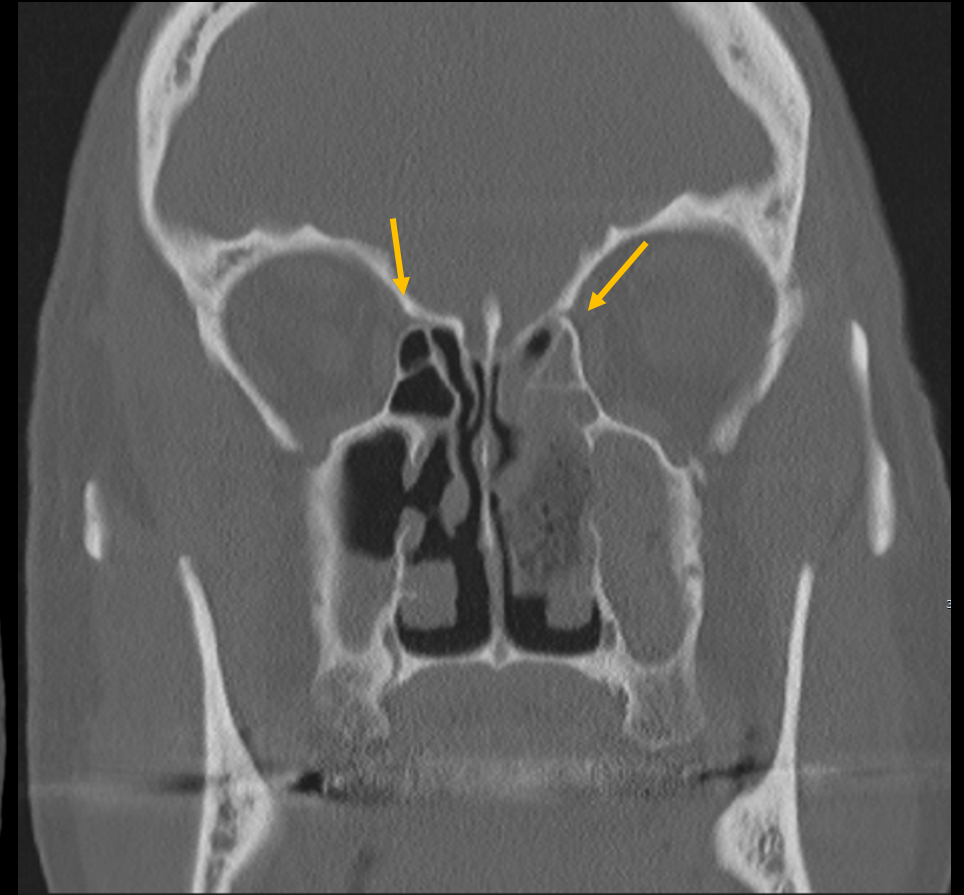
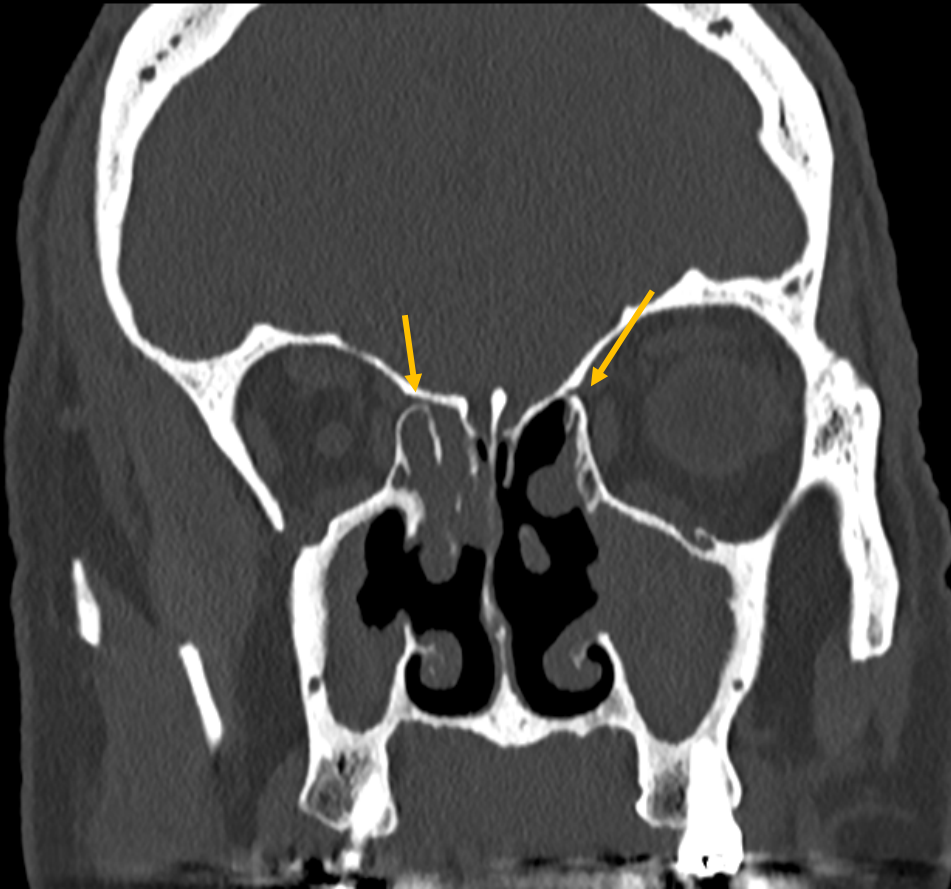


FIG 1. Readers' score distribution for spatial resolution and visualization of critical anatomic structures in different reformatted planes (A) and mean readers' scores for individual anatomic structures and overall image quality (B). All scores were based on a 5-point Likert scale, comparing PCD-CT with EID-CT: 1=inferior resolution with degraded visualization, 2=slightly inferior resolution without affecting visualization, 3=equivalent resolution and visualization, 4=slightly superior resolution without affecting visualization, and 5=superior spatial resolution with improved visualization.

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Sinus imaging

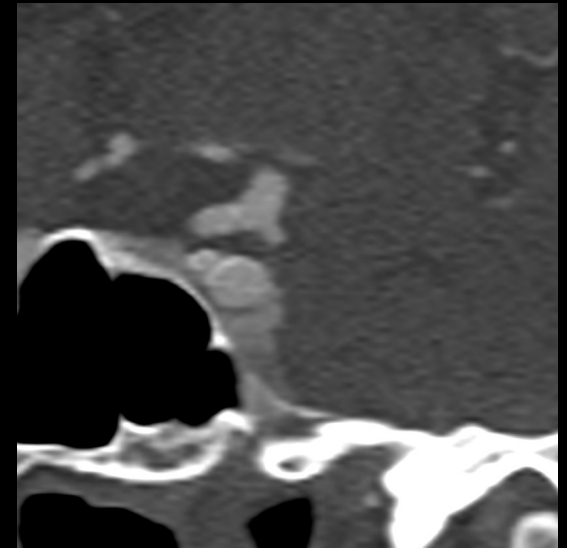
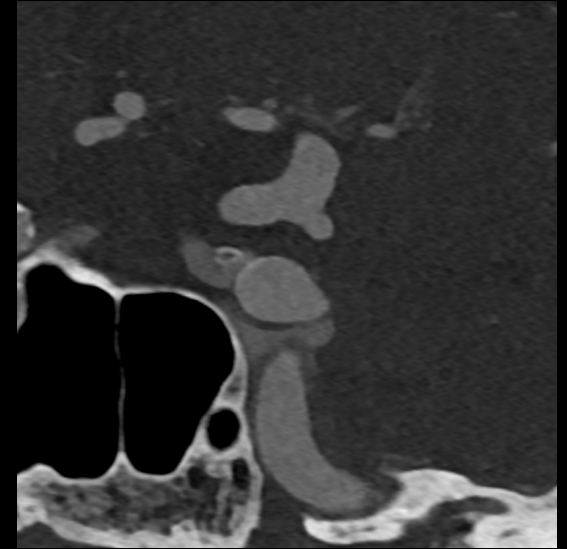
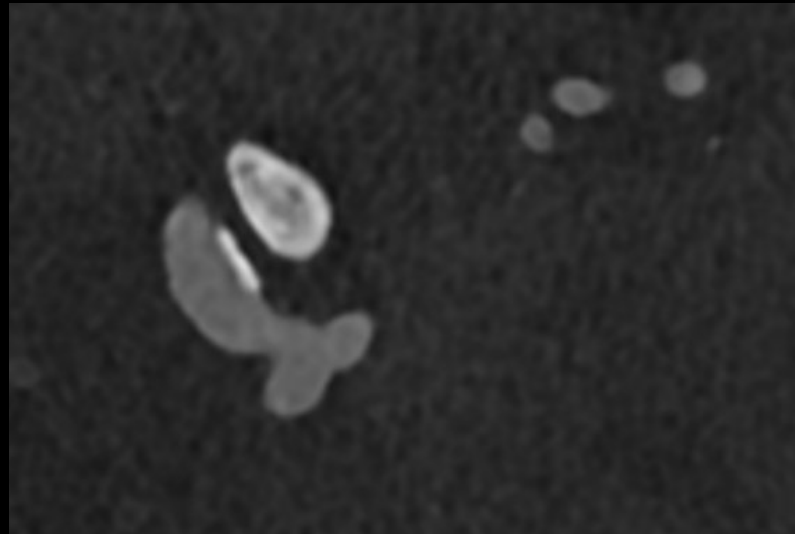
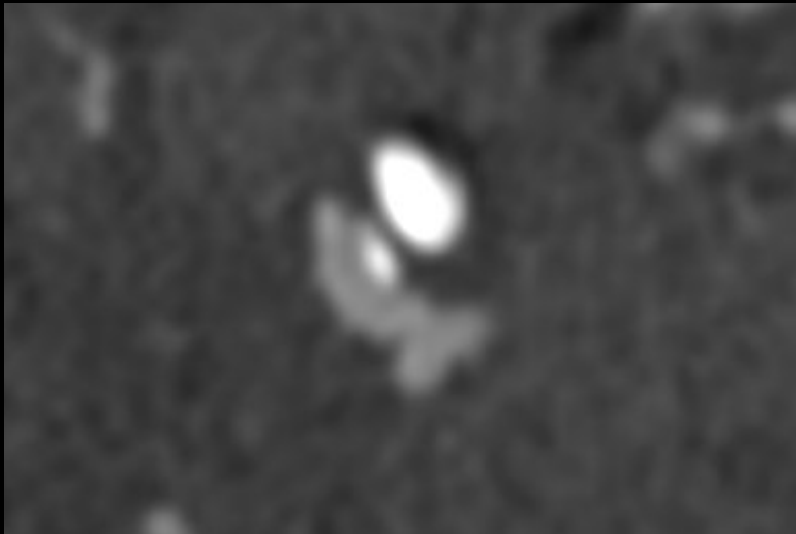


Patient with chronic sinusitis and postsurgical changes of functional endoscopic sinus surgery.

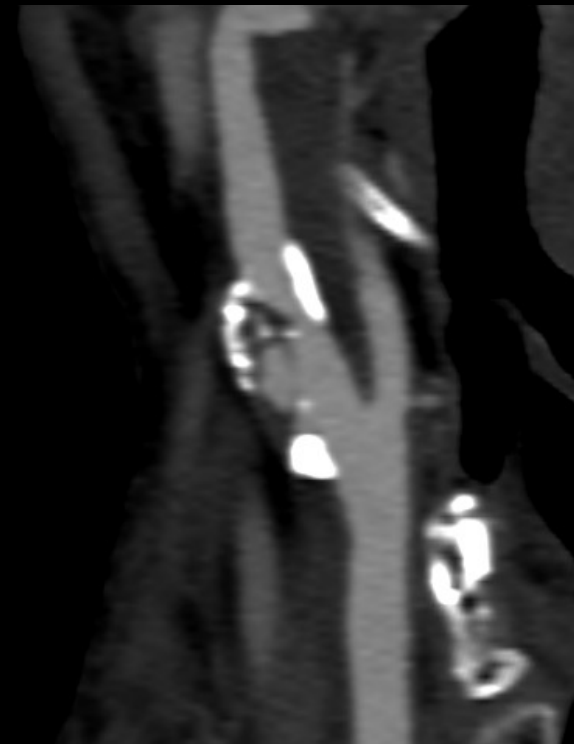
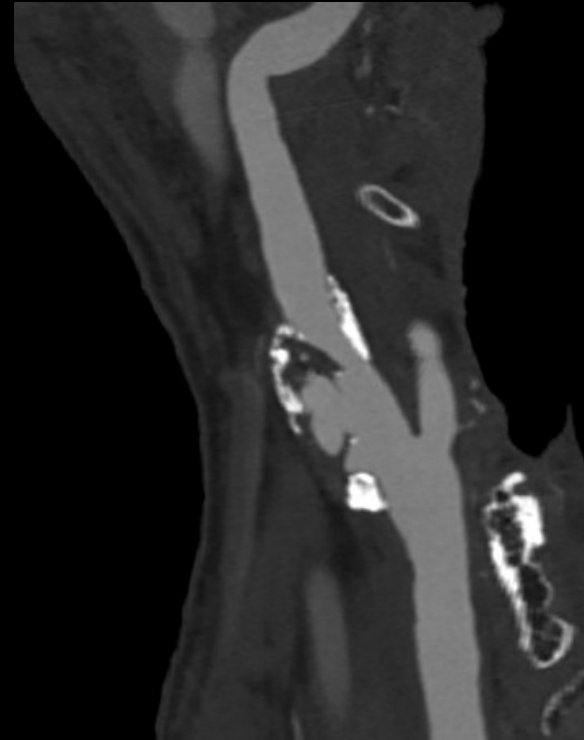
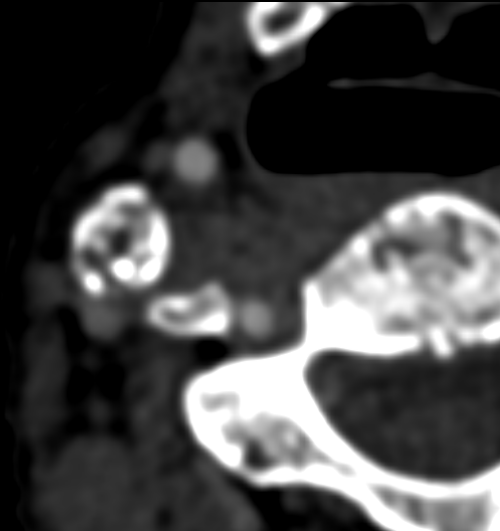
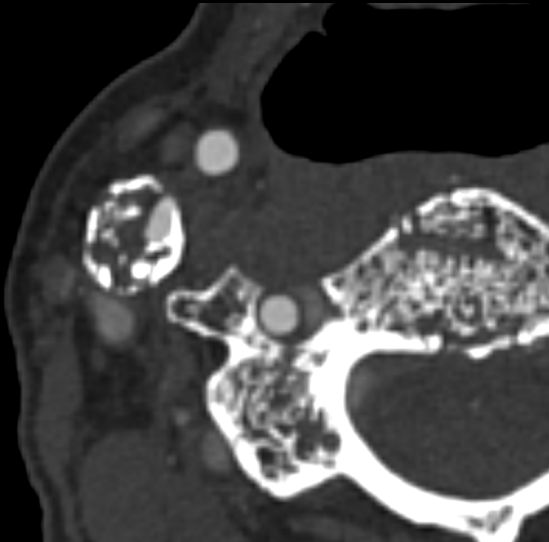
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Vascular imaging in head and neck



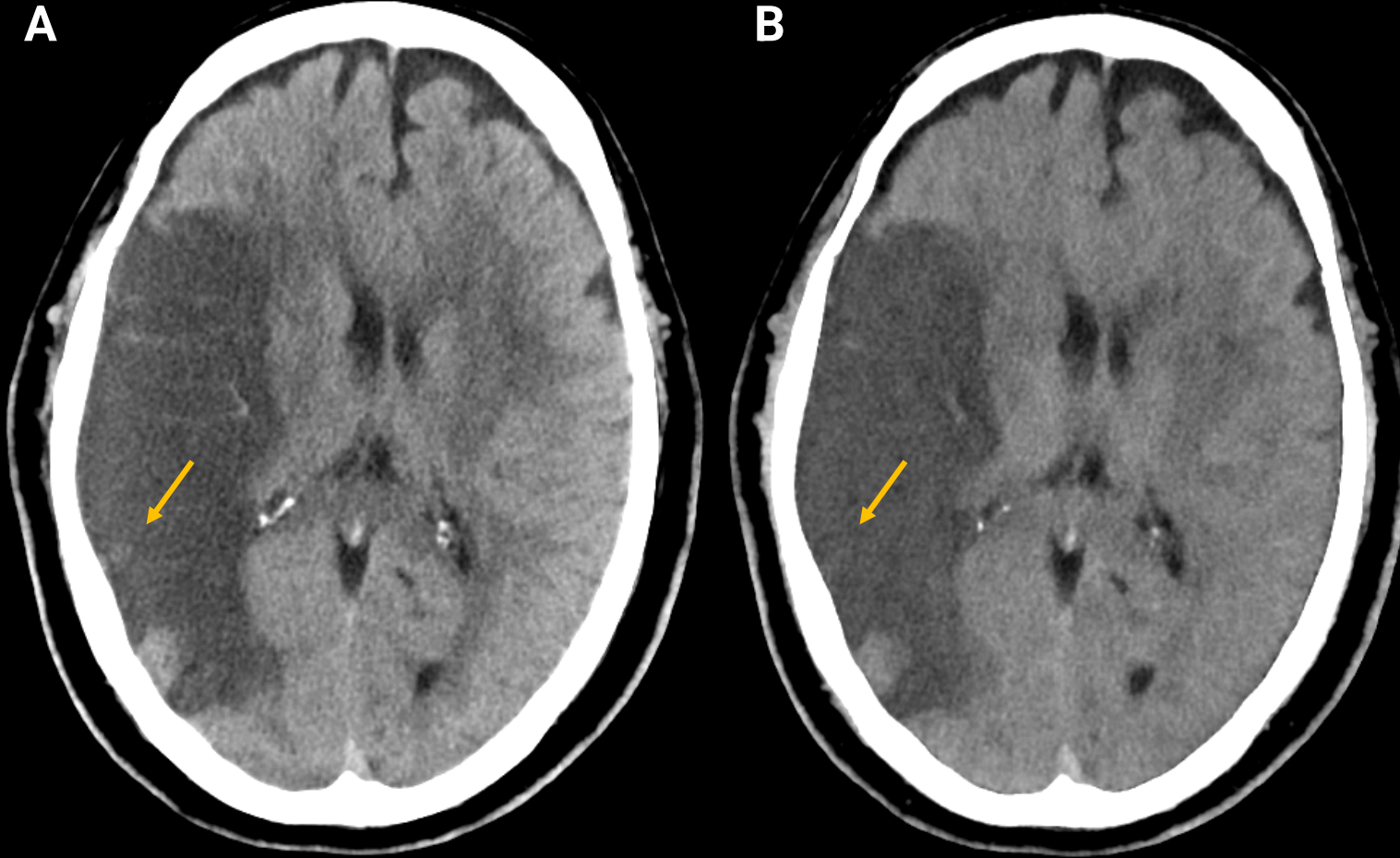
Vascular imaging in head and neck



PCD-CT - Clinical Applications in Neuroradiology

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Spectral imaging in head and neck

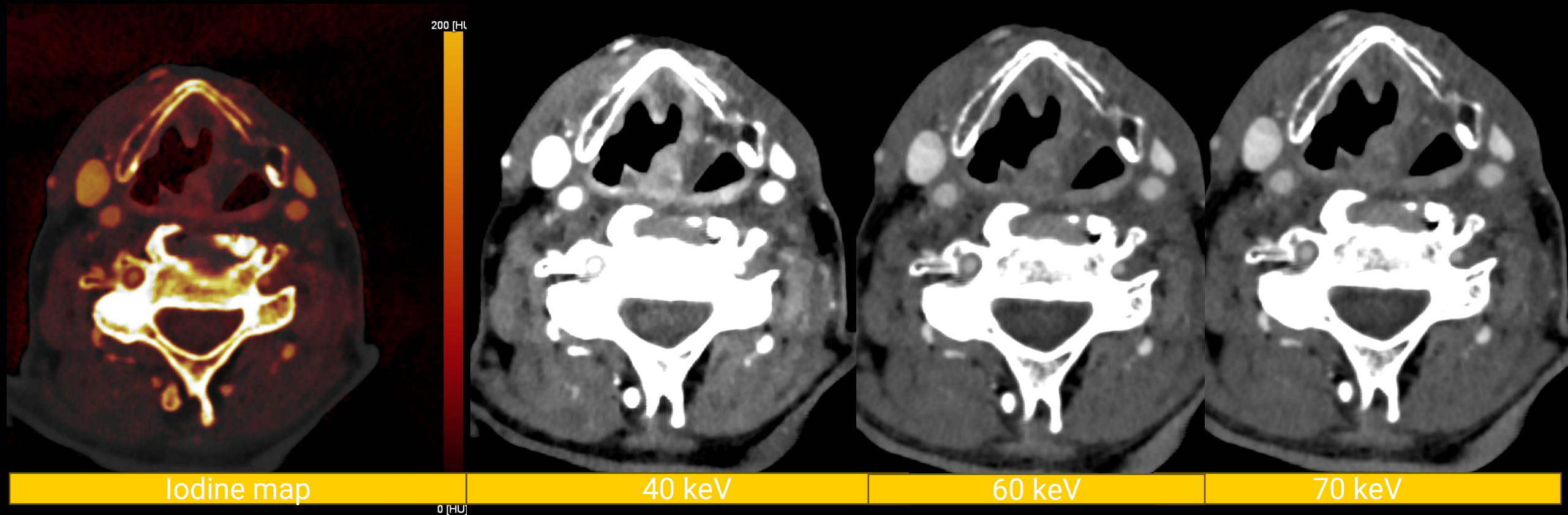


Axial PCD-CT of the brain in a patient with right MCA stroke, status post mechanical thrombectomy.

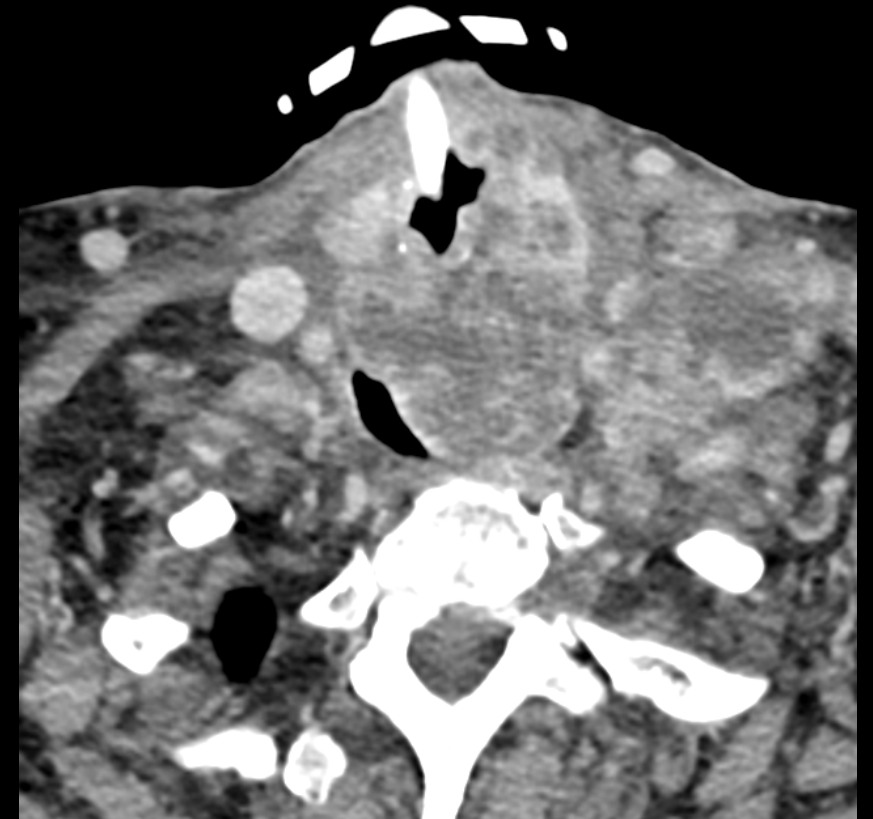
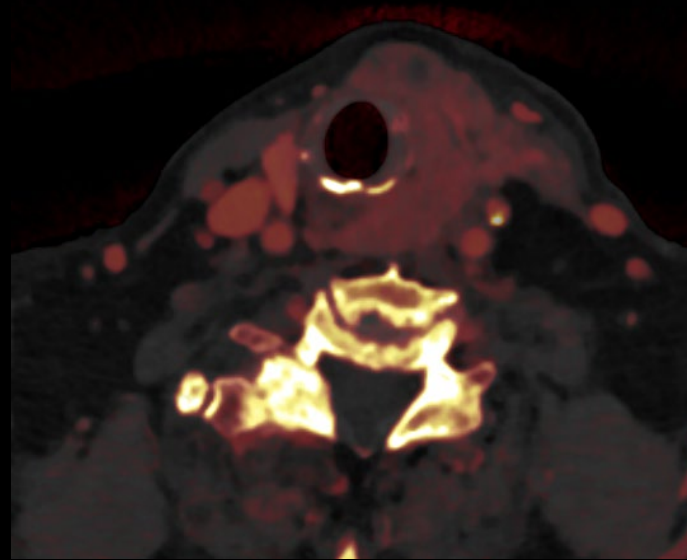
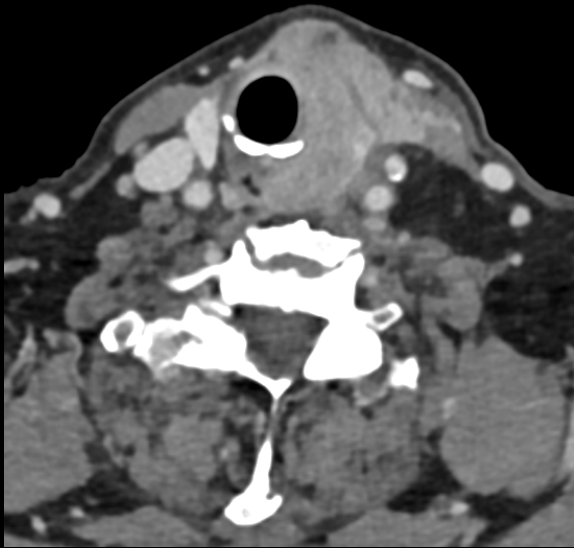
There is a large hypodense area in the right MCA distribution and scattered small hyperdensities (A).

Virtual non-contrast (VNC) images showed persistent hyperdensities, suggestive of hemorrhagic transformation (B). A few areas appear less dense on the VNC, suggesting contrast staining (arrows).

Spectral imaging in head and neck



Spectral imaging in head and neck



Photon-counting detector CT (PCD-CT)

Limitations

PCD-CT – Limitations

- Still in early stages of implementation. There is still need for optimization of some of the protocols.
- There is limited access to the technology (only a few institutions have access to PCD-CT).

Photon-counting detector CT (PCD-CT)

Future Implications

PCD-CT – Future Directions

- By measuring individual photon energies, PCD-CT is expected to have increased reproducibility of the multiple acquisition parameters needed for radiomics analyses.
- Multicontrast imaging is also a possibility with PCD-CT. This approach may increase contrast-to-noise and possibly decrease the volume of contrast needed for the study, decreasing also risk of adverse events.
- Technical improvements and imaging protocols optimization will enhance diagnostic precision in head and neck imaging.



Thank you!