CSF-VENOUS FISTULAS:

A MULTIMODALITY REVIEW OF VARIED IMAGING APPEARANCES

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Asheville, NC

Disclosures

- None

Educational Objectives

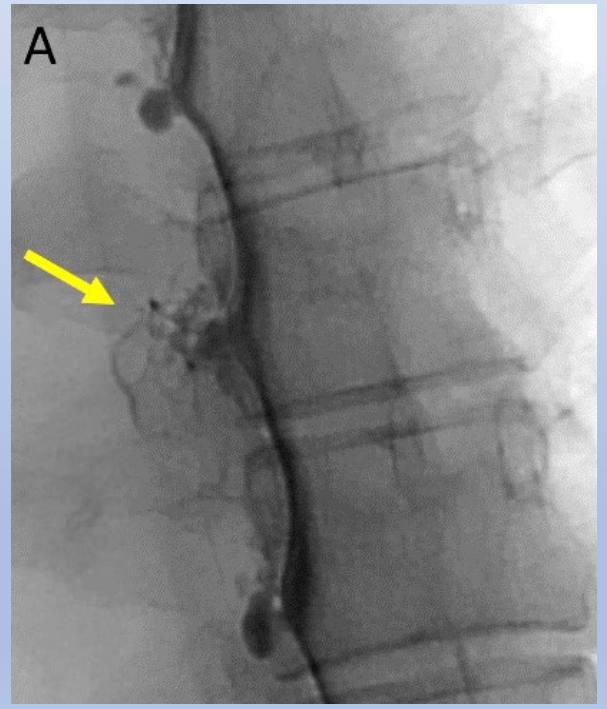
1. Recognize the importance of localizing CSF-venous fistulas (CVFs) and know typical appearances on digital subtraction myelography (DSM) and CT myelography (CTM)
2. Review basic spinal venous anatomy and correlate this with less commonly described filling patterns of CVFs
3. Appreciate the potential for false CVF localization and multifocal cerebrospinal fluid (CSF) leaks
4. Understand techniques that may be useful to increase conspicuity of CVFs
5. Describe potential advantages/disadvantages of photon-counting detector (PCD) CTM vs traditional energy-integrating detector (EID) CTM and DSM

Background

- CVFs are an increasingly recognized cause of spontaneous intracranial hypotension (SIH)
- Myelographic localization of CVFs is necessary to allow for targeted treatment
- Various advanced myelographic techniques have been used to localize CVFs
  - Most commonly these include DSM or CTM performed in the lateral decubitus position
- More recently, the potential benefits of PCD CTM have been described
- The classic appearance of a CVF is a hyperdense paraspinal vein arising from a thoracic nerve root sleeve diverticulum, though appearances and locations can vary
- This exhibit will highlight the varied appearances/locations of CVFs on multiple modalities with teaching points along the way

Classic CVF appearance

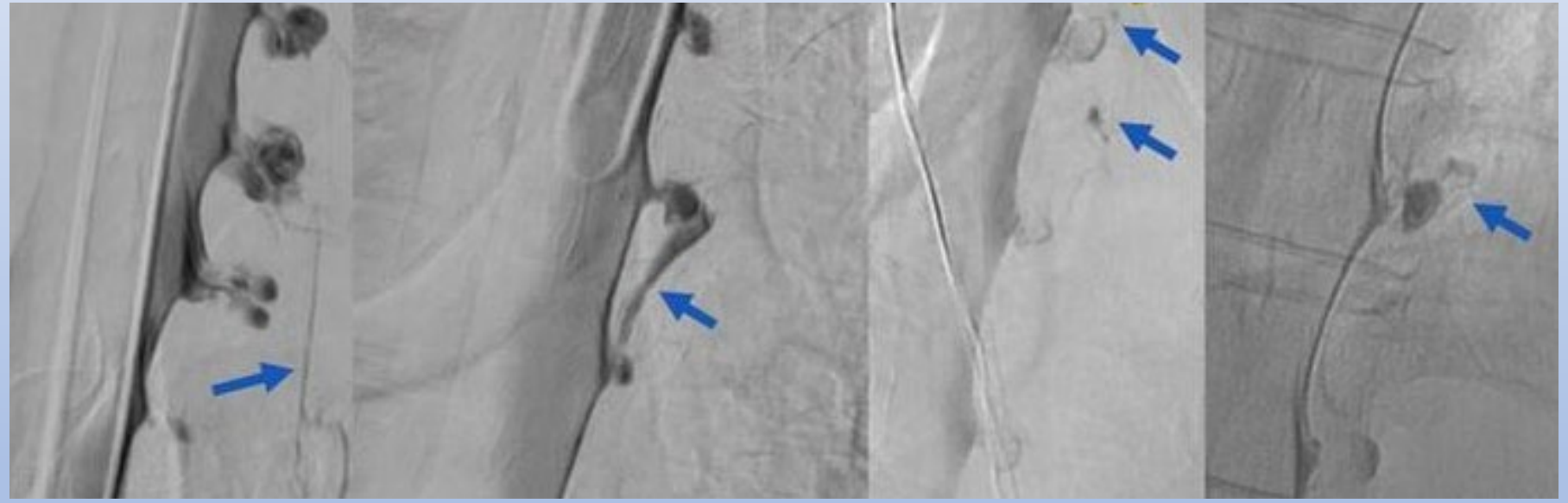
Typical appearance of a CVF on DSM (A), with linear contrast opacified veins extending from a nerve root sleeve diverticulum, and on CTM (B), with a contrast opacified paraspinal segmental vein “hyperdense paraspinal vein” extending anteriorly from a nerve root sleeve diverticulum. CVFs frequently but don’t always arise from nerve root sleeve diverticula.



Madhavan AA et al. Diagnostic Performance of Decubitus Photon-Counting Detector CT Myelography for the Detection of CSF-Venous Fistulas. AJNR Am J Neuroradiol. 2023 Dec 11;44(12):1445-1450.
Kranz PG et al. The "Hyperdense Paraspinal Vein" Sign: A Marker of CSF-Venous Fistula. AJNR Am J Neuroradiol. 2016 Jul;37(7):1379-81.

Multiple CVFs

Multiple CVFs in a single patient are shown on bilateral DSM images (arrows)

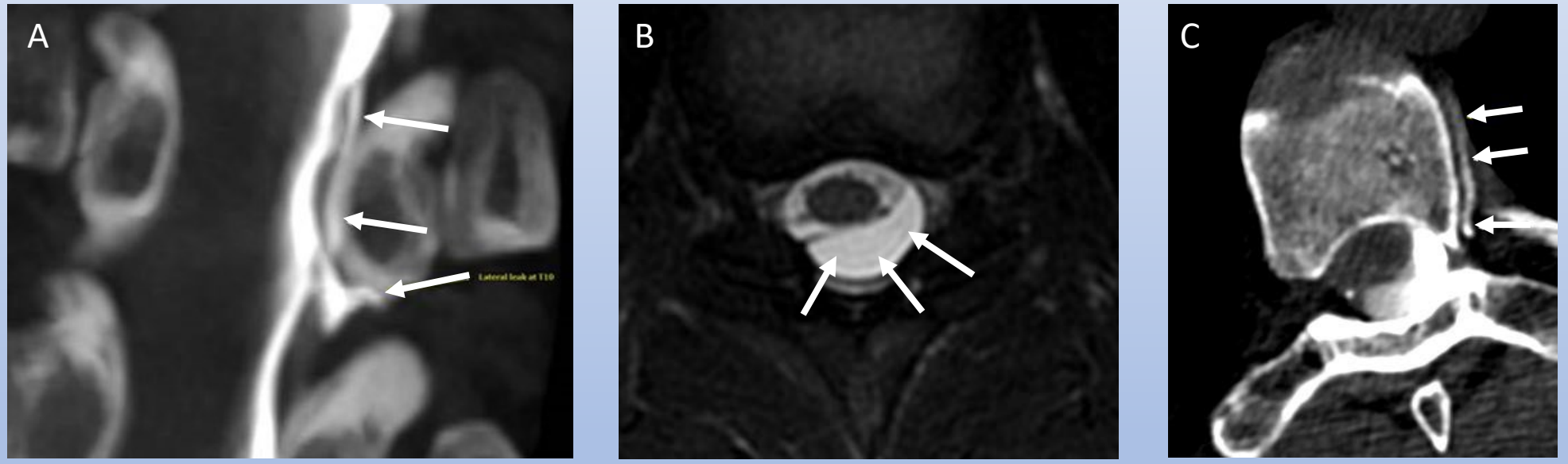


Teaching Point: While CVFs are more common on the right than the left and typically singular, do not be a victim of satisfaction of search. At our institution, we image the right side down first, and typically image the left even if a right-sided CVF is found.

Brinjikji W et al. Clinical and imaging outcomes of 100 patients with cerebrospinal fluid-venous fistulas treated by transvenous embolization. J Neurointerv Surg. 2023 Oct 28:jnis-2023-021012.

Coexistent CVF and lateral dural tear

Left T10 lateral dural tear with extradural contrast (A, arrows) on coronal reformatted CTM image. Pre-CTM MRI showed a left dorsolateral extradural fluid collection (B, arrows). There is also a separate left T7 CVF (C, arrows).

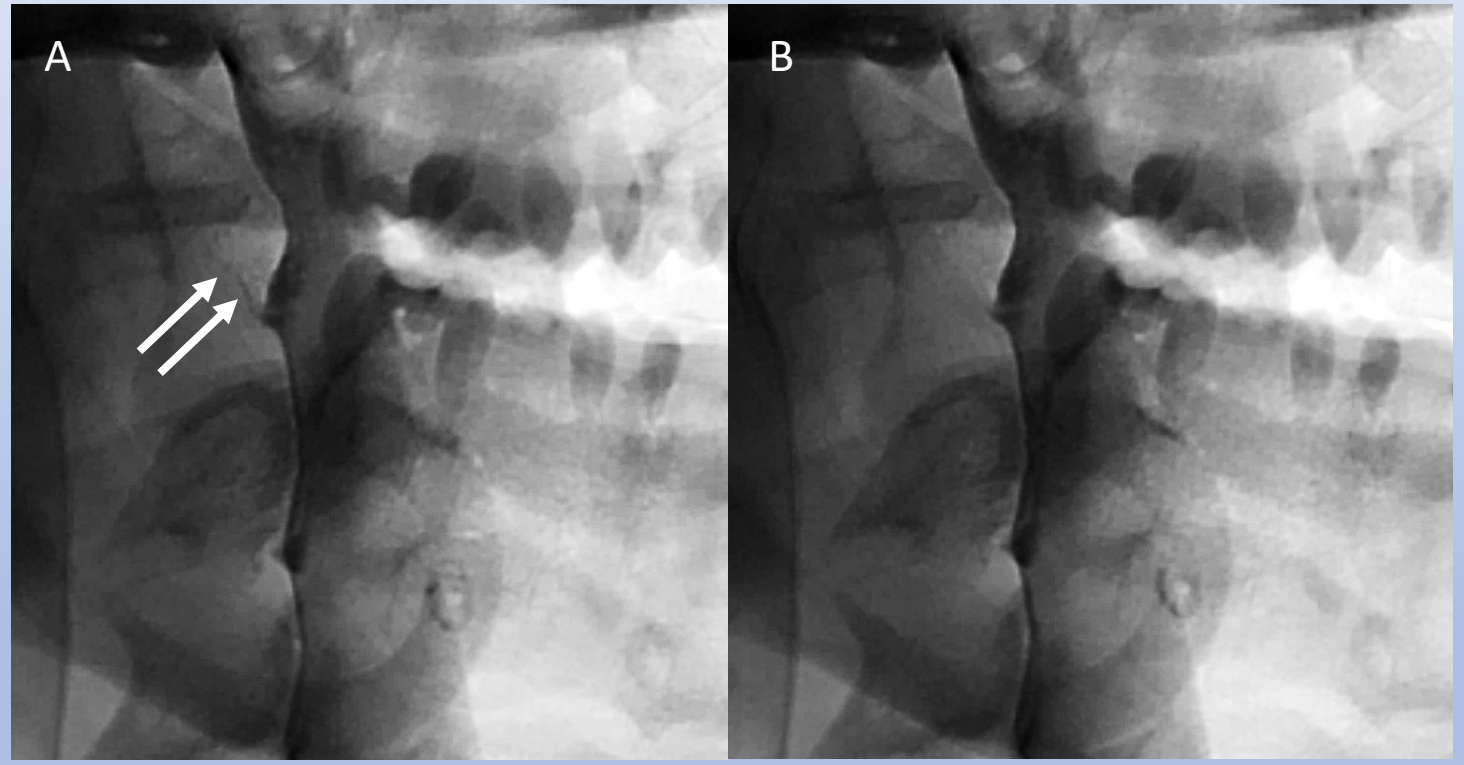


Teaching Point: CVFs and dural tears can rarely coexist in the same patient. This is important to recognize so both can be appropriately treated.

Schievink WI et al. Multiple Spinal CSF Leaks in Spontaneous Intracranial Hypotension: Do They Exist? Neurol Clin Pract. 2021 Oct;11(5):e691-e697.

Cervical CVF

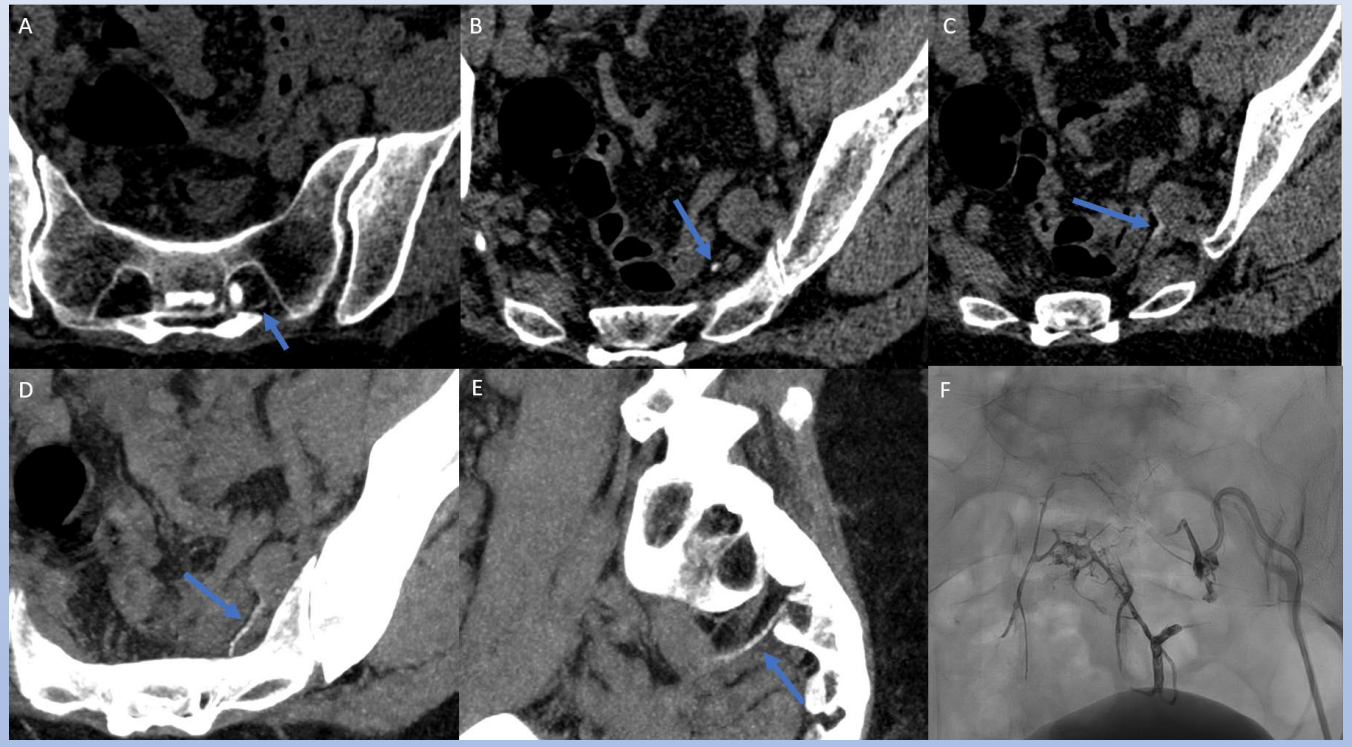
Left C1-2 CVF on sequential DSM images. The CVF is filling on image A and is not seen on image B.



Teaching Point: CVF's can occur in the cervical region. Consider imaging coverage through the cervical spine for DSM or CTM if a CVF is not visualized in a typical thoracic location in a high probability patient.

Sacral CVF

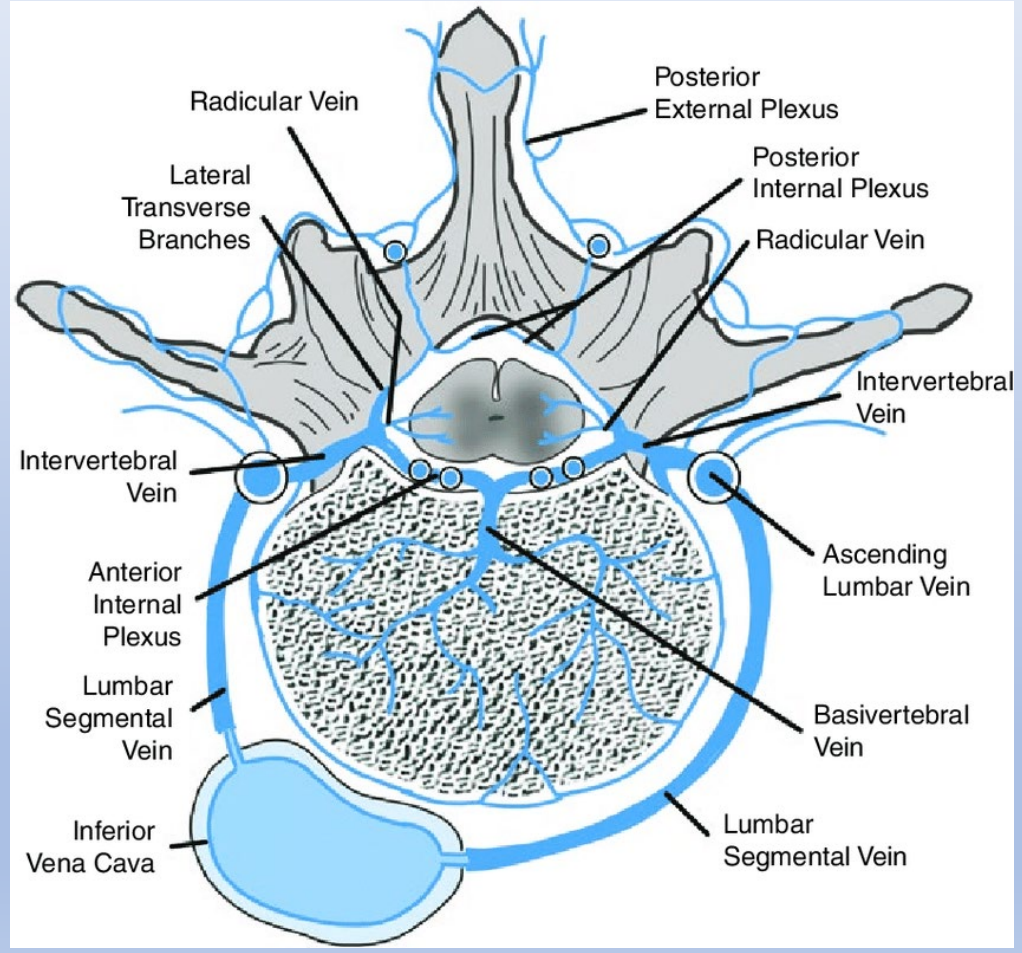
Left S2 CVF on axial (A-D) and sagittal (E) CTM. Post-onyx embolization (F)



Teaching Point: CVF's can occur in the sacral region. Consider reverse Trendelenburg positioning to achieve contrast opacification of the sacrum for DSM or CTM if a CVF is not visualized in a typical thoracic location in a high probability patient.

Mark IT et al. Sacral CSF-Venous Fistulas and Potential Imaging Techniques. AJNR Am J Neuroradiol. 2022 Dec;43(12):1824-1826.

Spinal Venous Anatomy

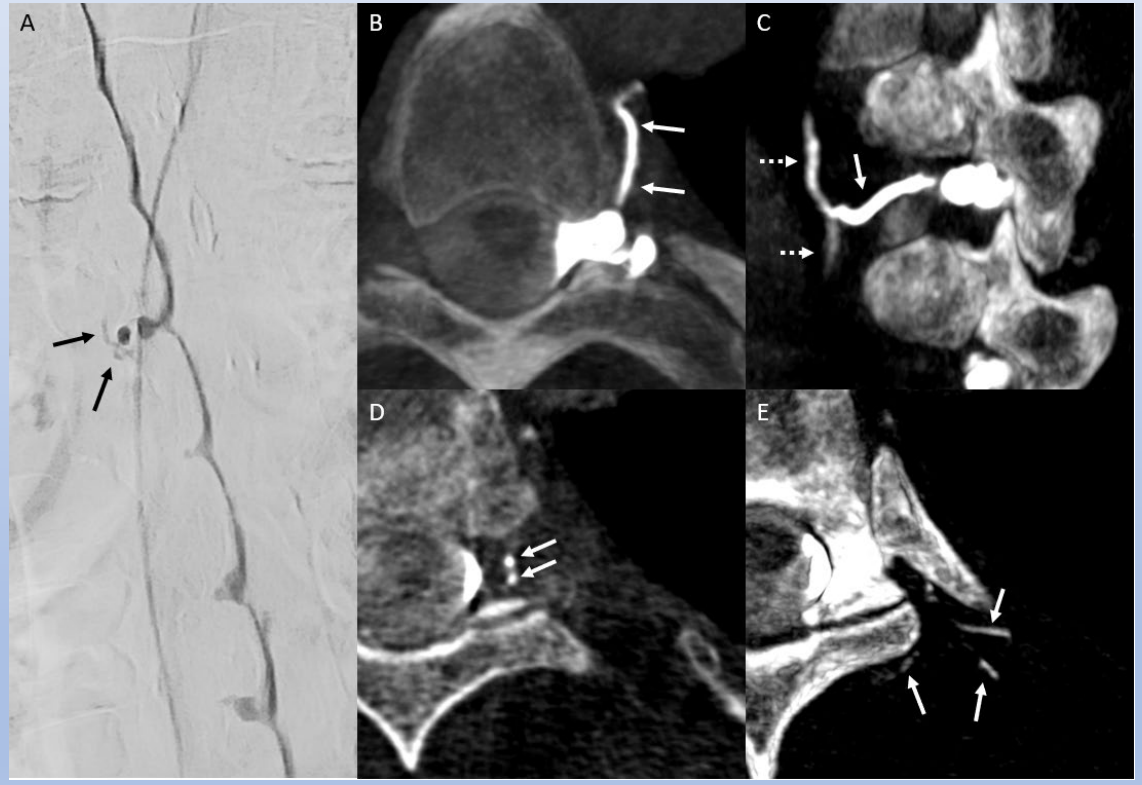


- CVFs have been classically described to drain anteriorly from the nerve root sleeve into the lumbar segmental vein (“hyperdense paraspinal vein”)
- Spinal venous anatomy is complex and CVFs can have multiple other patterns of filling including internal epidural plexus, basivertebral vein, intraosseous veins, posterolateral muscular branches, and combinations thereof

Epidural and CSE Anesthesia (Technique–Drugs) - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Vertebral-and-epidural-venous-system_fig20_316749846 [accessed 10 Apr, 2024]

CVF Involving Multiple Veins

Left T4 CVF on DSM (A, arrows) and cone beam CT (B-E) involving multiple veins including paraspinal segmental (B-C, arrows), hemiazygous (C, dashed arrows), internal epidural plexus (D, arrows), and posterolateral muscular branches (E, arrows).

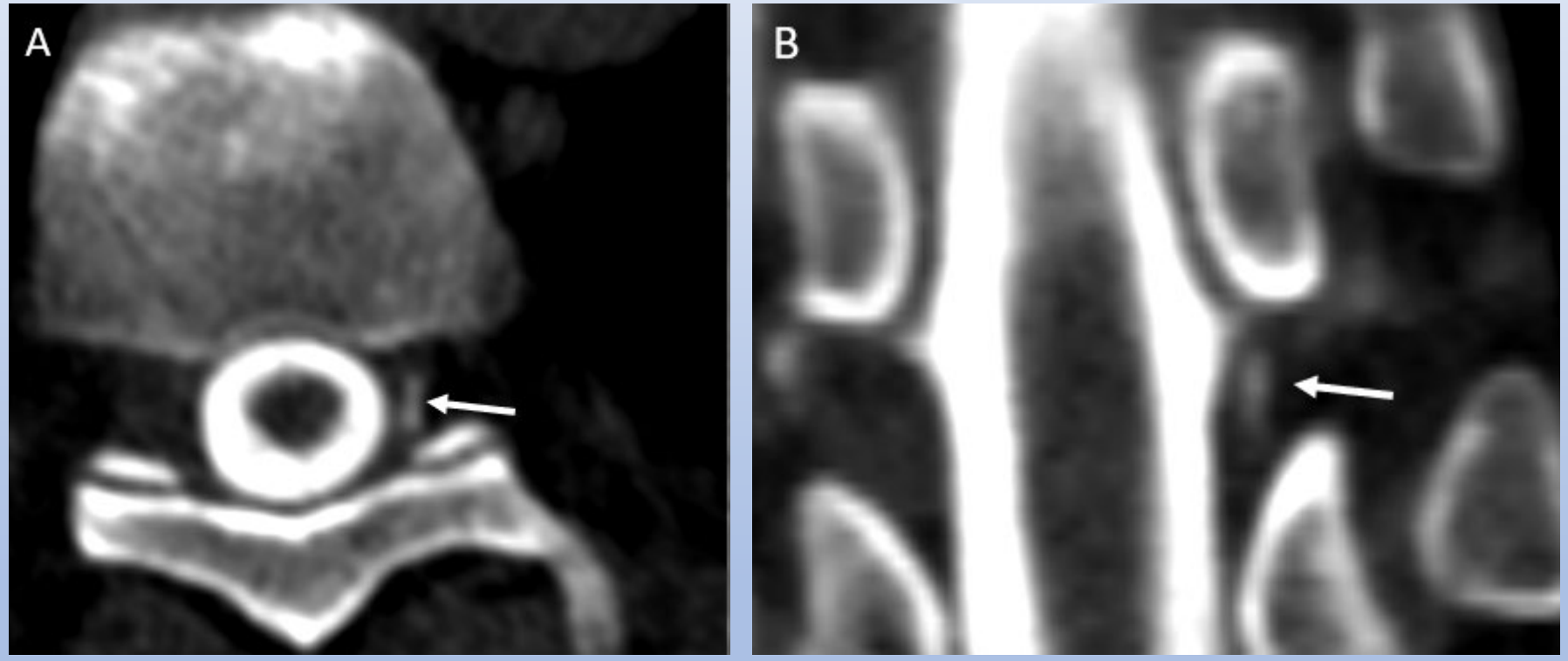


Teaching Point: Be aware of the various opacification patterns of CVFs. Many or single veins may be involved. Defining the involved veins can be helpful in pre-treatment planning.

Madhavan AA et al. Myelographic Techniques for the Localization of CSF-venous Fistulas: Updates in 2024. AJNR Am J Neuroradiol. 2024 Aug 1. doi: 10.3174/ajnr.A8299. Epub ahead of print. PMID: 39089875.

Internal Epidural Venous Plexus CVF

Left T9 CVF involving the internal epidural venous plexus on axial (A) and coronal (B) conventional CTM images

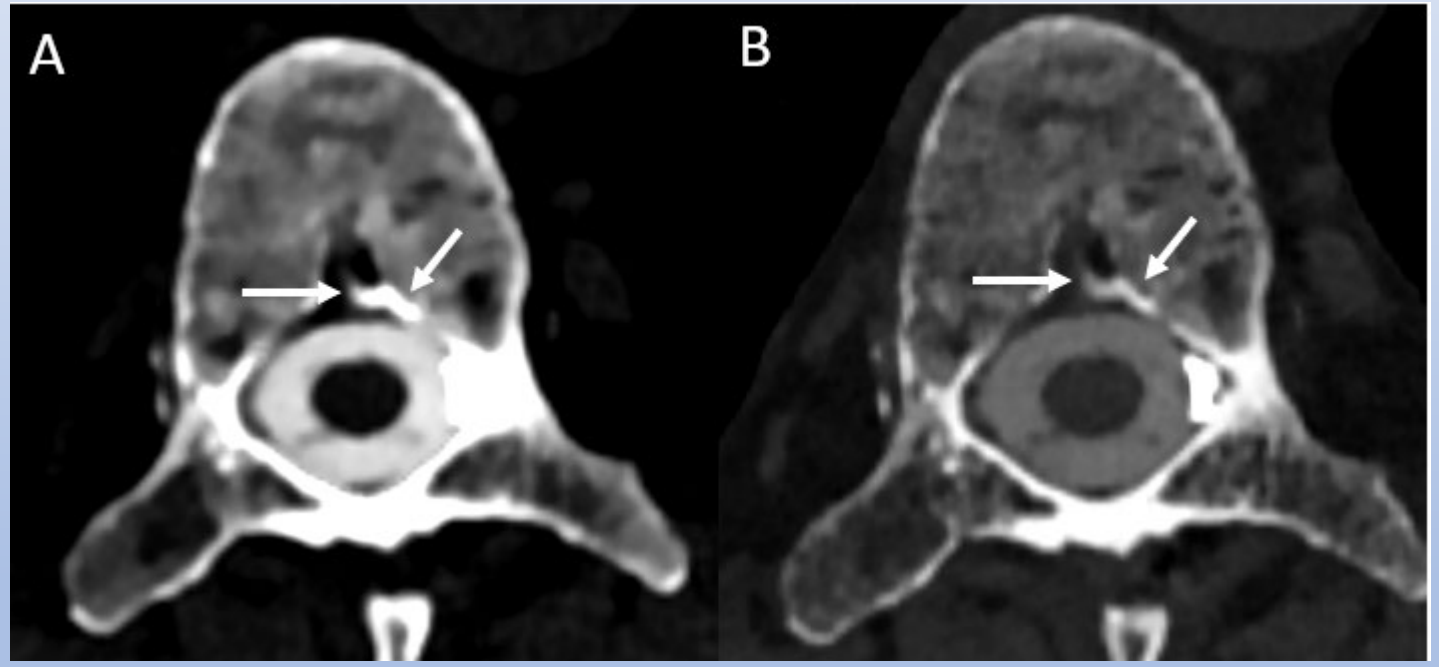


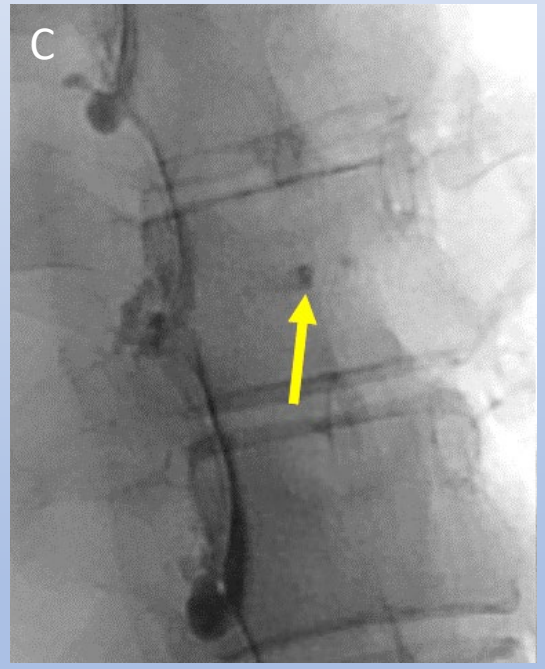
Teaching Point: The internal epidural venous plexus may be the only site of CVF drainage. As this typically occurs near the neck of the nerve root sleeve, be careful not to mistake it for contrast in the nerve root sleeve. While CVFs can occasionally be seen on conventional supine or prone CTM, lateral decubitus positioning is much more sensitive.

Madhavan AA et al. Myelographic Techniques for the Localization of CSF-venous Fistulas: Updates in 2024. AJNR Am J Neuroradiol. 2024 Aug 1. doi: 10.3174/ajnr.A8299. Epub ahead of print. PMID: 39089875.

Basivertebral Vein Involvement of CVF

Left T10 CVF involving the basivertebral vein (A and B, arrows) on 0.4mm 40 keV (A) and 0.2mm T3D (B) images from a left lateral decubitus PCD-CTM. Example of basivertebral vein involvement of a CVF on DSM (C, arrow).



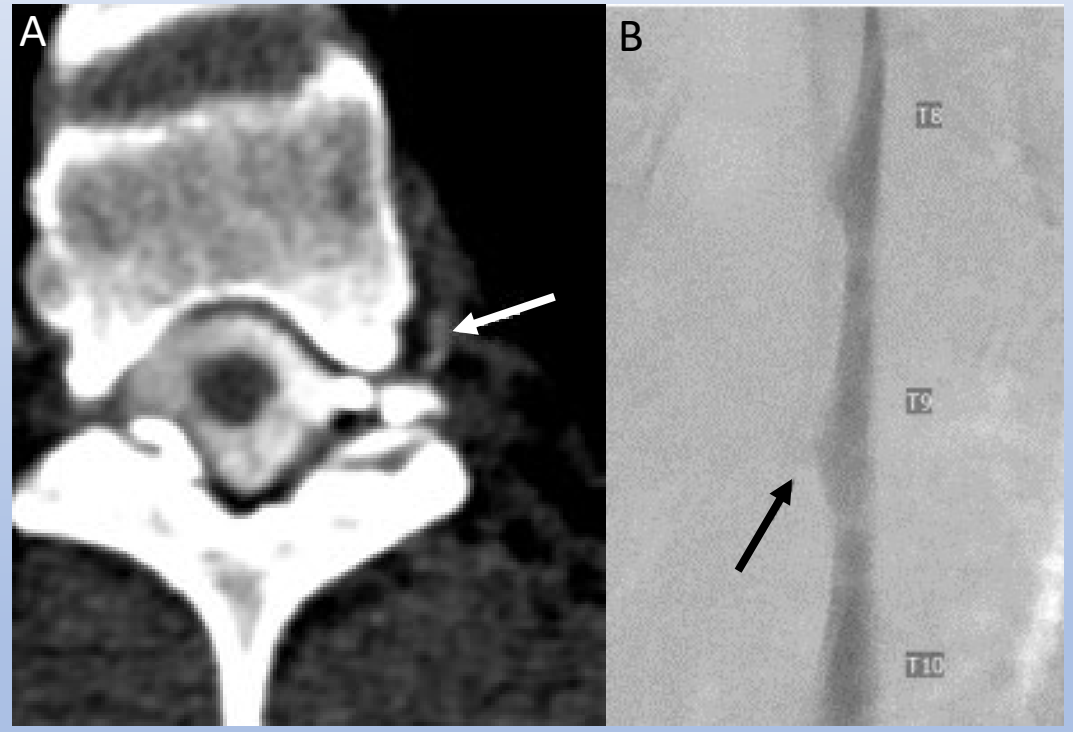


Teaching Point: The basivertebral vein may be the only site of visible contrast opacification of a CVF. This may be difficult to differentiate from adjacent cortex on CT and is a potential blind spot for DSM search patterns when focusing on the foramina.

Madhavan AA et al. Diagnostic Performance of Decubitus Photon-Counting Detector CT Myelography for the Detection of CSF-Venous Fistulas. AJNR Am J Neuroradiol. 2023 Dec 11;44(12):1445-1450.

DSM negative, delayed CTM positive

Left T9 CVF arising from a diverticulum on delayed left lateral decubitus CTM (A) following negative DSM (B).

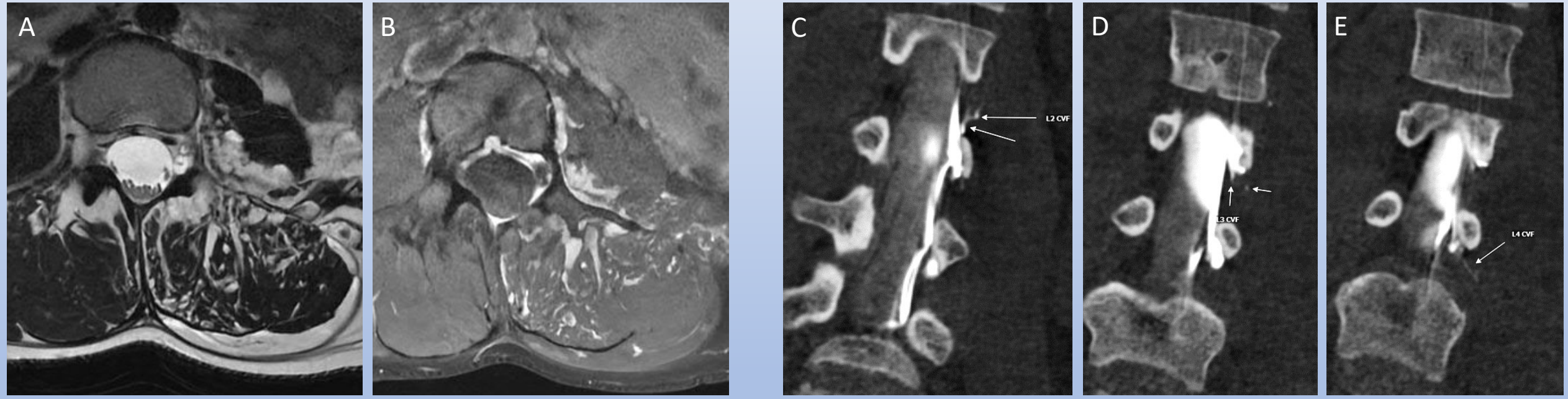


Teaching Point: Delayed CTM performed immediately following DSM can show CVFs that are occult on DSM. This is most commonly due to delayed filling of a diverticulum from which a CVF arises or obscuration of the CVF by the contrast column on DSM.

Shlapak DP et al. Incremental diagnostic yield and clinical outcomes of lateral decubitus CT myelogram immediately following negative lateral decubitus digital subtraction myelogram. Neuroradiol J. 2023 Oct;36(5):593-600.

CVF with paraspinal vascular malformation

Patient with Klippel-Trenaunay syndrome and a large left lumbar paraspinal venous malformation on MRI (A-B) with associated complex CVF with multilevel involvement from L2-4 on CTM (C-E)

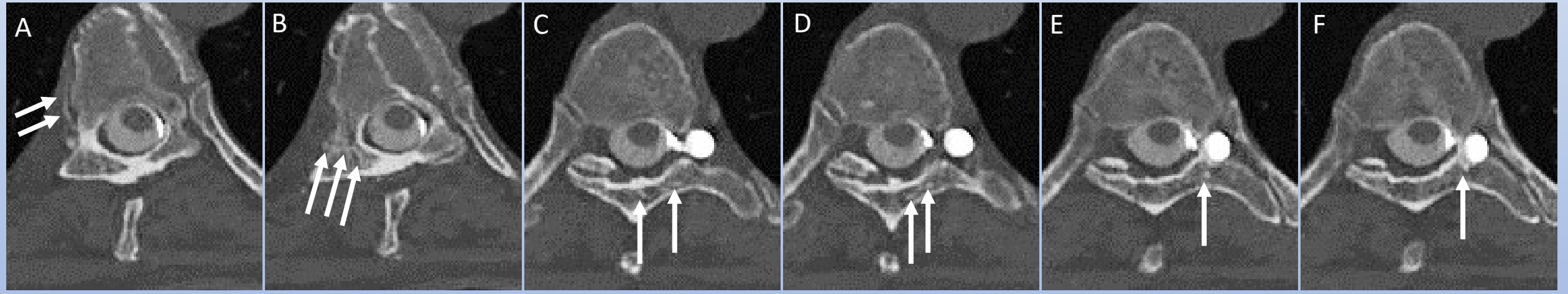


Teaching Point: CVFs may be associated with paraspinal vascular malformations. Scrutinize these locations for CVFs in patients with SIH and known paraspinal vascular malformations or vascular malformation syndromes.

Schievink WI et al. Spontaneous spinal CSF-venous fistulas associated with venous/venolymphatic vascular malformations: report of 3 cases. J Neurosurg Spine. 2019 Nov 1;32(2):305-310.

False localizing CVF

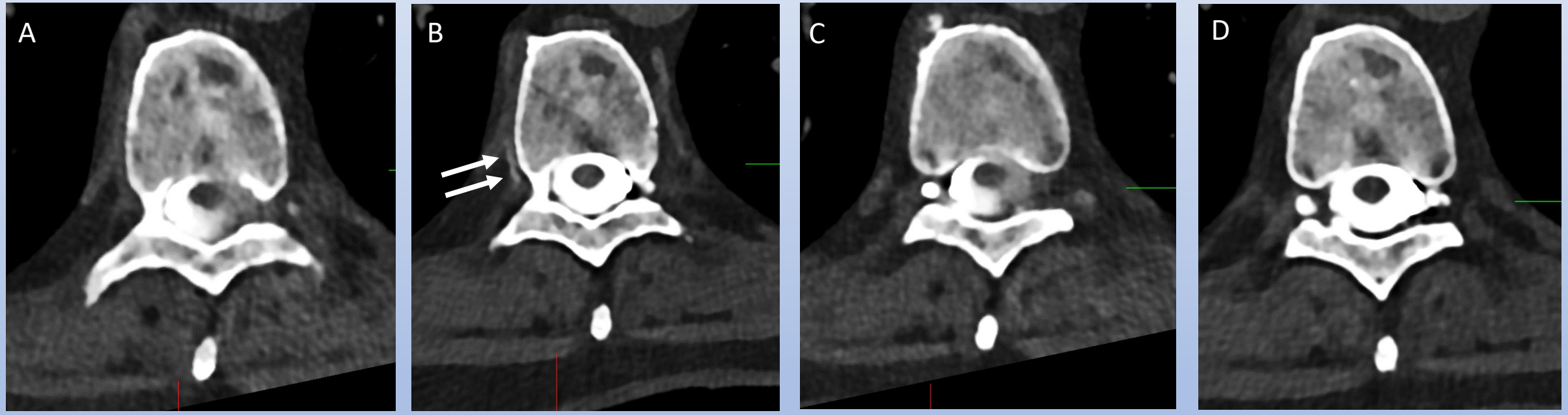
Left decubitus PCD-CTM shows a left T7 CVF (A-F, arrows) arising from a large diverticulum remodeling the adjacent bone (E-F) with intraosseous venous drainage through the posterior elements (B-F) extending to the contralateral side to drain into a right paraspinal vein (A), which could be falsely localized to the right T7 foramen. Venous opacification was not demonstrated on the right decubitus exam (not shown).



Teaching Point: Beware of falsely localizing CVFs and scrutinize venous drainage patterns, particularly when a CVF appears to arise on the non-dependent side when the patient is in decubitus position (opposite the dependent contrast). A pre-contrast or delayed CT may be useful to differentiate intraosseous venous contrast from bone.

CVF seen best on contralateral side down CTM

Right T8 CVF which is not visualized on right side down CTM (A) but is present on subsequent left side down CTM (B, arrows). Contrast fills a small right T8 diverticulum just inferior to the CVF on both the right (C) and left (D) side down exams.

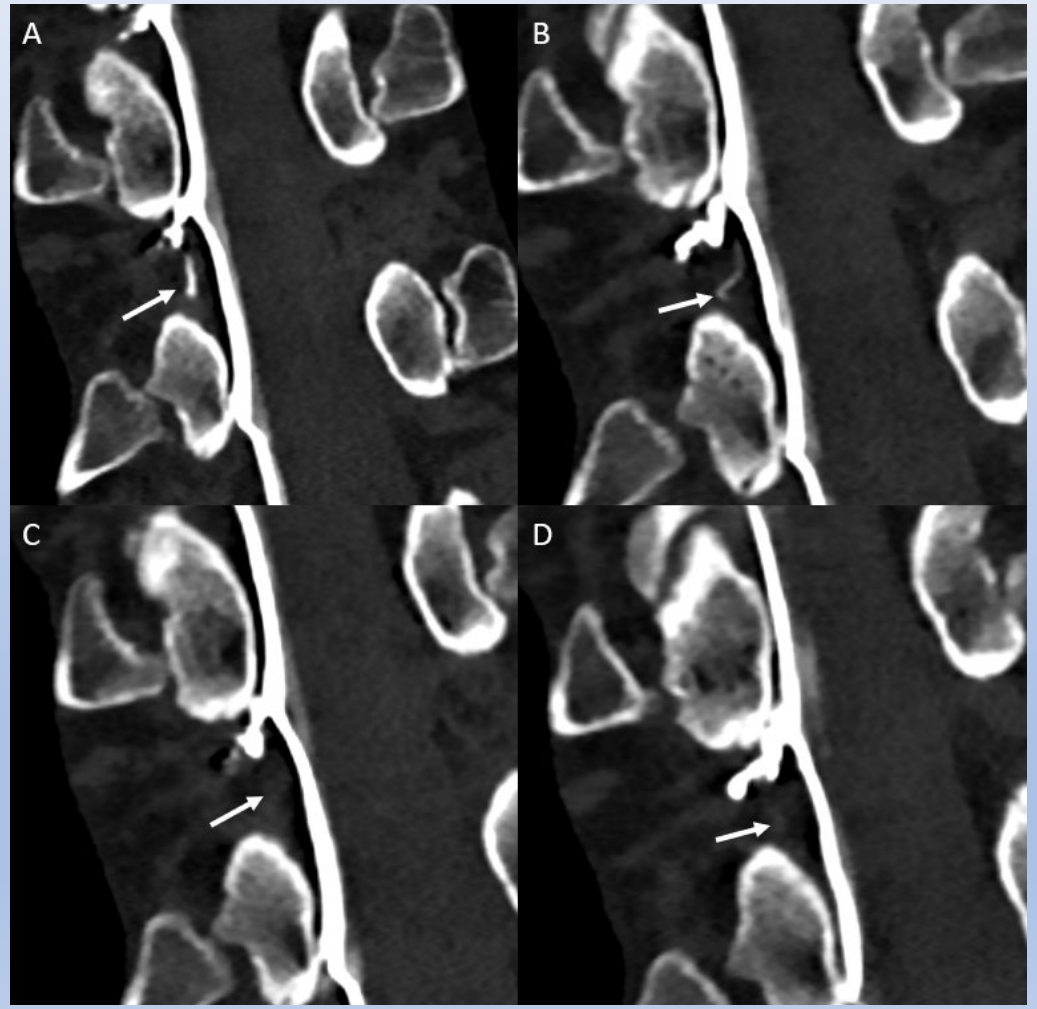


Teaching Point: CVFs can rarely be better seen on contralateral side down imaging. This may occur when the patient has both sides studied in a single exam and the patient is turned to the second side, possibly due to delayed filling of a diverticulum or intermittent/variable CVF opacification. Scrutinize the entire exam, not just the side with dependent contrast. As on the previous case, scrutinize for intraosseous venous drainage which may lead to false localization.

Potential Benefit of Resisted Inspiration

- Has been described as a potential adjunct to increase CVF contrast opacification due to increases in CVF to venous pressure gradients
- Have patient breathe in through a straw or syringe while imaging
- Better for use with CTM as less affected by the respiratory motion artifact than DSM

Potential Benefit of Resisted Inspiration



Adjacent coronal reformatted PCD-CTM images at two different timepoints (A-B versus C-D). The right T11 CVF is clearly demonstrated during resisted inspiration (A-B, arrows) and occult during slow inspiration (C-D, arrows). The CVF was also occult during images acquired with inspiratory breath hold (not shown).

Mark IT et al. Resisted Inspiration: A New Technique to Aid in the Detection of CSF-Venous Fistulas. AJNR Am J Neuroradiol. 2022 Oct;43(10):1544-1547.

Kranz PG et al. Resisted Inspiration Improves Visualization of CSF-Venous Fistulas in Spontaneous Intracranial Hypotension. AJNR Am J Neuroradiol. 2023 Aug;44(8):994-998.

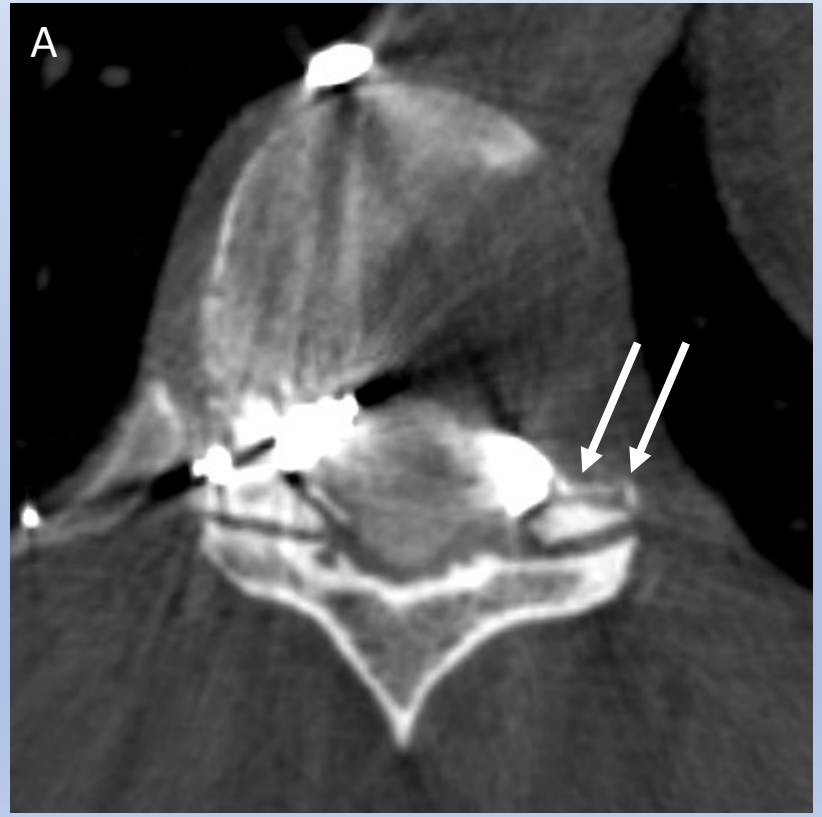
Madhavan AA et al. Myelographic Techniques for the Localization of CSF-venous Fistulas: Updates in 2024. AJNR Am J Neuroradiol. 2024 Aug 1. doi: 10.3174/ajnr.A8299. Epub ahead of print. PMID: 39089875.

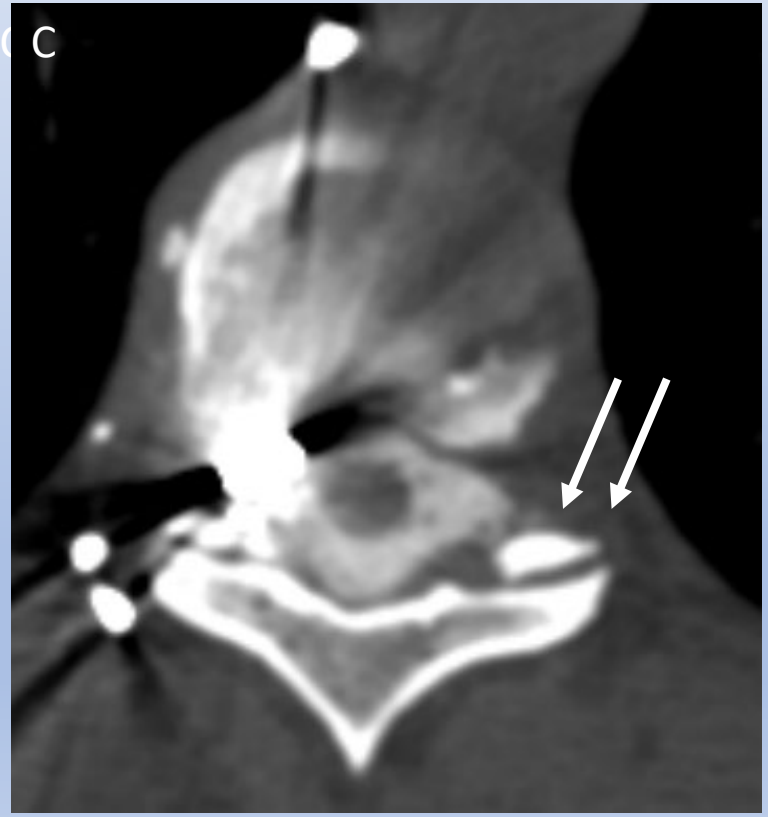
Potential Benefit of Cone Beam CT

- Can be a useful adjunct to DSM
  - To better define an equivocal DSM finding
  - To better study a disproportionately large/irregular diverticulum if DSM is negative
  - To better delineate the venous anatomy of a CVF for pre-treatment planning
- Performed during active contrast injection, immediately following DSM, with flowing contrast opacifying the level of interest

Potential Benefit of Cone Beam CT

Patient with prior CVF embolization at right T10 and T11 and recurrent symptoms. Cone beam CT (A) immediately following left decubitus DSM (B) demonstrates a left T10 CVF (A, arrows) which is not seen on DSM (B, arrows) or post-DSM delayed left decubitus CTM (C, arrows)





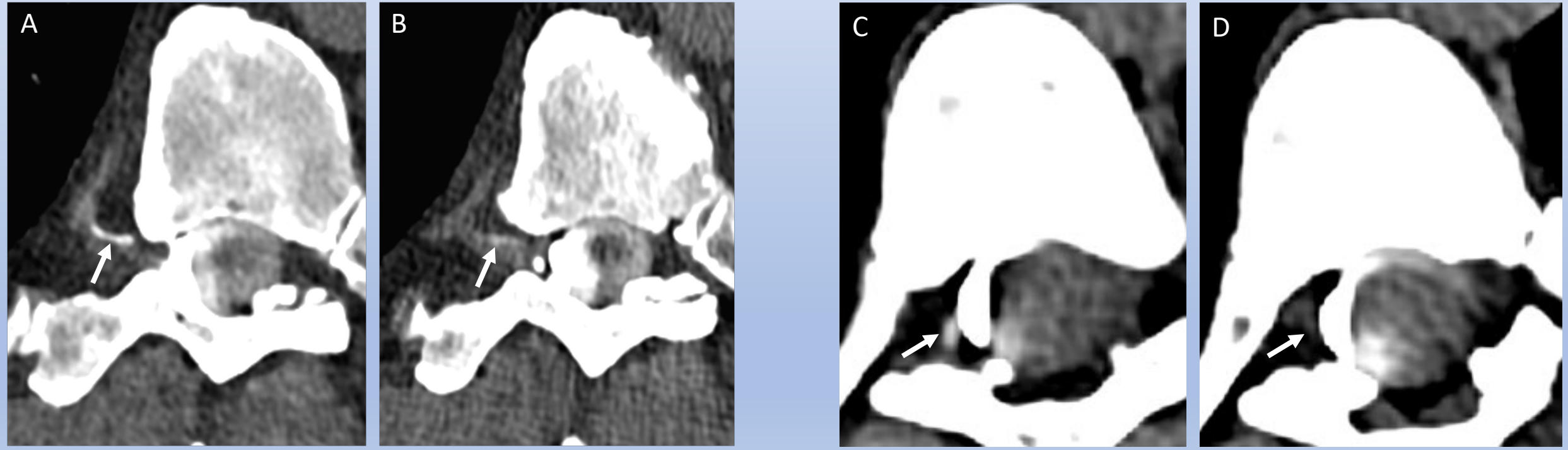
Madhavan AA et al. Conebeam CT as an Adjunct to Digital Subtraction Myelography for Detection of CSF-Venous Fistulas. AJNR Am J Neuroradiol. 2023 Mar;44(3):347-350.

Benefit of Multiphase CTM

- Techniques vary (1-6 CTM acquisitions described)
- With multiphase techniques, CVFs infrequently seen on all phases, suggesting multiple phases and/or specific timing relative to contrast injection may be beneficial
- Likely a combination of dynamic imaging (multiphasic acquisitions during active contrast injection) and dense opacification of the dependent lateral thecal sac play a role in CVF conspicuity

Benefit of Multiphase CTM

Patient 1 (A-B) with a CVF that is best demonstrated on image A (arrow) and less conspicuous on a subsequent CTM acquisition several seconds later (B, arrow). Patient 2 (C-D) with an internal epidural venous plexus CVF only demonstrated on image C (arrow) and occult on a subsequent acquisition several seconds later (D, arrow).



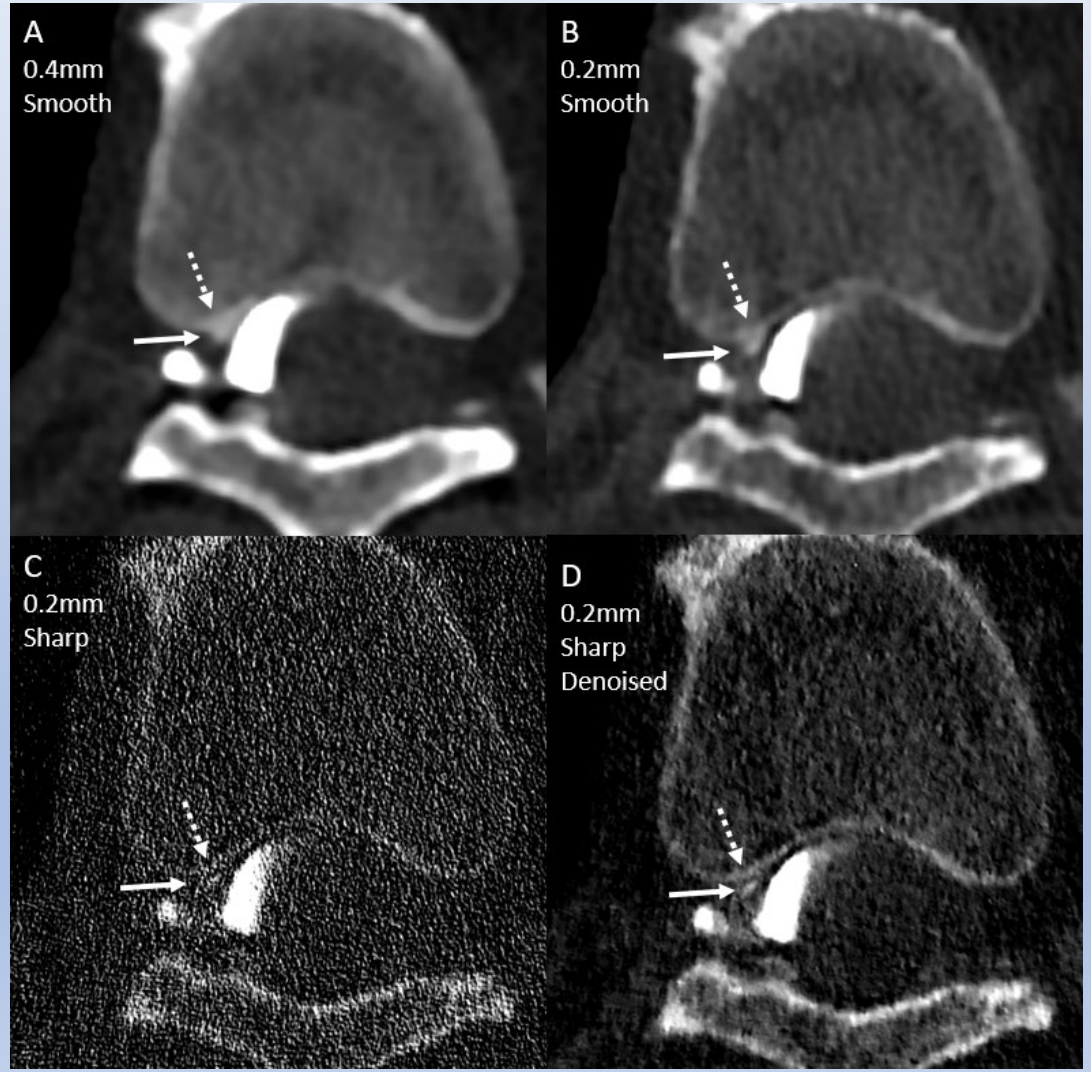
Benefits of PCD CTM

- Increased spatial, contrast, and temporal resolution compared to EID CTM
  - Inherent capability for monoenergetic images (↑iodine conspicuity)
  - Potential for denoised sharp kernel high resolution reconstructions
    - May help to distinguish subtle findings
- Certain locations of CVFs are probably better seen than on DSM due to obscuration from contrast on single plane DSM
  - Internal epidural venous plexus
  - In plane with a large contrast opacified diverticulum
- Can do both sides in a single day vs DSM typically requiring 2 days due to contrast limitations
- Typically performed without sedation
  - DSM usually with sedation

Madhavan AA et al. Diagnostic Performance of Decubitus Photon-Counting Detector CT Myelography for the Detection of CSF-Venous Fistulas. AJNR Am J Neuroradiol. 2023 Dec 11;44(12):1445-1450.

Madhavan AA et al. Application of a Denoising High-Resolution Deep Convolutional Neural Network to Improve Conspicuity of CSF-Venous Fistulas on Photon-Counting CT Myelography. AJNR Am J Neuroradiol. 2023 Dec 29;45(1):96-99.

Benefits of PCD CTM



Four identical images from a right lateral decubitus PCD-CTM with various reconstructions: 0.4 mm smooth kernel (A), 0.2 mm smooth kernel (B), 0.2 mm sharp kernel (C), and 0.2 mm sharp kernel with denoising (D). A right T8 CVF involving the ventral internal epidural venous plexus (A-D, solid arrows) is best seen and distinguished from the posterior vertebral body cortex (A-D, dashed arrows) on the 0.2 mm sharp kernel denoised image (D).

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Potential Disadvantages of PCD CTM

- Not widely available yet
- Artifact related to embolization material in previously treated CVF patients (DSM better)

Summary

1. Recognize the importance of localizing CSF-venous fistulas (CVFs) and know typical appearances on digital subtraction myelography (DSM) and CT myelography (CTM)
2. Review basic spinal venous anatomy and correlate this with less commonly described filling patterns of CVFs
3. Appreciate the potential for false CVF localization and multifocal cerebrospinal fluid (CSF) leaks
4. Understand techniques that may be useful to increase conspicuity of CVFs
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Questions

Please email with any questions

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