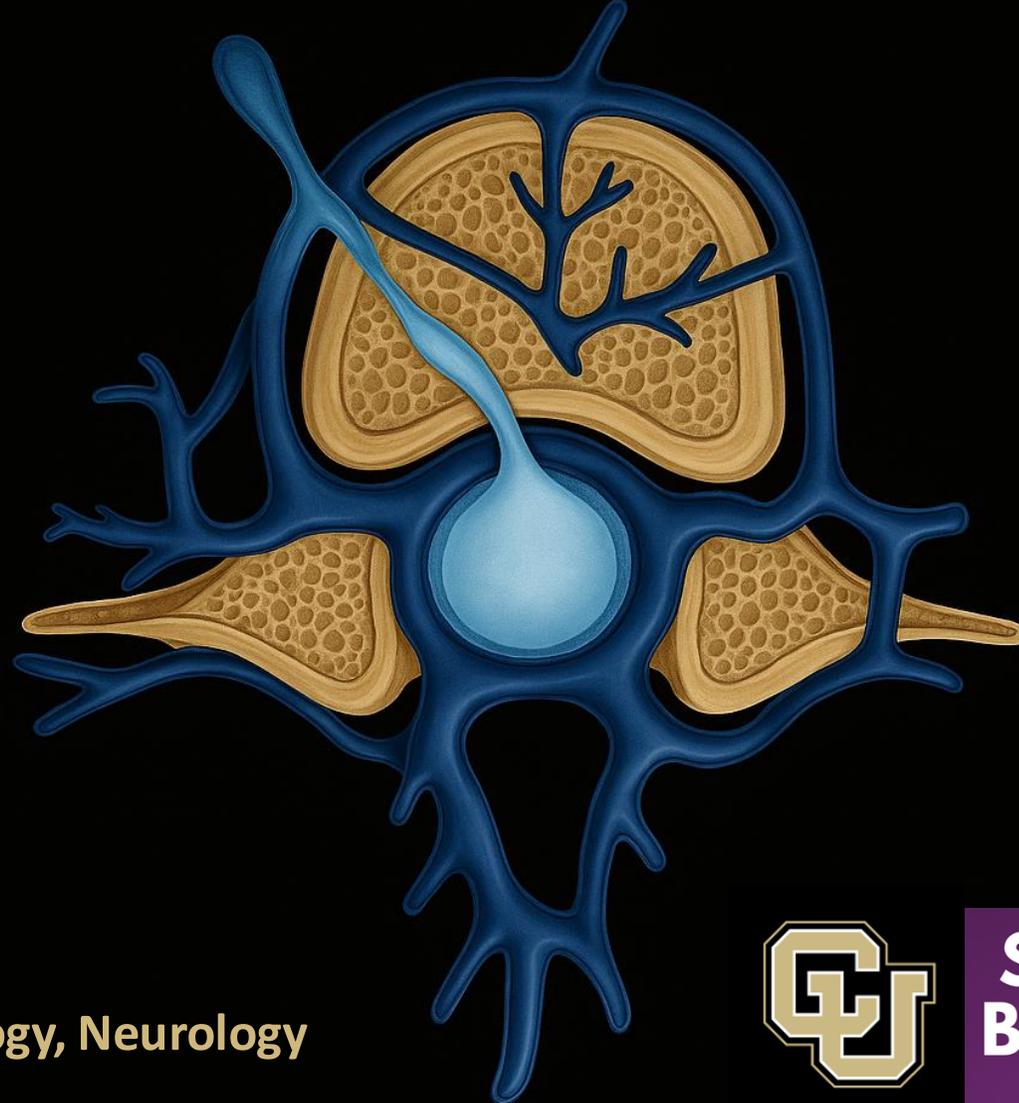


CSF Venous Fistulas:

Beyond the 'Hyperdense Paraspinal Vein'



Andrew L. Callen MD
Associate Professor of Neuroradiology, Neurology
Director, CU CSF Leak Program



**SPINAL CSF LEAK:
BRIDGING THE GAP**

"Making the invisible visible"

DISCLOSURES

Medical Advisory Board:

Spinal CSF Leak Foundation

Spinal CSF Leak Canada

Consultant:

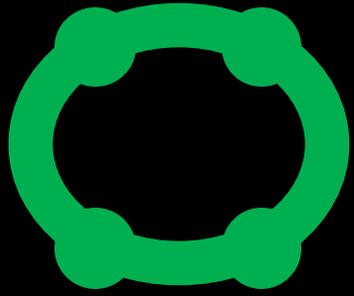
Eli Lilly

Patent:

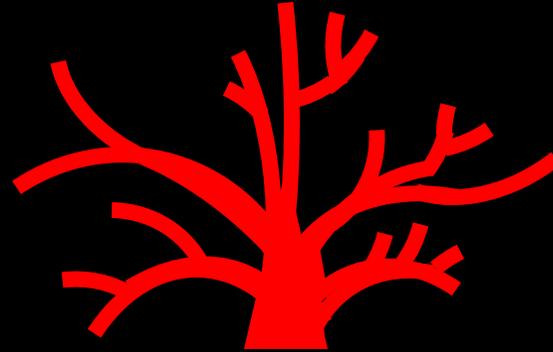
Myelography positioning device



University of Colorado
Anschutz Medical Campus

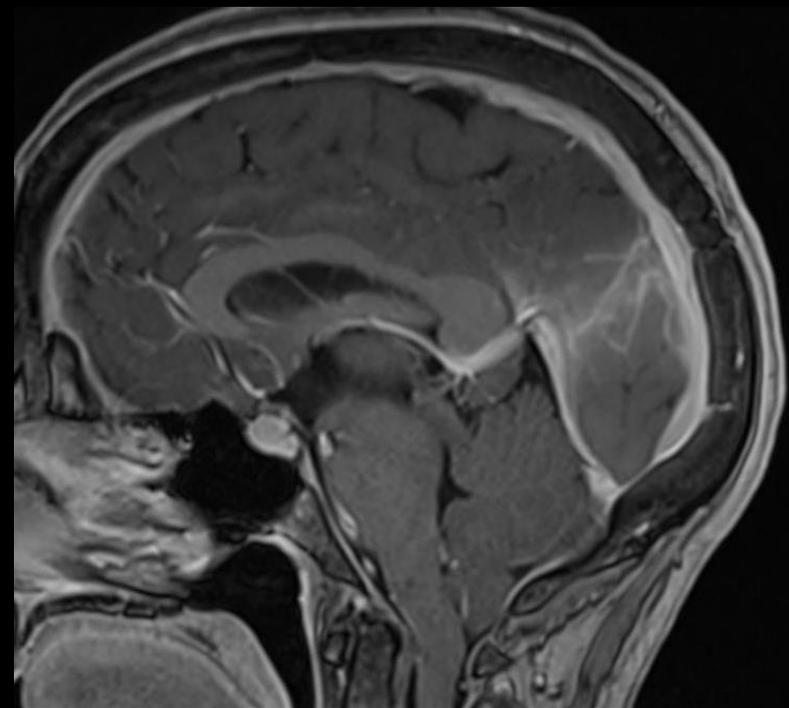


Agenda



1. The history of CSF venous fistulas
2. CVF anatomy and pathophysiology
3. Myelography:
 - Techniques
 - Under-recognized CVF appearances

Pre- 2013:



+



=

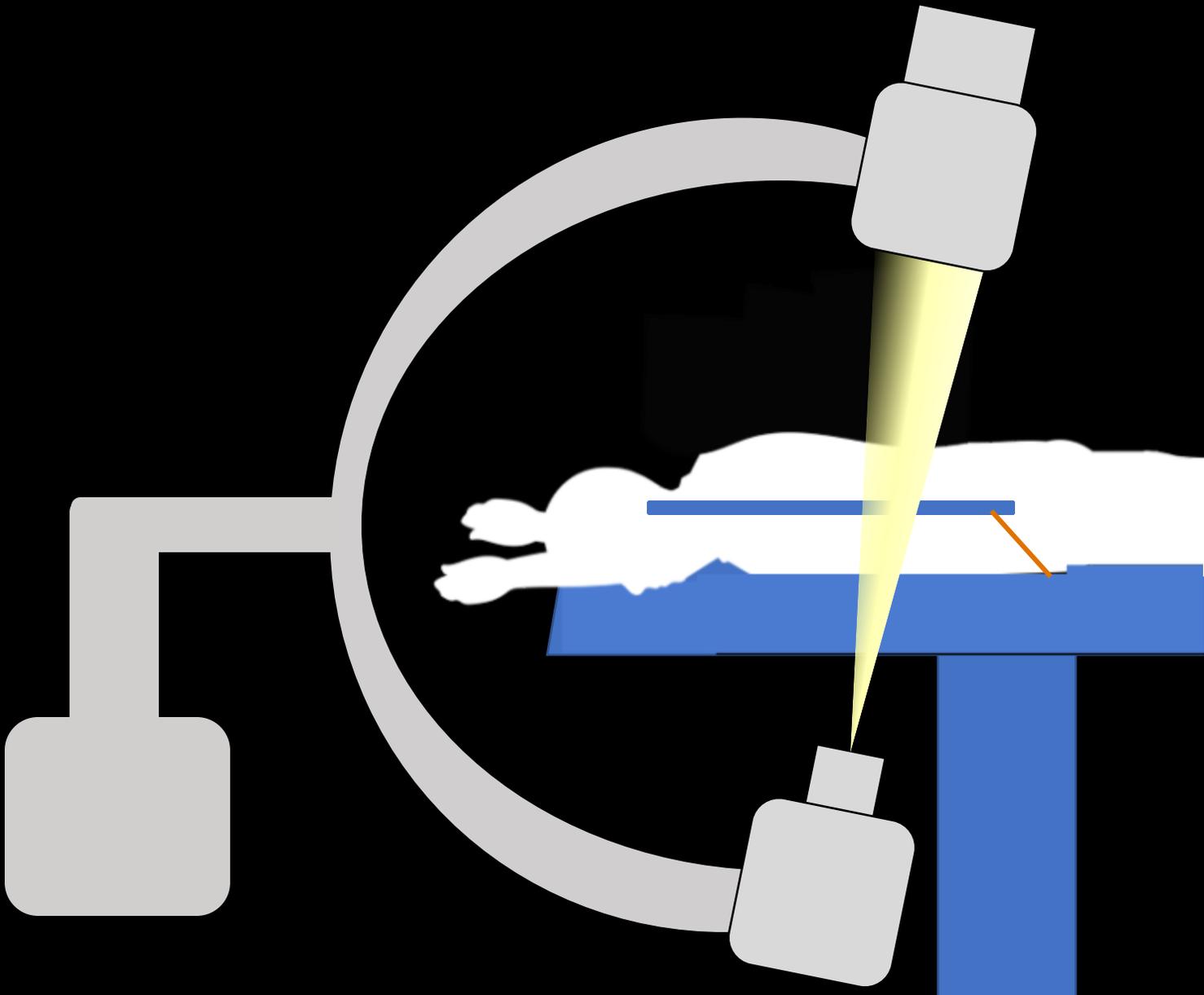


**Brain MRI: positive
for SIH**

**Spine MRI:
No fluid collection**

**Conventional CTM:
No leak???**

2013: CVF Identified on DSM



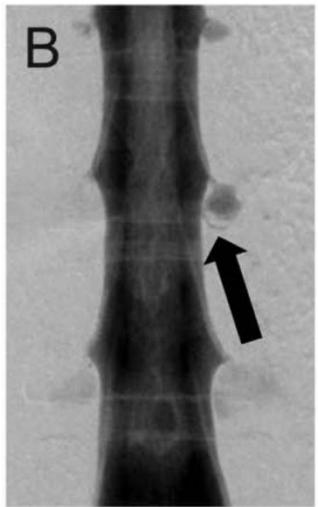
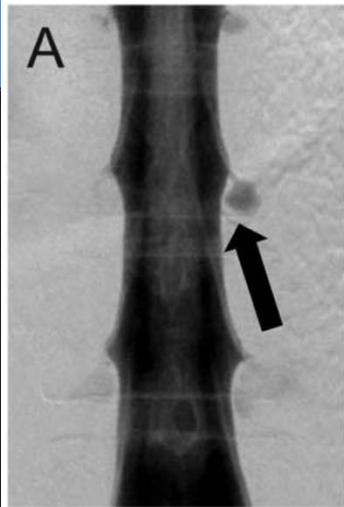
DSA: Digital Subtraction Angiography

DSM: Digital Subtraction Myelography

Neurology®

CSF–venous fistula in spontaneous intracranial hypotension

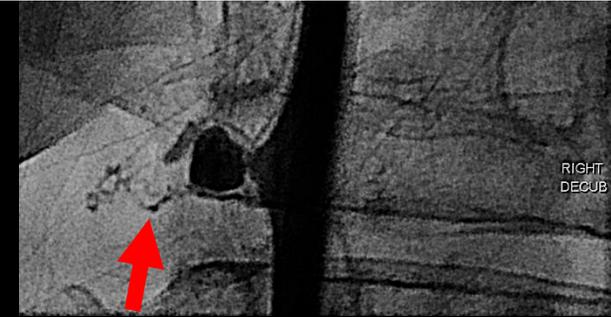
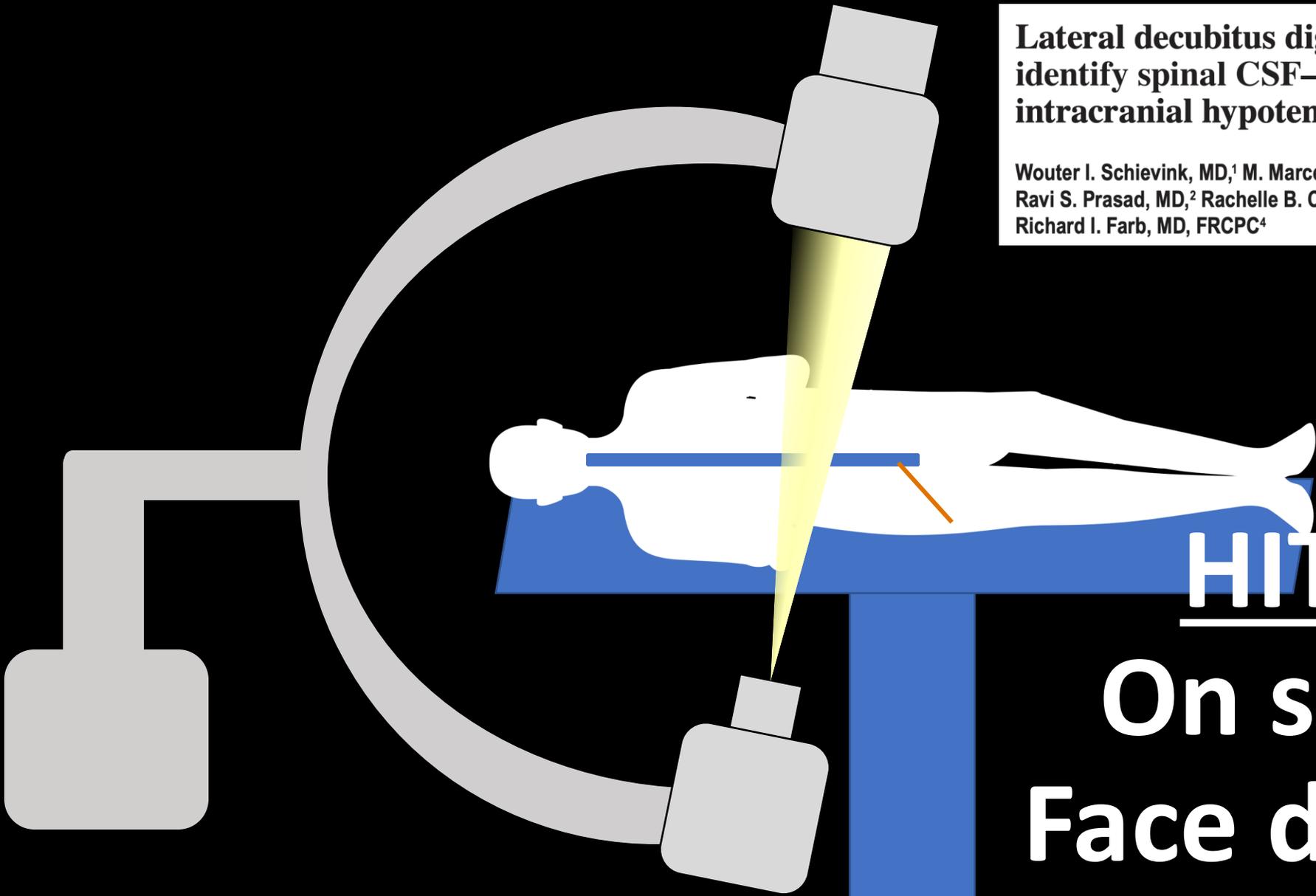
Wouter I. Schievink, MD, Franklin G. Moser, MD, MMM, and M. Marcel Maya, MD | [AUTHORS INFO &...](#)



2019: Laying On Side > Face Down

Lateral decubitus digital subtraction myelography to identify spinal CSF–venous fistulas in spontaneous intracranial hypotension

Wouter I. Schievink, MD,¹ M. Marcel Maya, MD,² Franklin G. Moser, MD, MMM,² Ravi S. Prasad, MD,² Rachele B. Cruz, MSN, APRN, NP-C,¹ Miriam Nuño, PhD,³ and Richard I. Farb, MD, FRCPC⁴



HIT RATE:

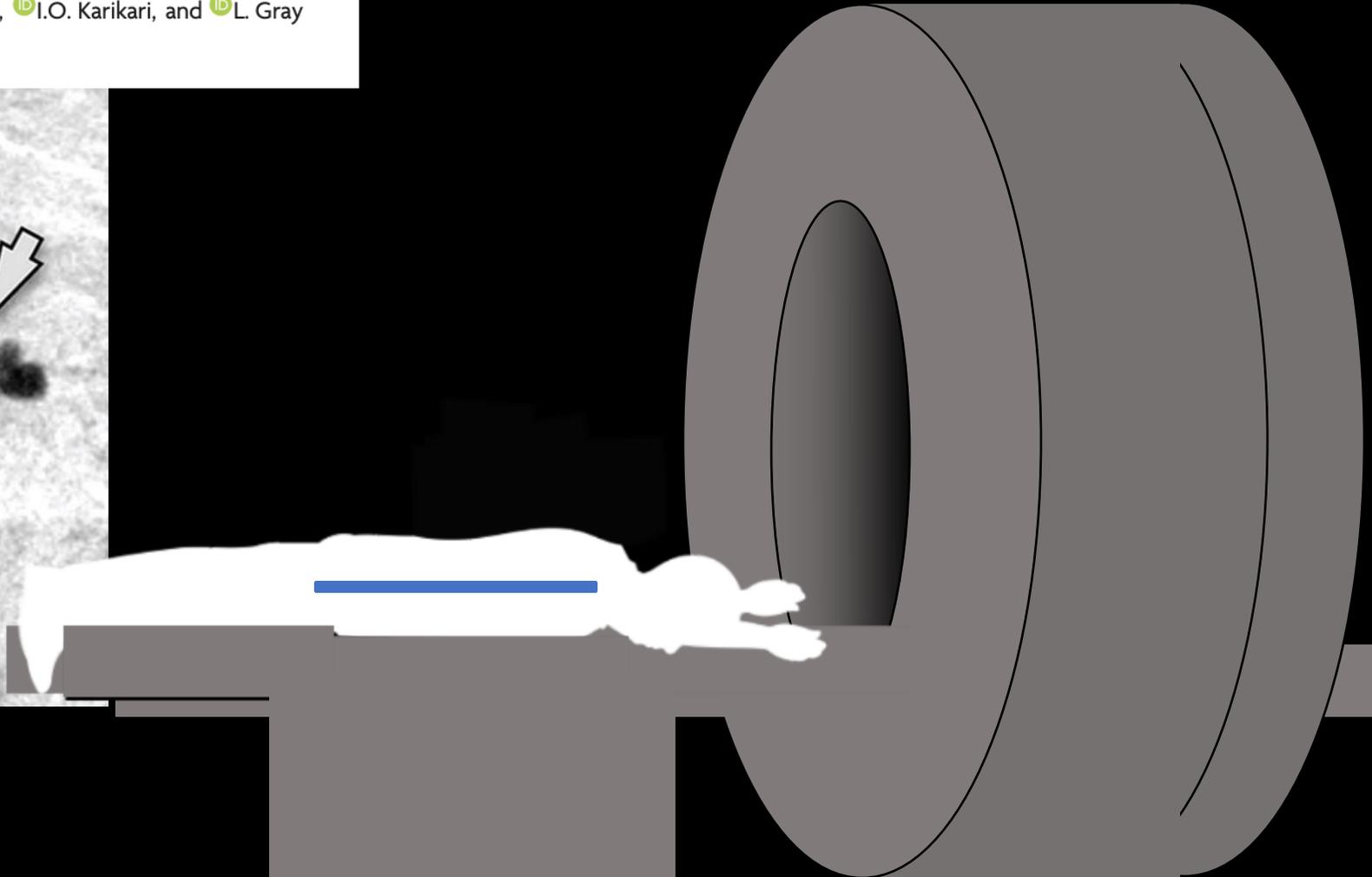
On side: 74%

Face down: 15%

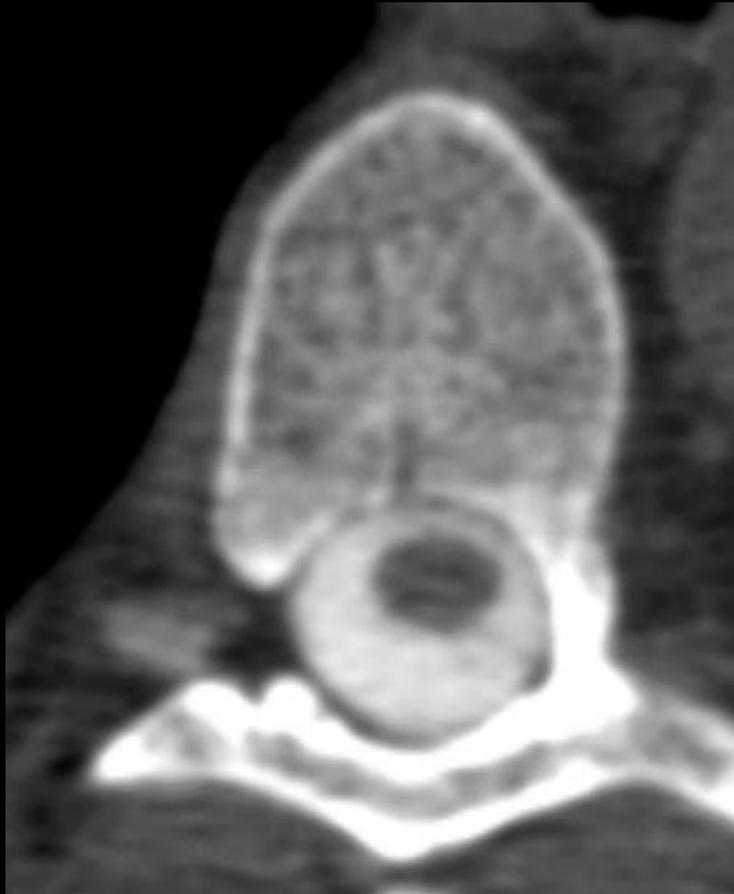
2016: First Description of CVF on CTM

The “Hyperdense Paraspinal Vein” Sign: A Marker of CSF-Venous Fistula

 P.G. Kranz,  T.J. Amrhein,  W.I. Schievink,  I.O. Karikari, and  L. Gray



61M, YEARS OF ORTHOSTATIC HEADACHE

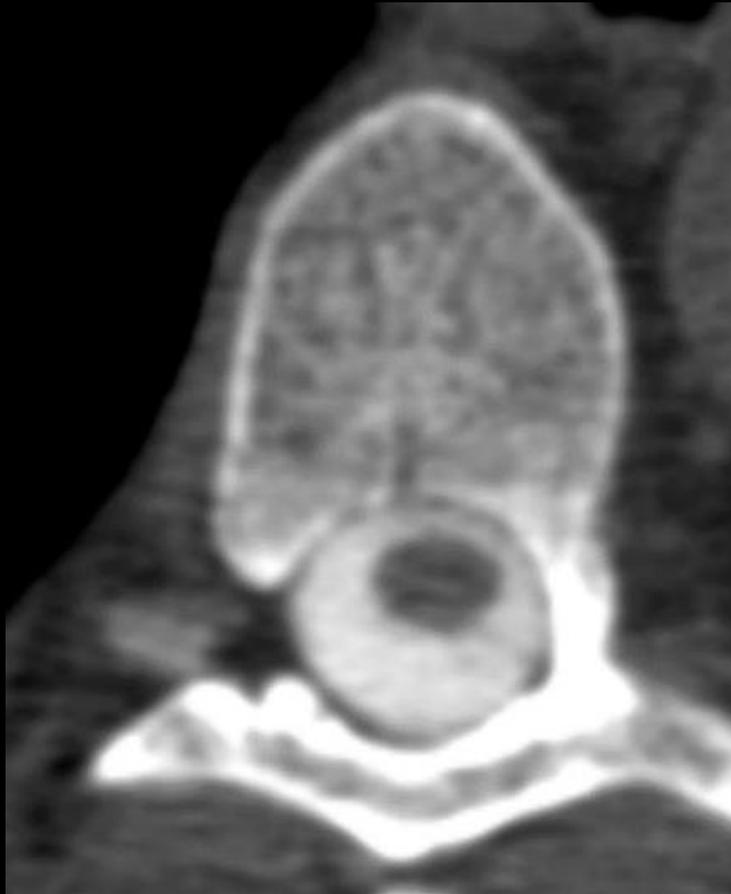


2016: CTM
"No leak"

2016 Diagnoses:

1. Migraine
2. Tension headache
3. Trigeminal Autonomic Cephalalgia
4. TMJ myofascial syndrome
5. Occipital neuralgia
6. Supraorbital neuralgia

61M, YEARS OF ORTHOSTATIC HEADACHE



2016: CTM
"No leak"

2021 Diagnosis:

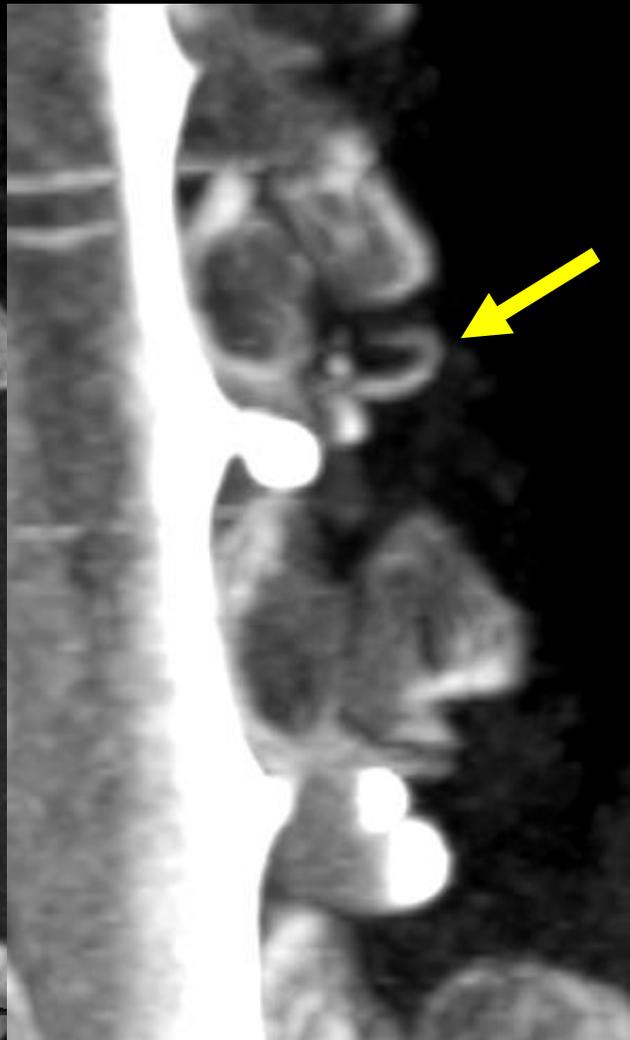
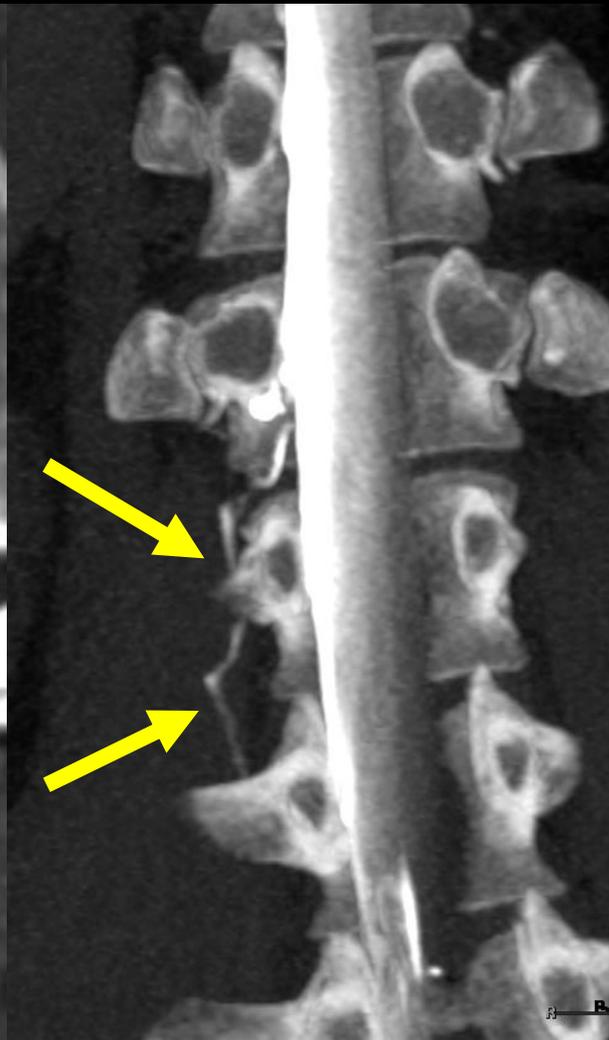
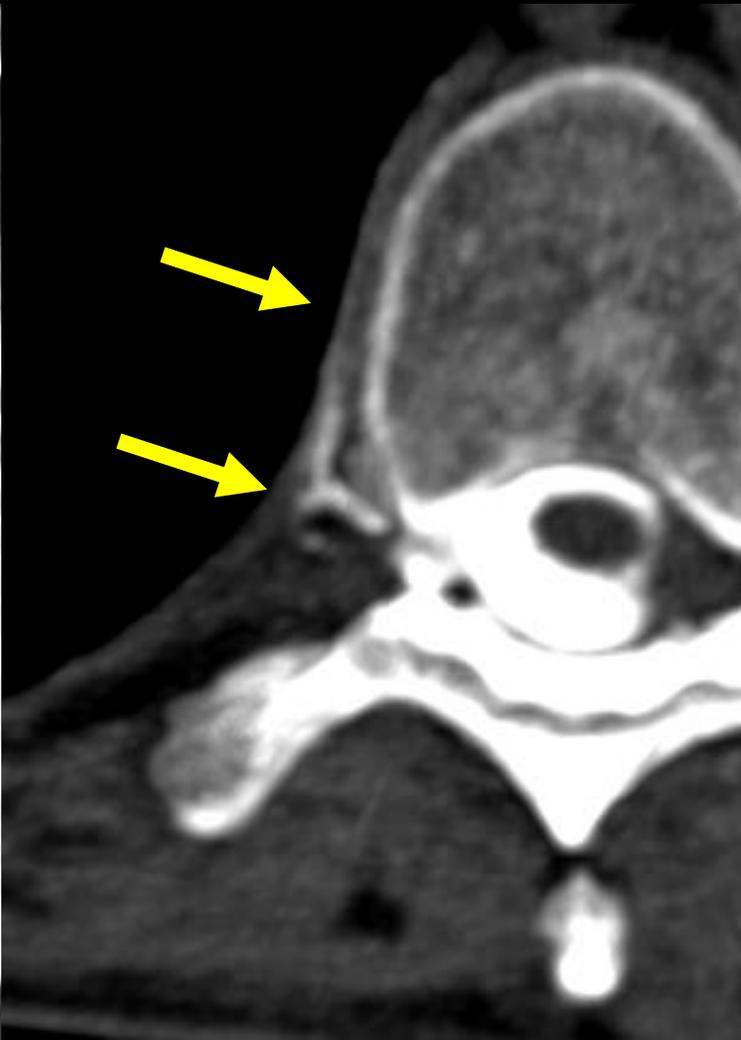
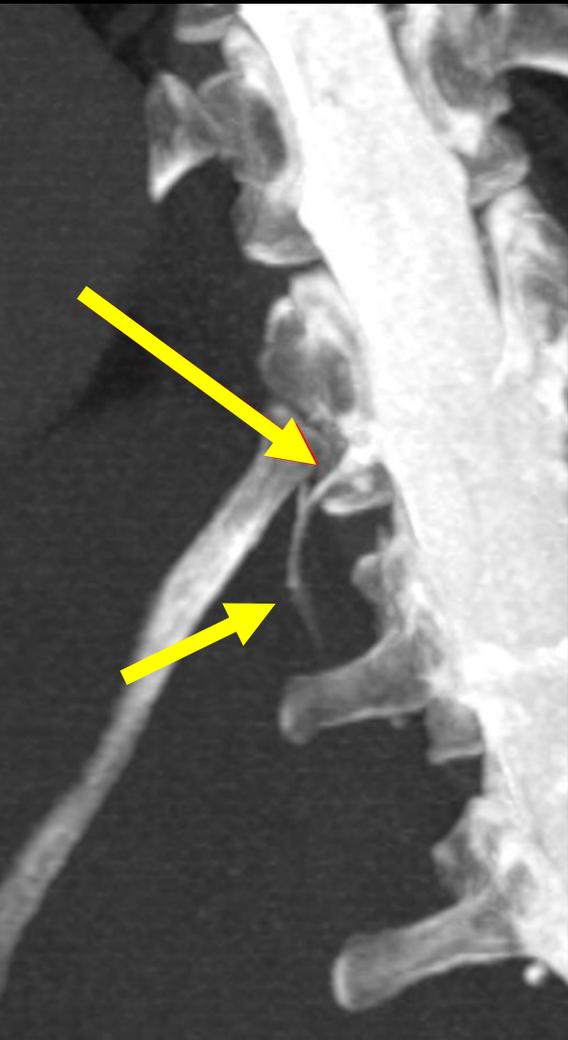
1. SIH due to CVF



2021: LAT DECUBITUS CTM

Simple, right?

Just find the hyperdense paraspinous vein!

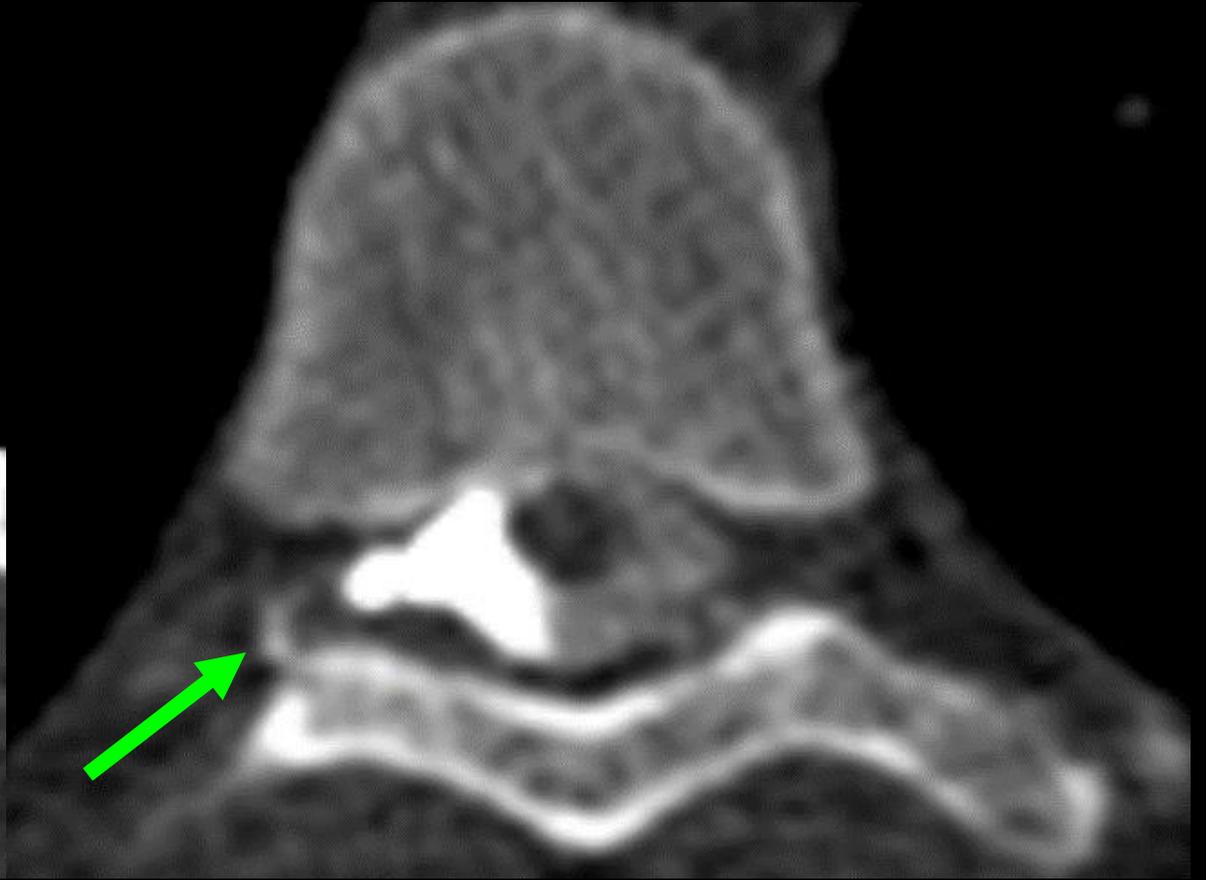


Yet we can still miss them...

First try: Negative



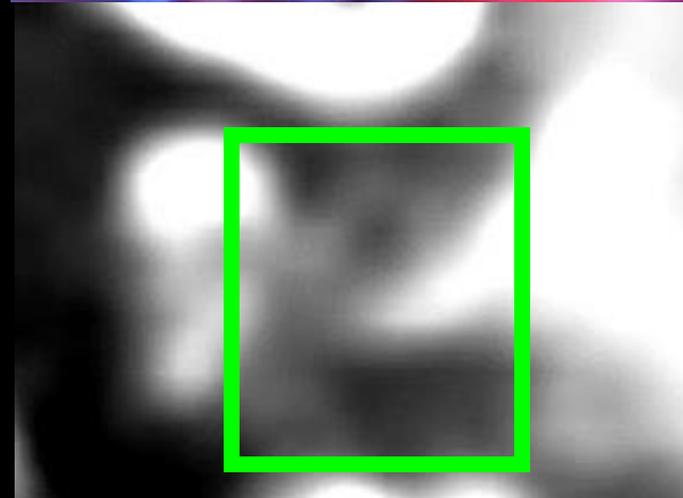
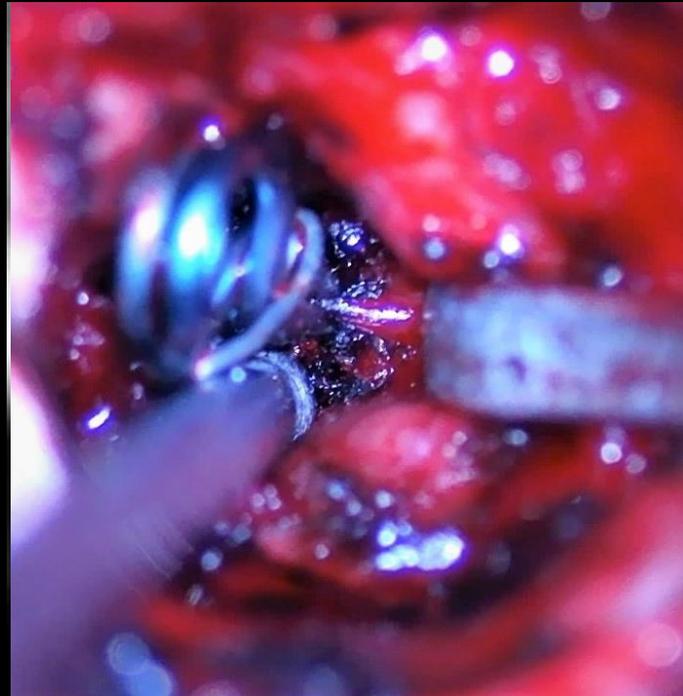
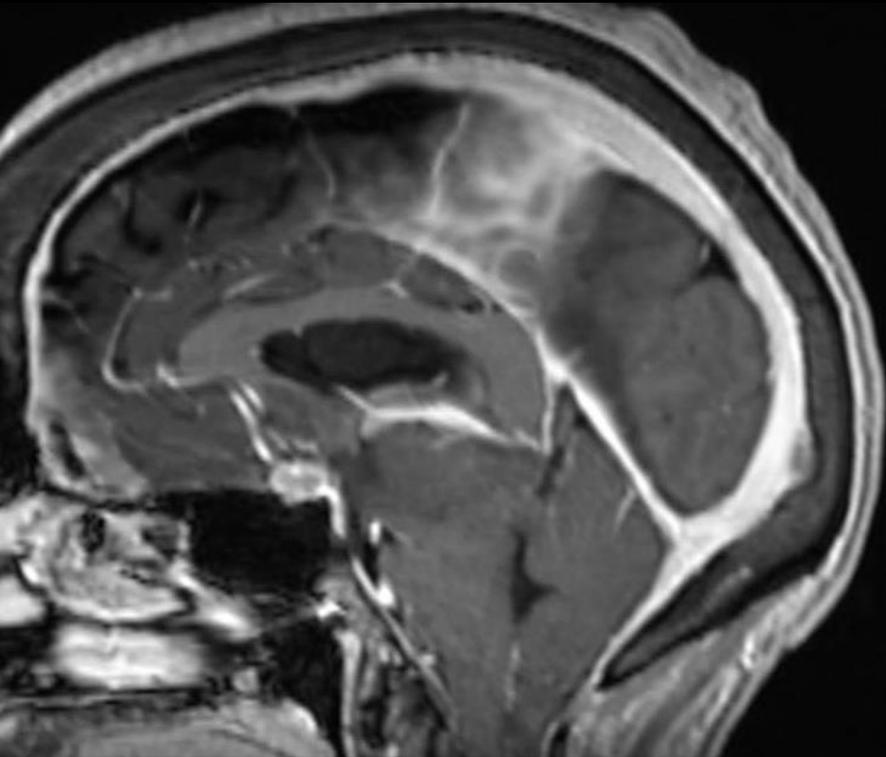
Repeat: + CVF



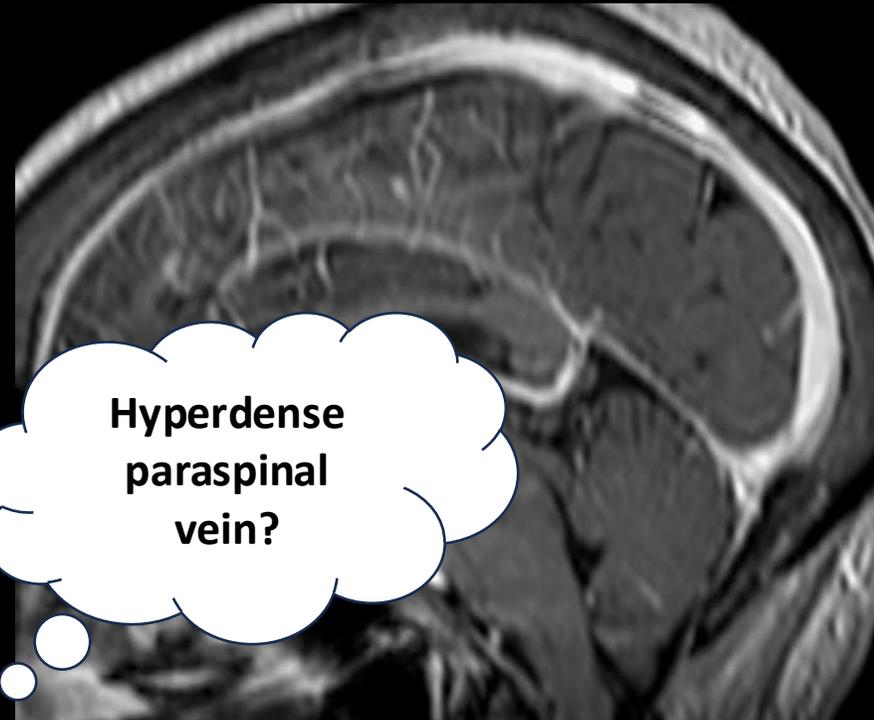
ERRORS OF TECHNIQUE?

Or “find” them, but not see them

Pre

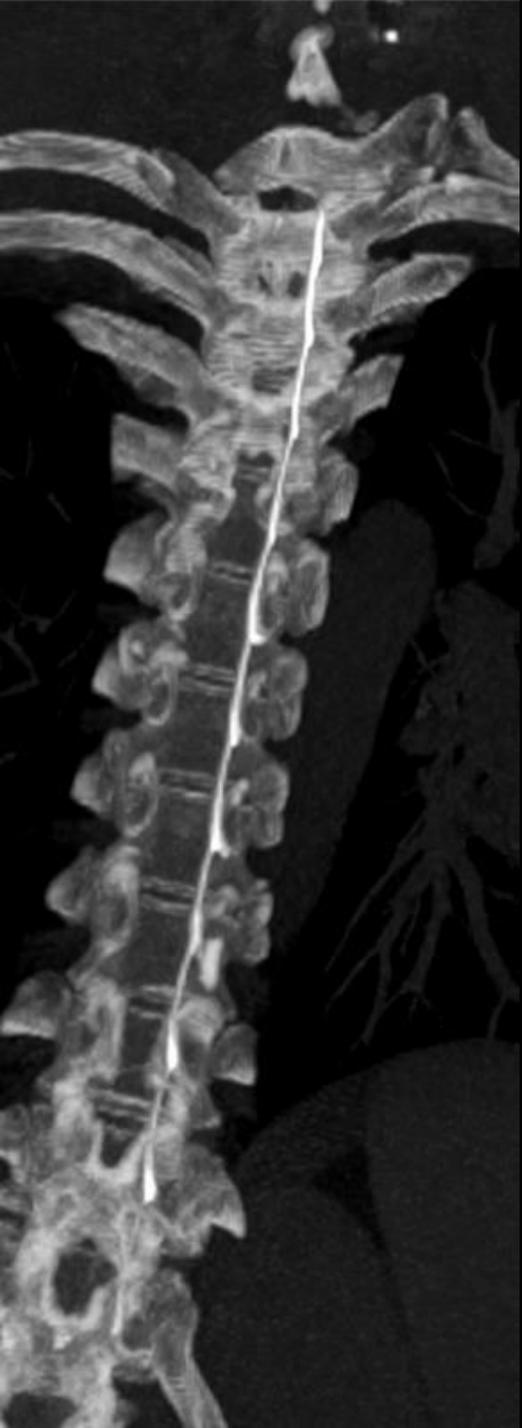


Post

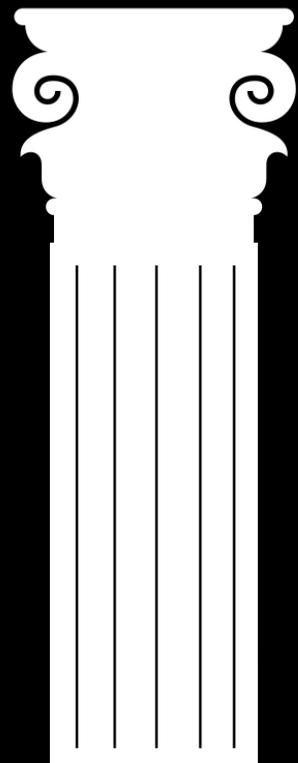


Hyperdense
paraspinal
vein?

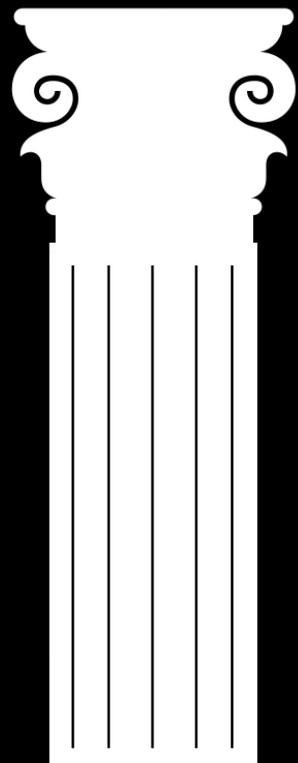
**ERRORS OF
PERCEPTION?**



CVF DETECTION



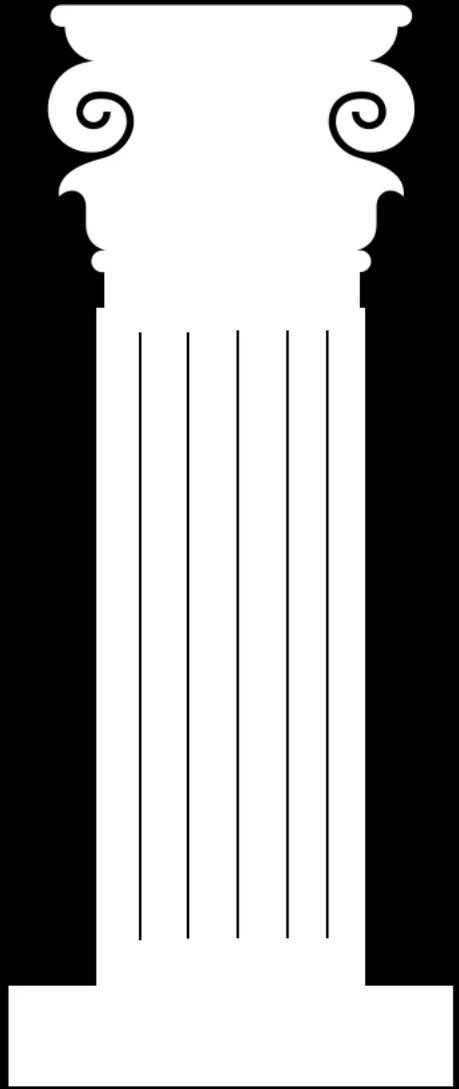
TECHNIQUE



PERCEPTION

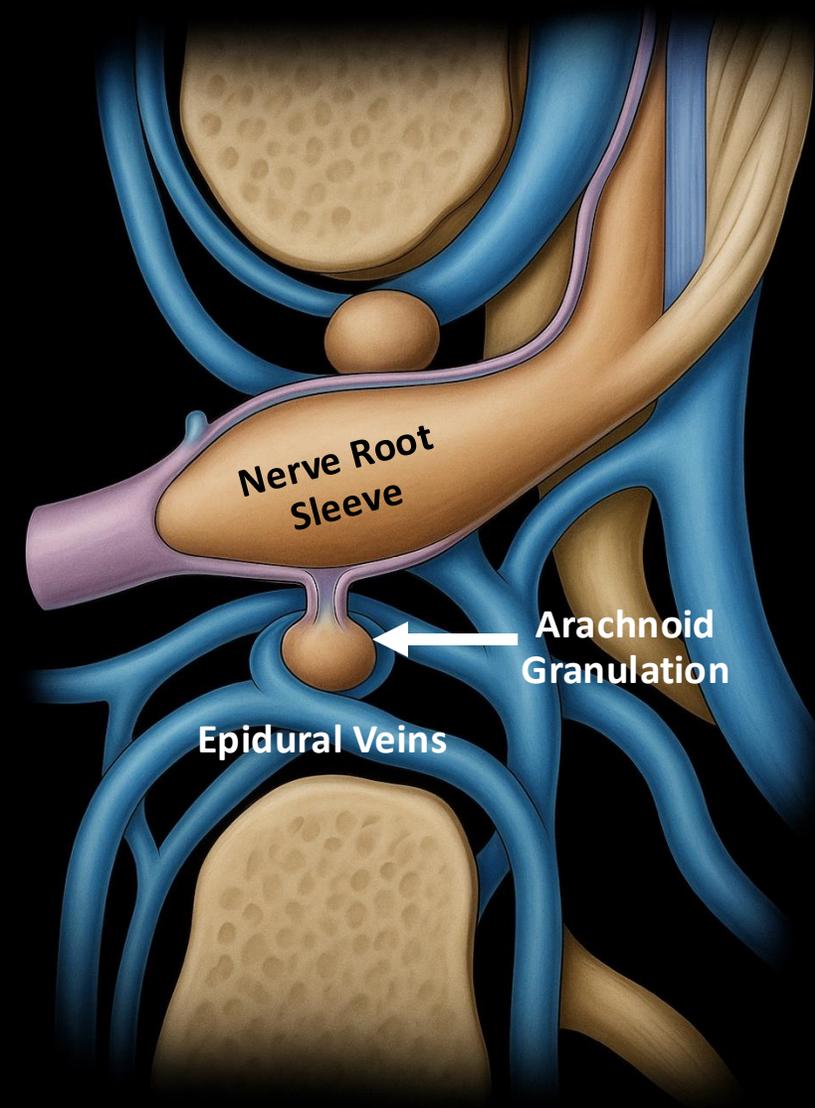


PERCEPTION



1. What are CVF and why do they form?
2. Where can they occur?
(anatomy)

Normal CSF Resorption in the Spine



- Spinal arachnoid villi + granulations:
- ~20% of total CSF resorption
 - Higher distribution in thoracic spine

Theory:
Damage to
 $AV/AG = CVF$

Spinal CSF absorption in healthy individuals

Mikael Edsbagge,¹ Magnus Tisell,¹ Lars Jacobsson,² and Carsten Wikkelso¹

¹Hydrocephalus Research Unit, Institute of Clinical Neuroscience and ²Department of Radiophysics, Sahlgrenska University Hospital, Göteborg University, S-413 45 Göteborg, Sweden

Human Spinal Arachnoid Villi and Granulations

D. K. Kido, D. G. Gomez, A. M. Pavese, Jr., and D. G. Potts

Human spinal arachnoid villi revisited: immunohistological study and review of the literature

R. SHANE TUBBS, M.S., P.A.-C., PH.D.,^{1,8} AKE HANSASUTA, M.D.,² WILLIAM STETLER, B.S.,³ DAVID R. KELLY, M.D.,⁴ DANITRA BLEVINS, H.T.L.(A.S.C.P.),⁴ RITA HUMPHREY, H.T.(A.S.C.P.),⁴ GINA D. CHUA, H.T.L.(A.S.C.P.),⁴ MOHAMMADALI M. SHOJA, M.D.,⁵ MARIOS LOUKAS, M.D., PH.D.,^{6,7} AND W. JERRY OAKES, M.D.⁸

Why do CVF Occur?

Theories:

1. Pre-existing high pressure (*intrinsic*)
2. Injury (*extrinsic*)
 1. Trauma
 2. Needles/Surgery
 3. Inflammation/degeneration

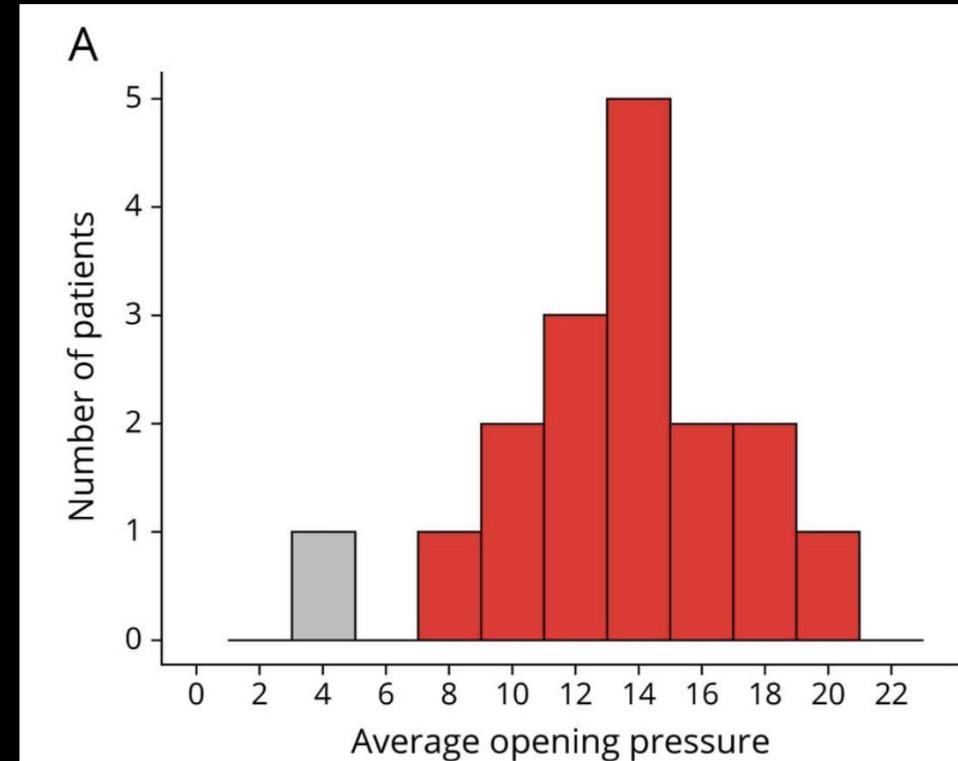
Pre-existing high pressure (intrinsic)

Majority of CVF patients: normal or *elevated* opening pressure

- What was pressure pre-leak?
- CVF = “release valve”?

Higher BMI seen in CVF patients¹

- IIH spectrum/relationship?

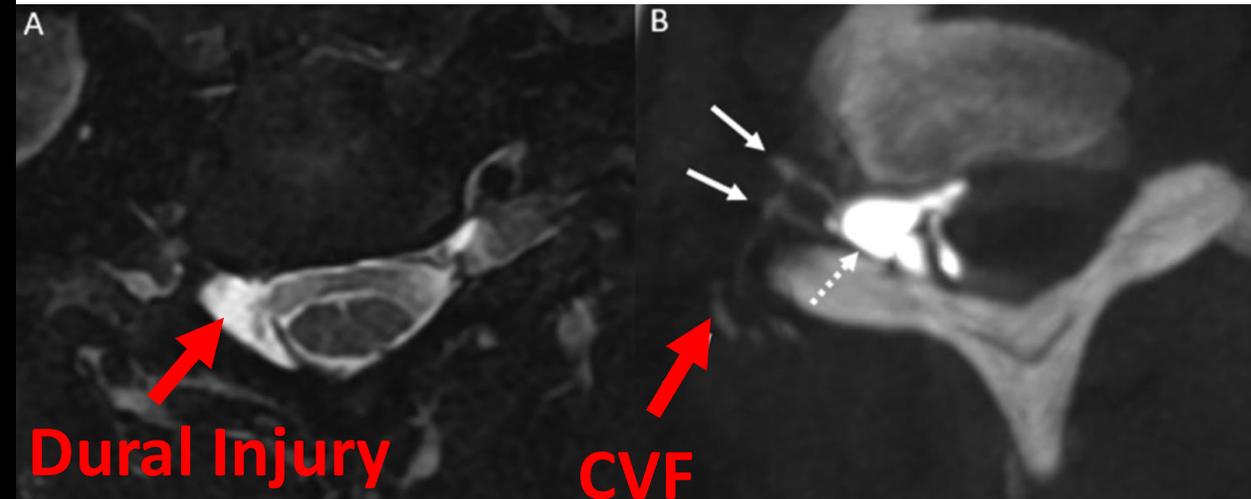


Callen et al. *Neurology* 2023

Injury (extrinsic)

CSF-venous fistulas associated with traumatic spinal pseudomeningoceles

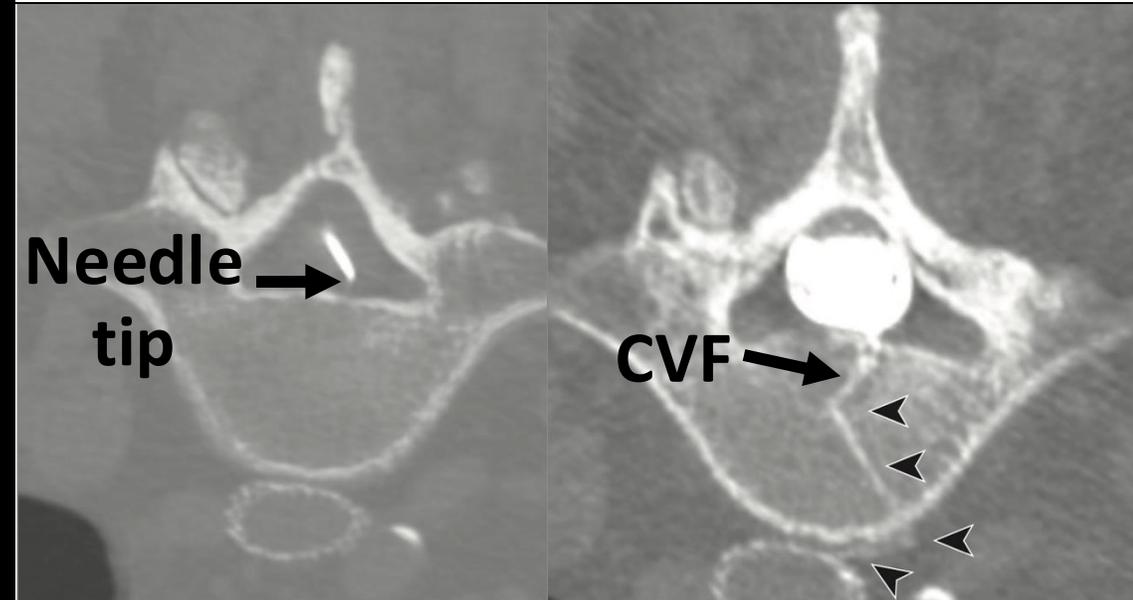
Ajay A Madhavan¹ , Jeremy K Cutsforth-Gregory², Neeraj Kumar², Ivan Garza², Mark A Whealy², Narayan R Kissoon² and Waleed Brinjikji¹



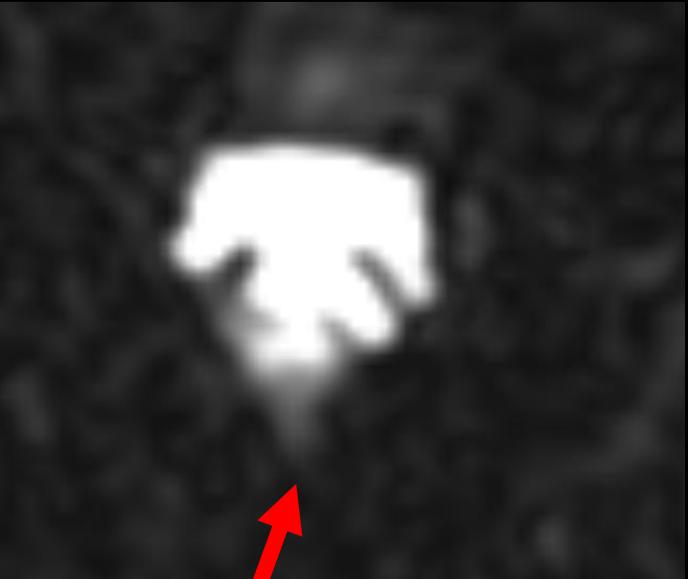
Images in Neurology

Iatrogenic Cerebrospinal Fluid-Venous Fistula

M. Travis Caton Jr, MD; Zhe Guan, MD; Paolo Bolognese, MD

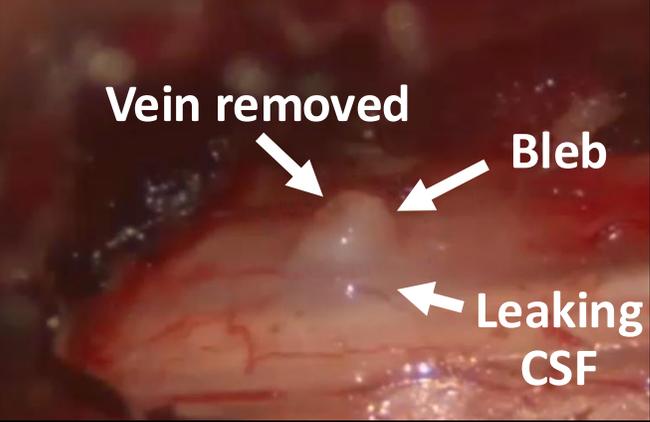
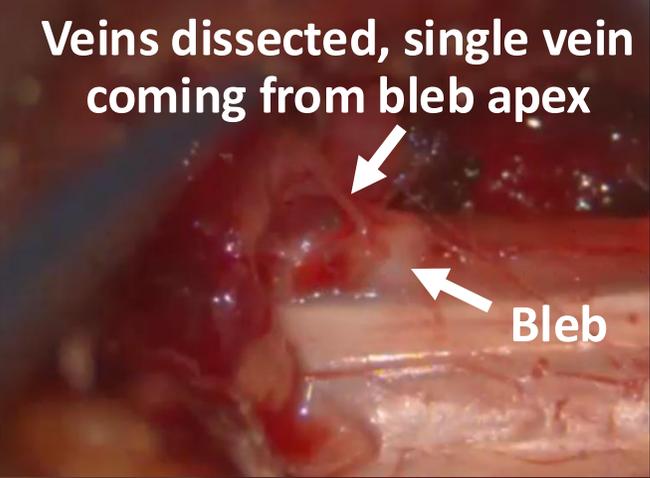
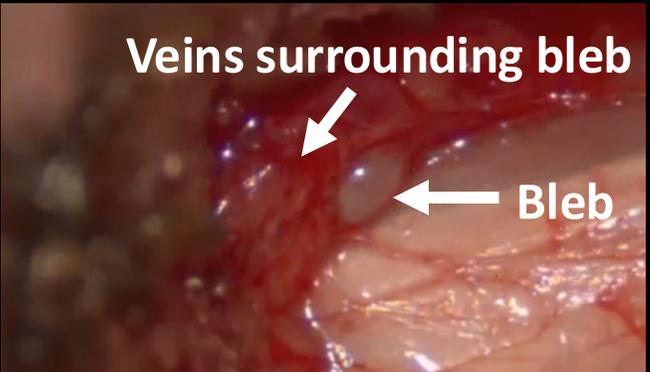


40F, chronic PDPH



**Bleb @ L4-L5
(location of LP)**

INTRAOPERATIVE



Operative images courtesy of Dr. Peter Lennarson

Extrinsic: Meningeal Diverticula

CVF usually near biggest diverticulum

AJNR Spine MRI Diverticular Patterns Predict
CSF-Venous Fistula Location: A 100-Patient Study
Mark D. Mamlouk, James F.R. Latoff, Adriana Gutierrez, Mark F. Sedrak

More diverticula = Higher chance of CVF?

(OUR PRELIMINARY DATA)

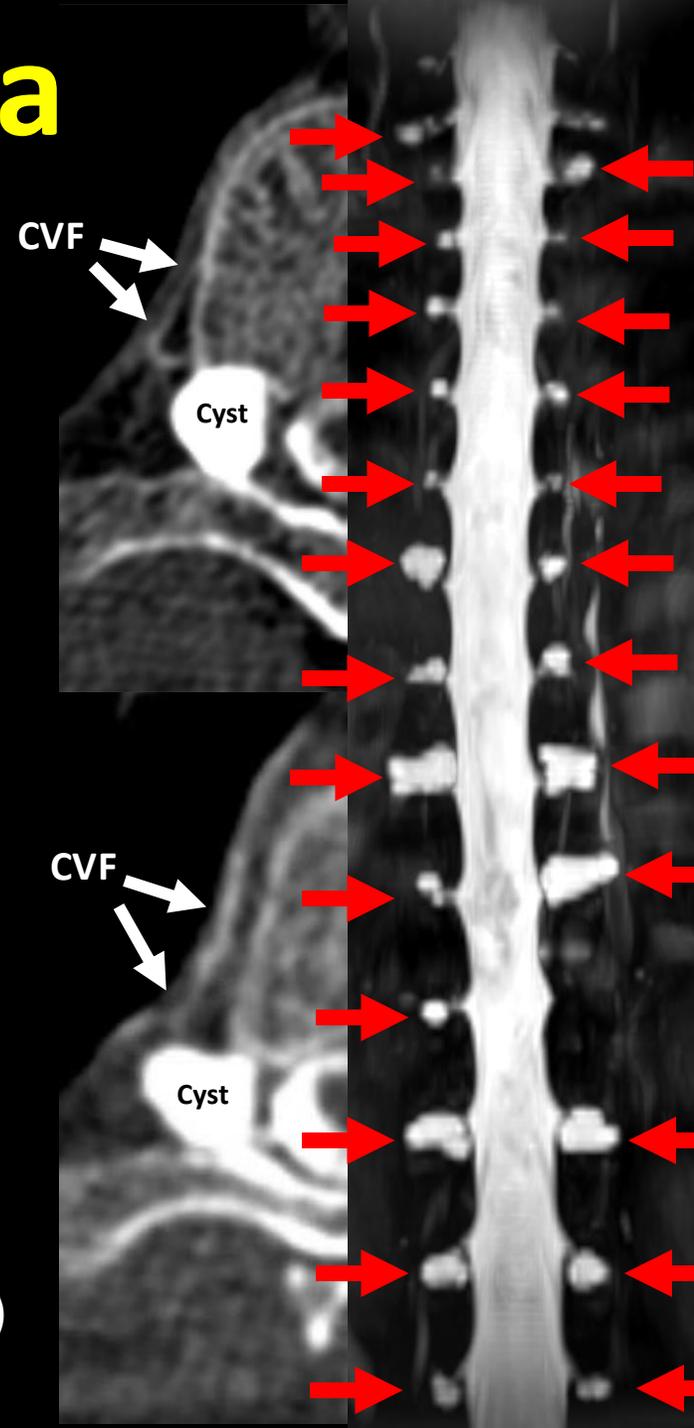
Patients with CVF

- **Larger** diverticula (8.2 vs 7.2 mm, $p = 0.005$)
- **More** diverticula (median 21 vs 9, $p = 0.03$)

Older patients

- **Larger and more** diverticula ($p = 0.44/0.37$, $p = 0.004/0.015$)

Campbell, Montes, Bhaumik, Lennarson, Callen (Submitted)



Chronic Inflammation/Stress?

CVF often near osteoarthritis (OA)

OA linked to pro-vascular inflammatory factors (TGF- β , BMP, IGF-1)

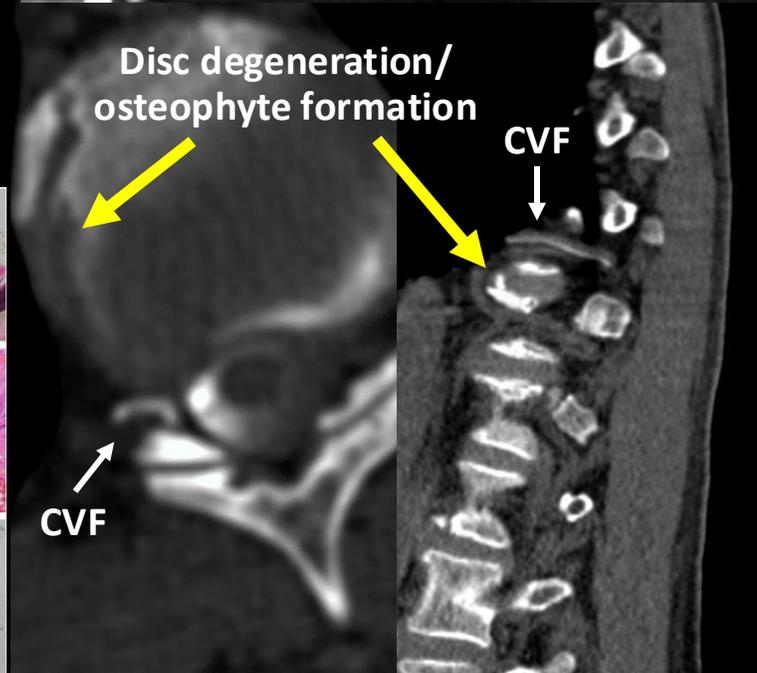
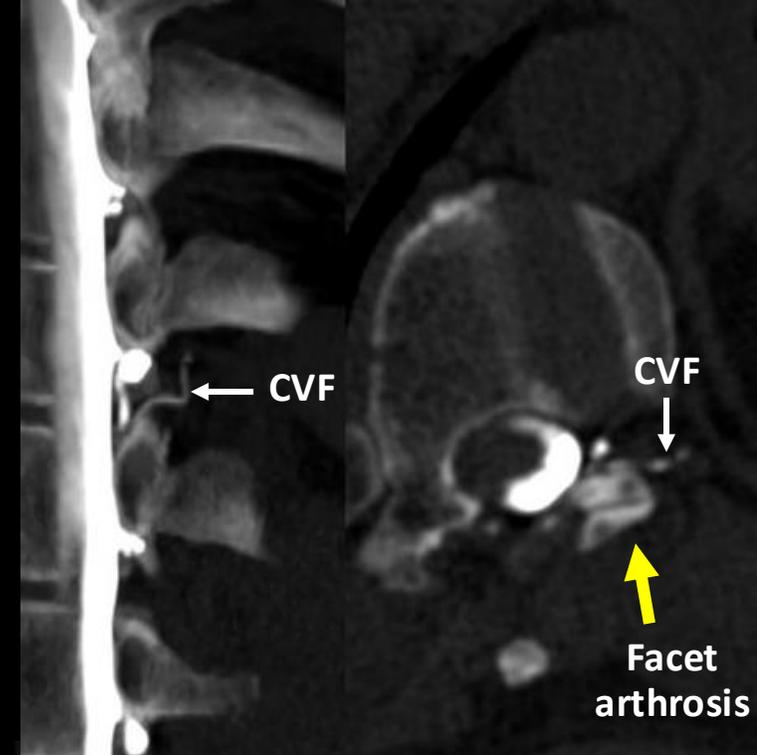
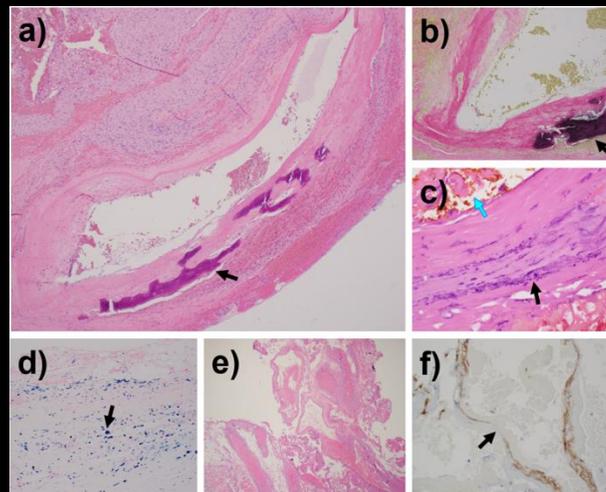
The Spatial Relationship between Spinal Osteoarthritis and CSF Venous Fistulas in Patients with Spontaneous Intracranial Hypotension

AJNR Emma M.Z. Sechrist, Samantha L. Pisani Petrucci, Nadya Andonov, Peter Lennarson, and Andrew L. Callen

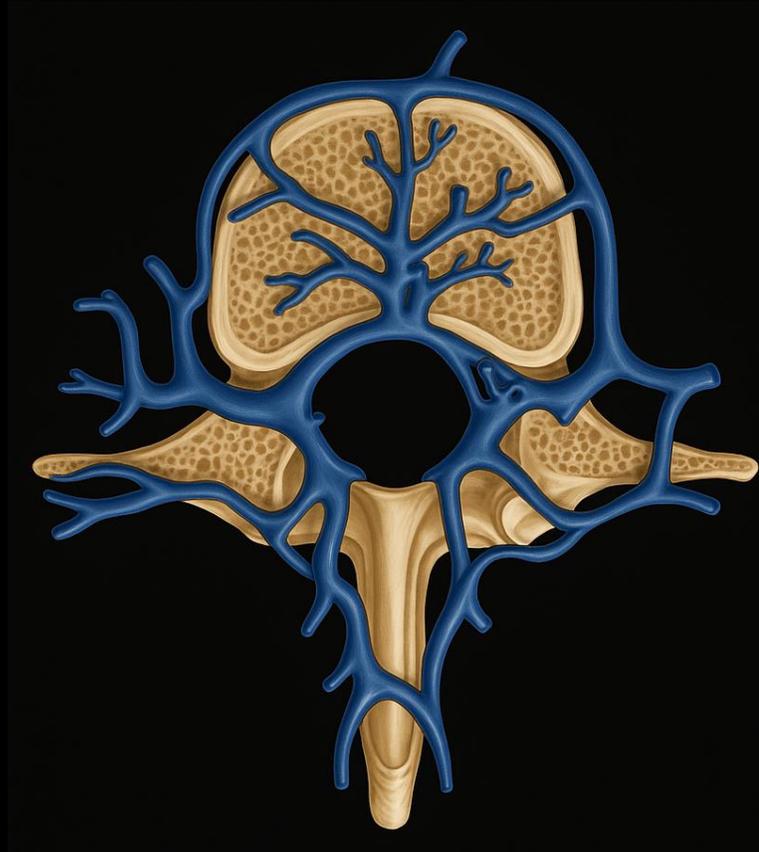
Chronic vascular and dural changes observed microscopically

Histopathologic Analysis of 5 Patients with CSF-Venous Fistulas after Surgical Nerve Root Ligation and Resection

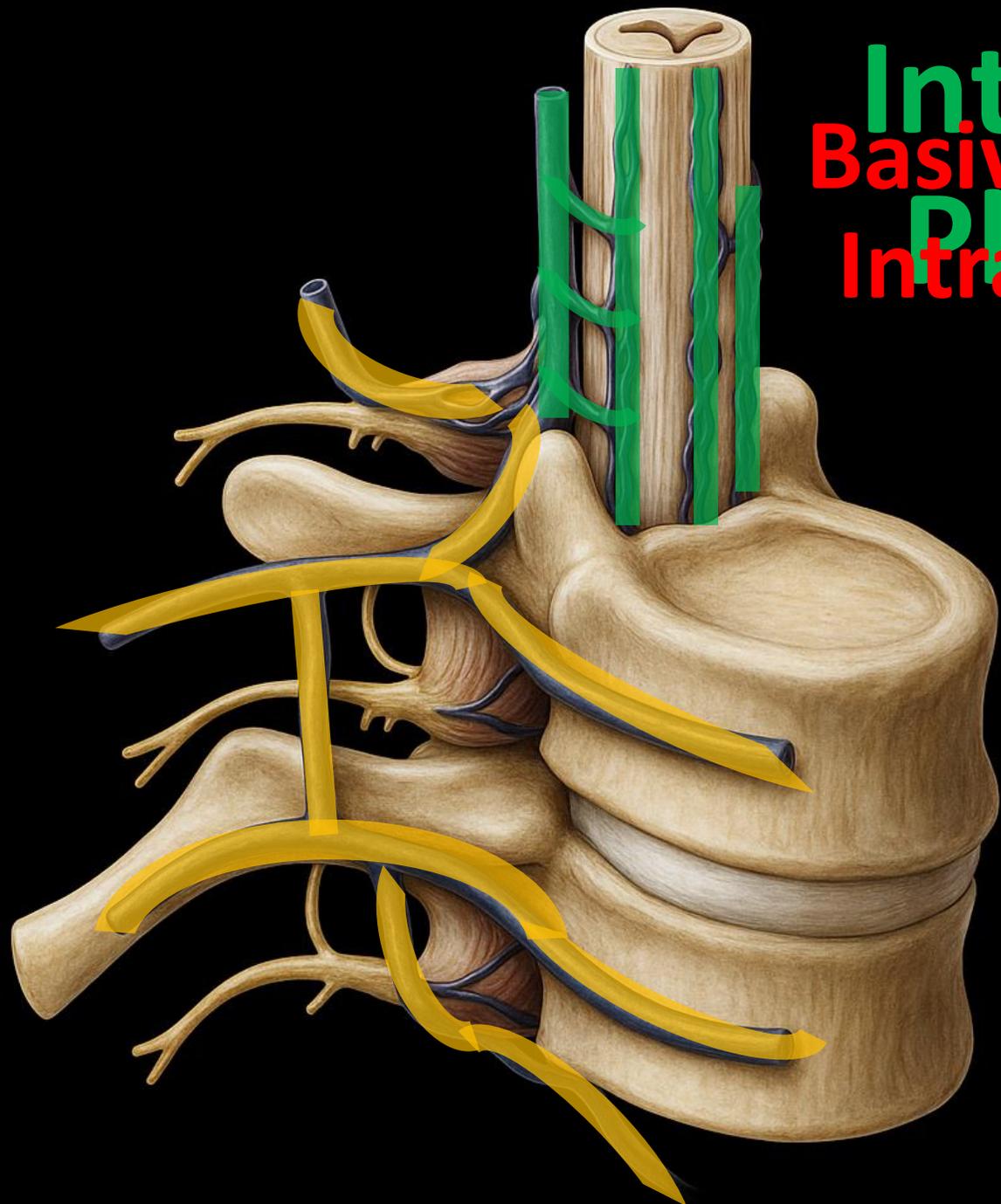
AJNR Andrew V. Mecum, B.K. Kleinschmidt-DeMasters, Debayan Bhaumik, Samantha L. Pisani Petrucci, Peter J. Lennarson, and Andrew L. Callen



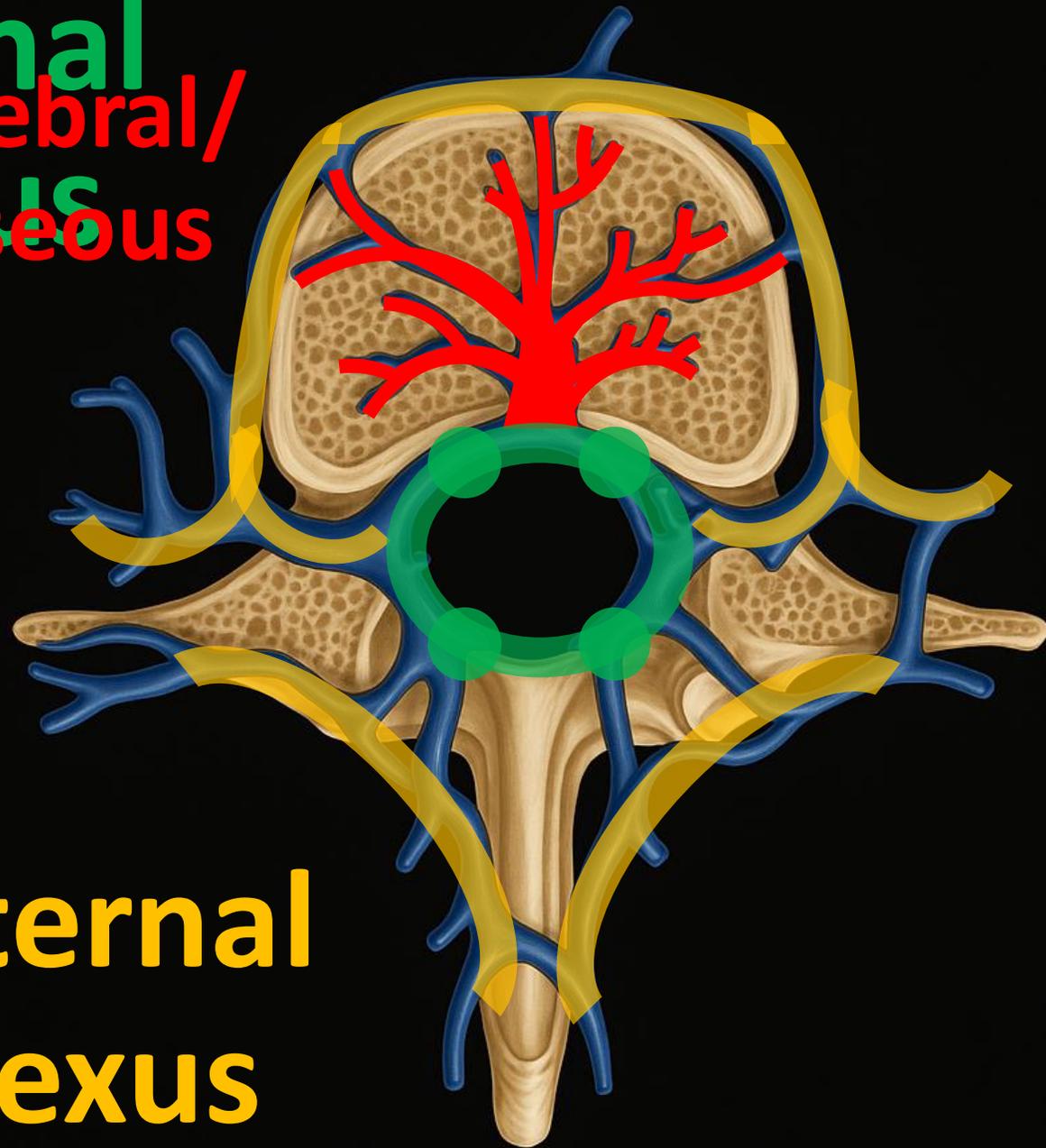
Anatomy of CSF Venous Fistulas



(Anatomy of Spinal Veins)

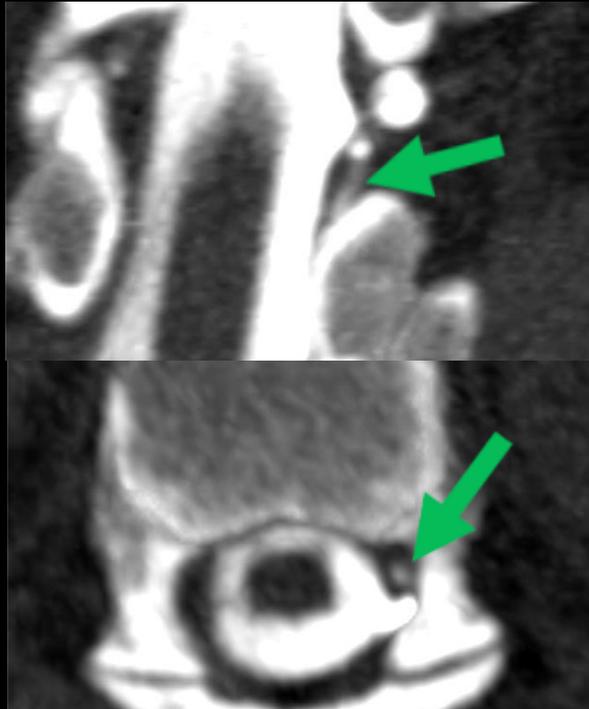
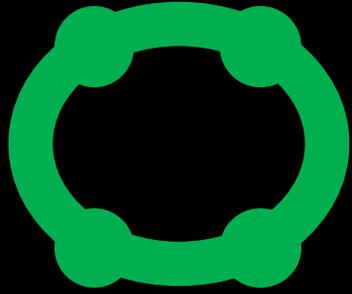


Internal
**Basivertebral/
Intraosseous**

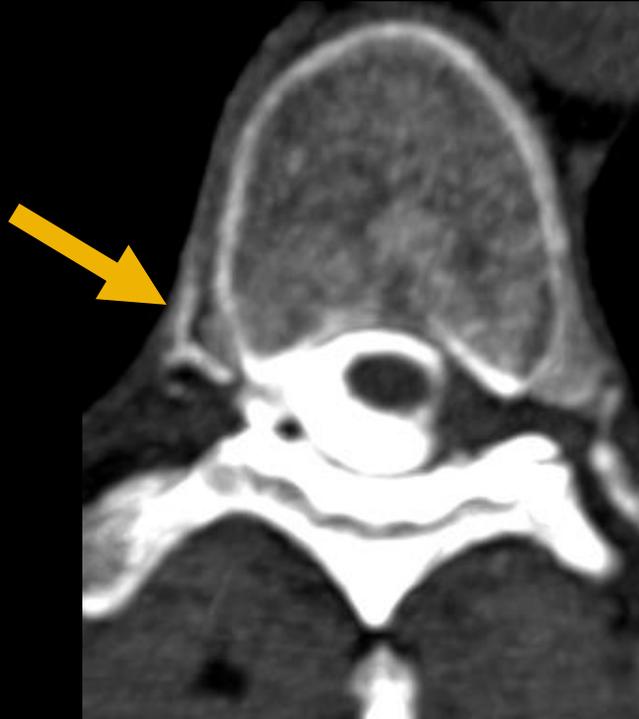


**External
Plexus**

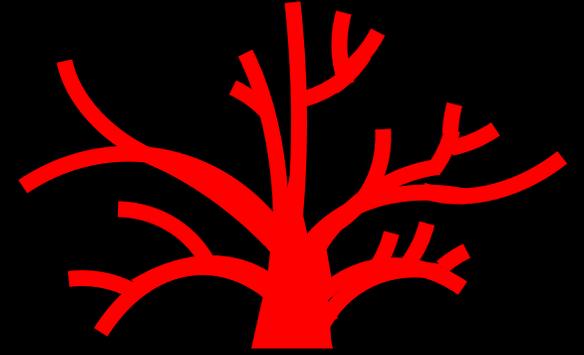
Internal Epidural

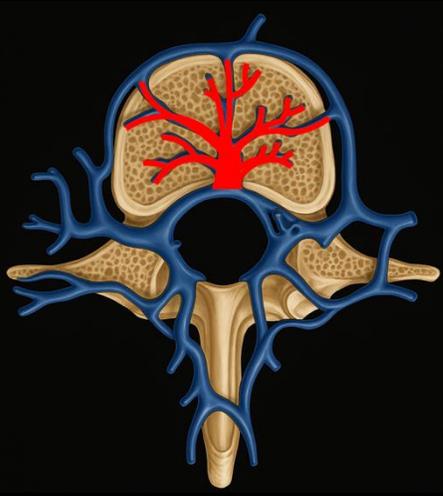


External Epidural

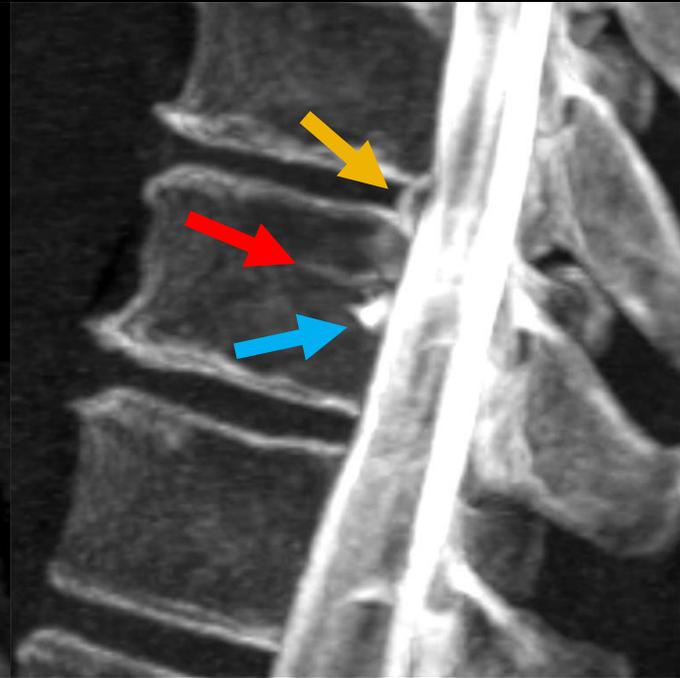
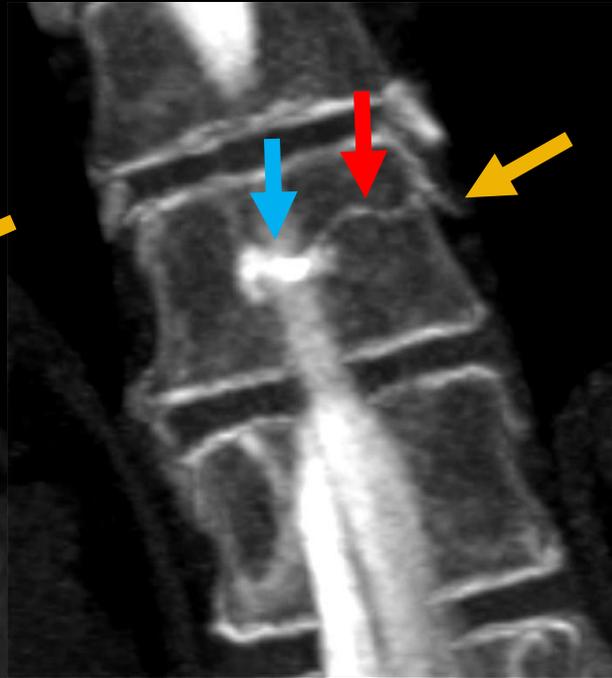
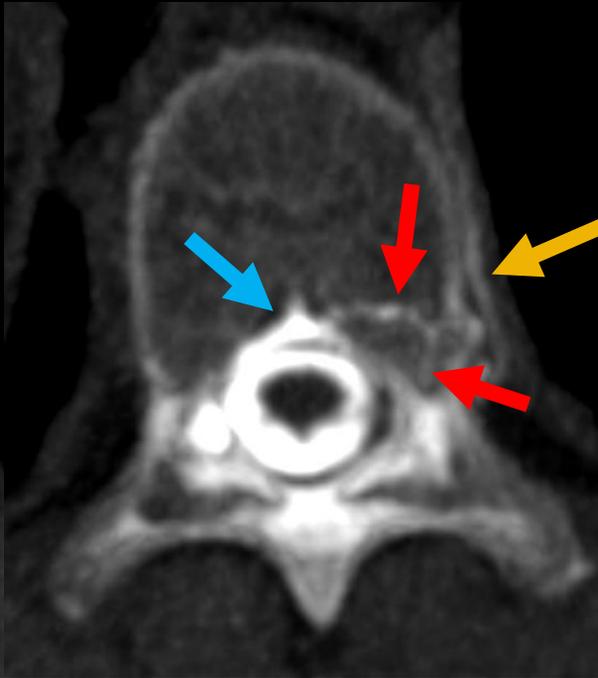


Basivertebral





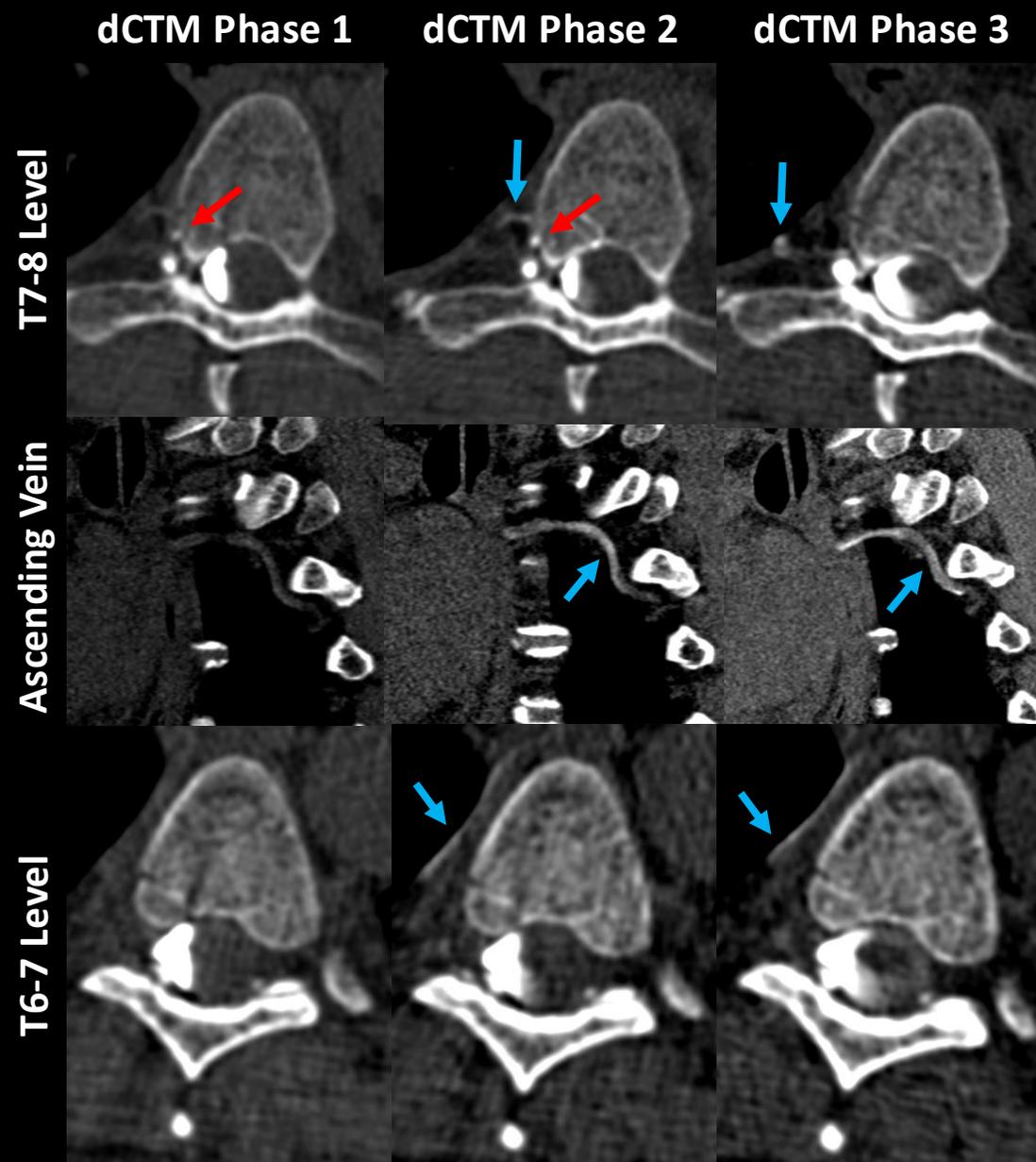
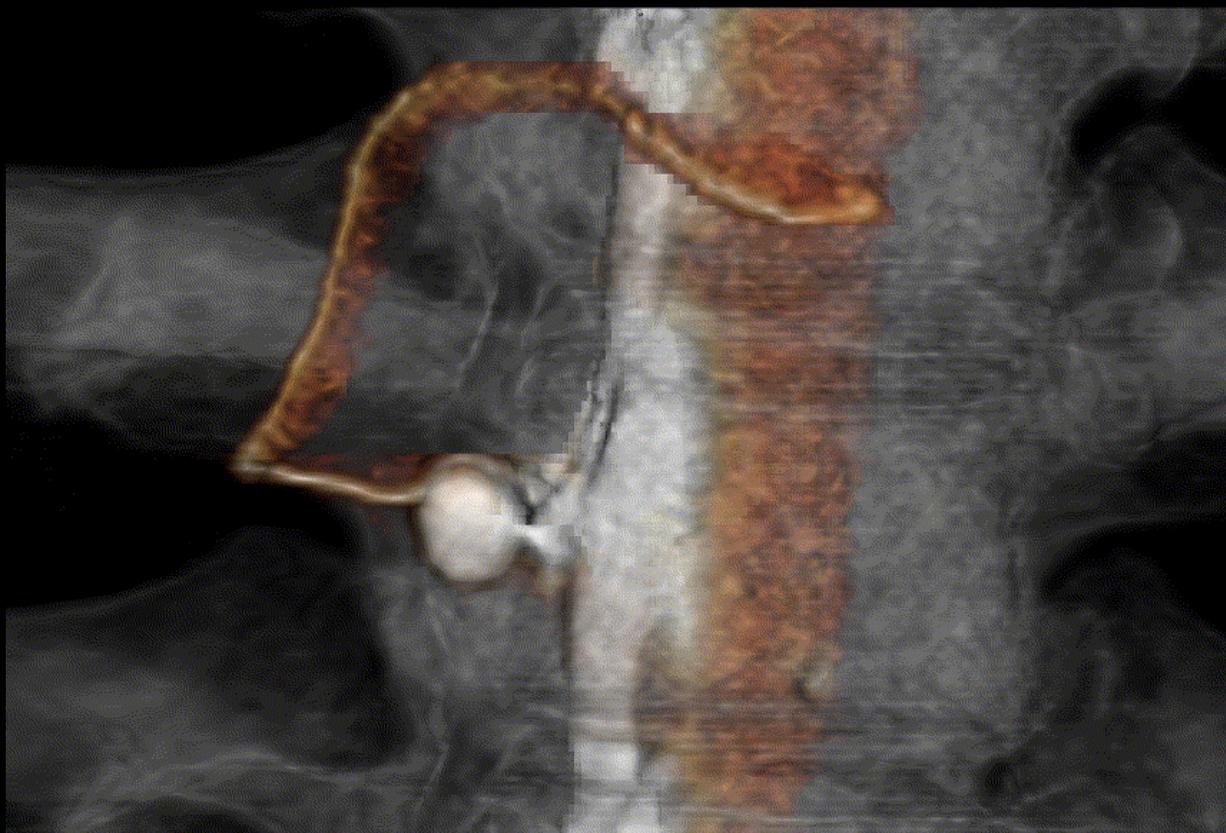
Basivertebral/Intraosseous CVF Require Careful Scrutinization



Early
(Note lack of opacification)

45 sec delay
Basivertebral, intraosseous, paraspinal

Can Drain to Adjacent Levels



Multiple CVFs

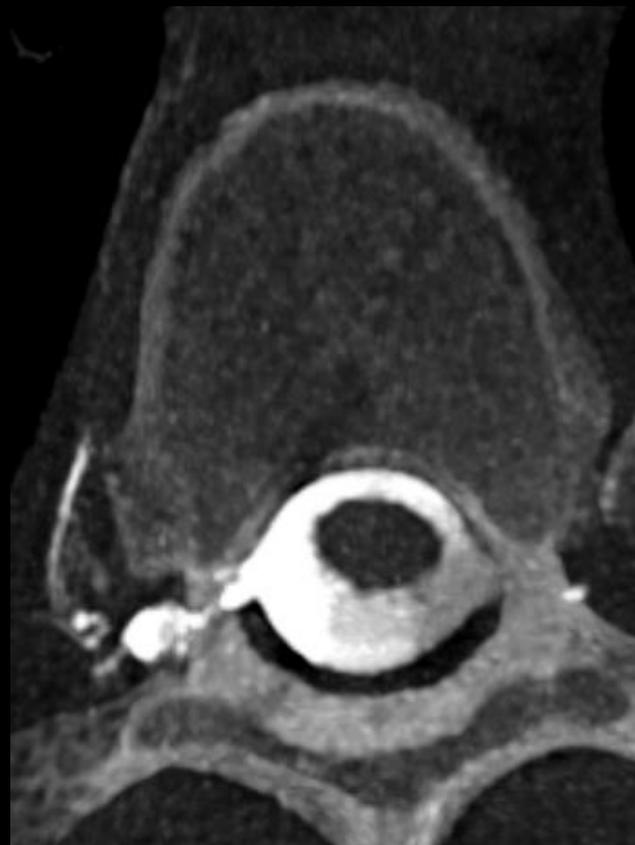
Case Courtesy of Dr. Lalani Carlton Jones

Multiple Synchronous CSF-Venous Fistulas in Spontaneous Intracranial Hypotension: A Multi-Institutional Case Series

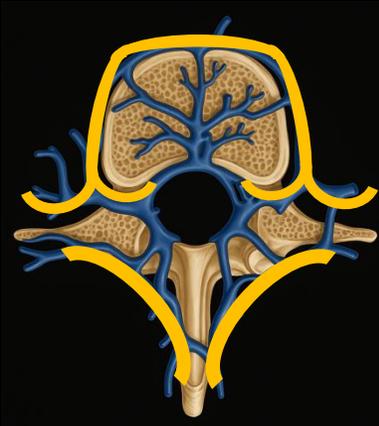
Ajay A. Madhavan, Timothy J. Amrhein, Michelle L. Kodet, Niklas Lutzen, Michael D. Malinzak, Jeremy K. Cutsforth-Gregory, Ian T. Mark, Ivan Garza, Eike I. Piechowiak, and Lalani Carlton Jones

Right T7-T8

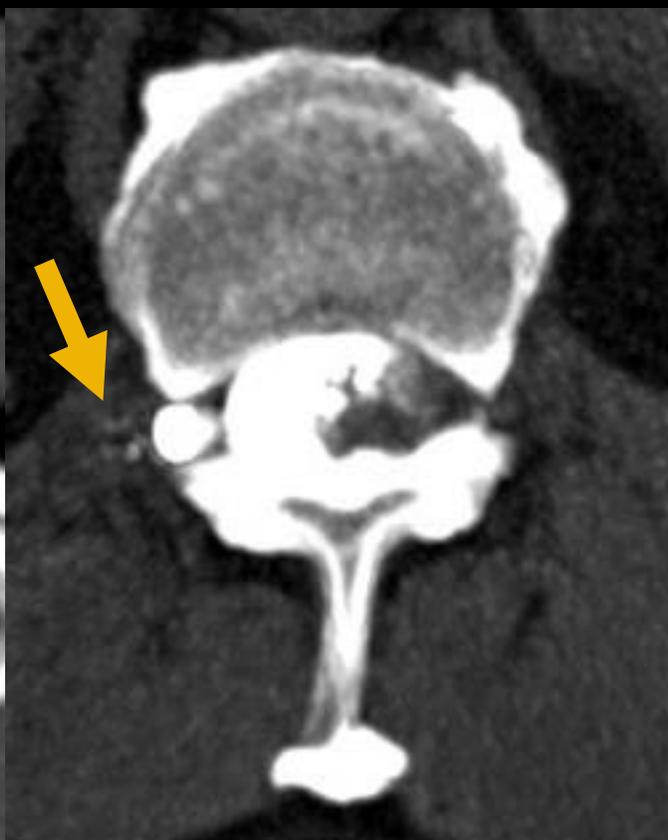
Right T10-T11



Multiple CVFs Rare?



T7-T8

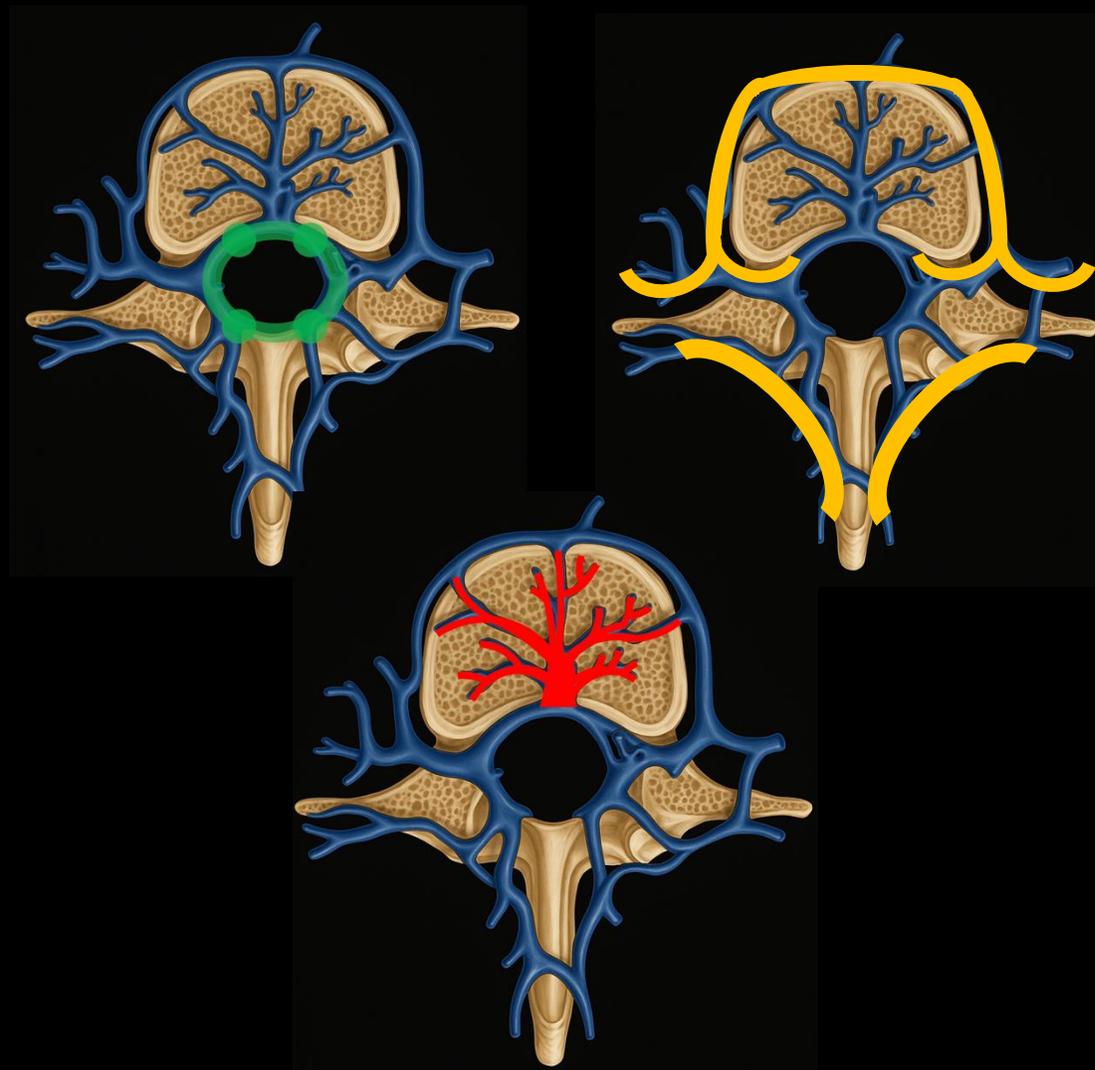
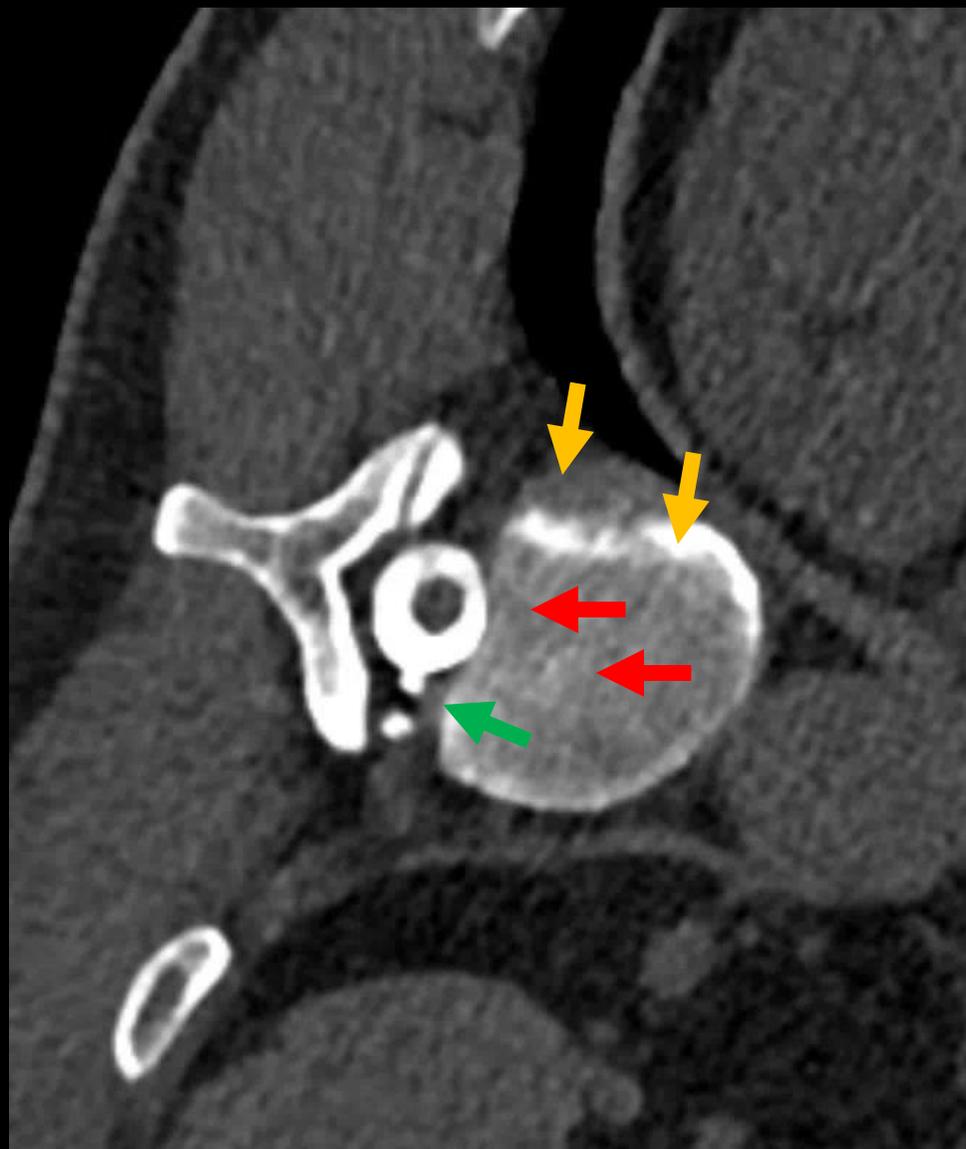


T11-T12



L1-L2

Paradoxical/Contralateral Drainage



Paradoxical/Contralateral Drainage

Right Side Down



Left Side Down



Can MRI help RULE OUT CVF?



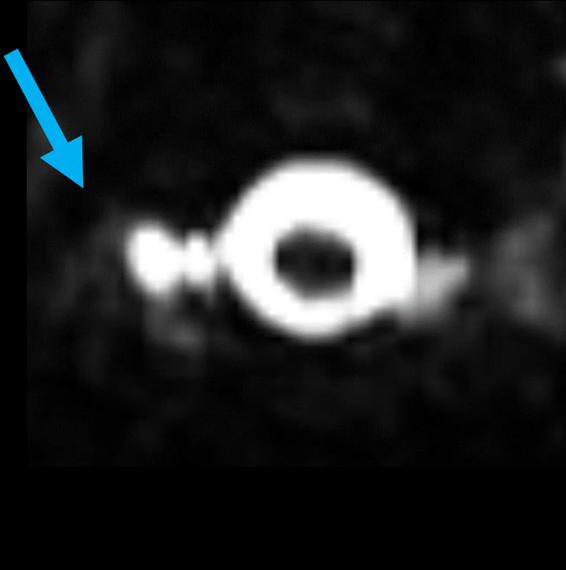
dCTM



3D T2 FS



dCTM

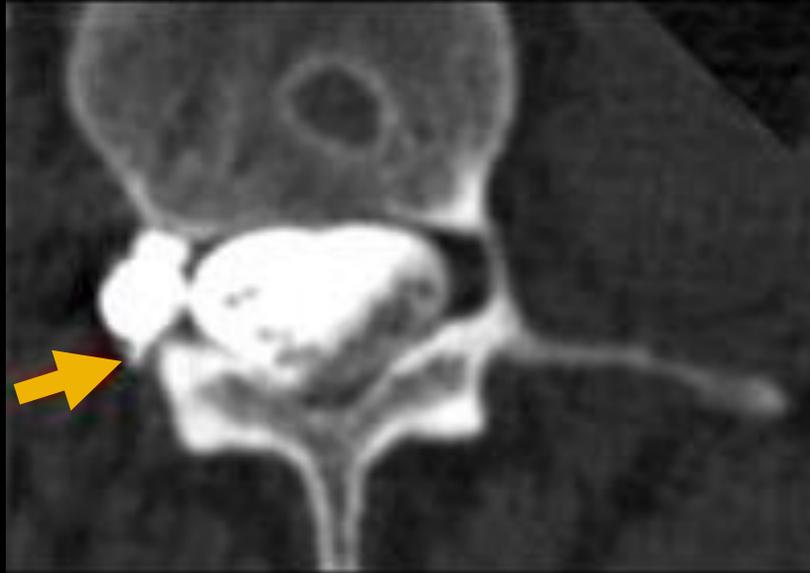


3D T2 FS

DIVERTICULUM

CVF

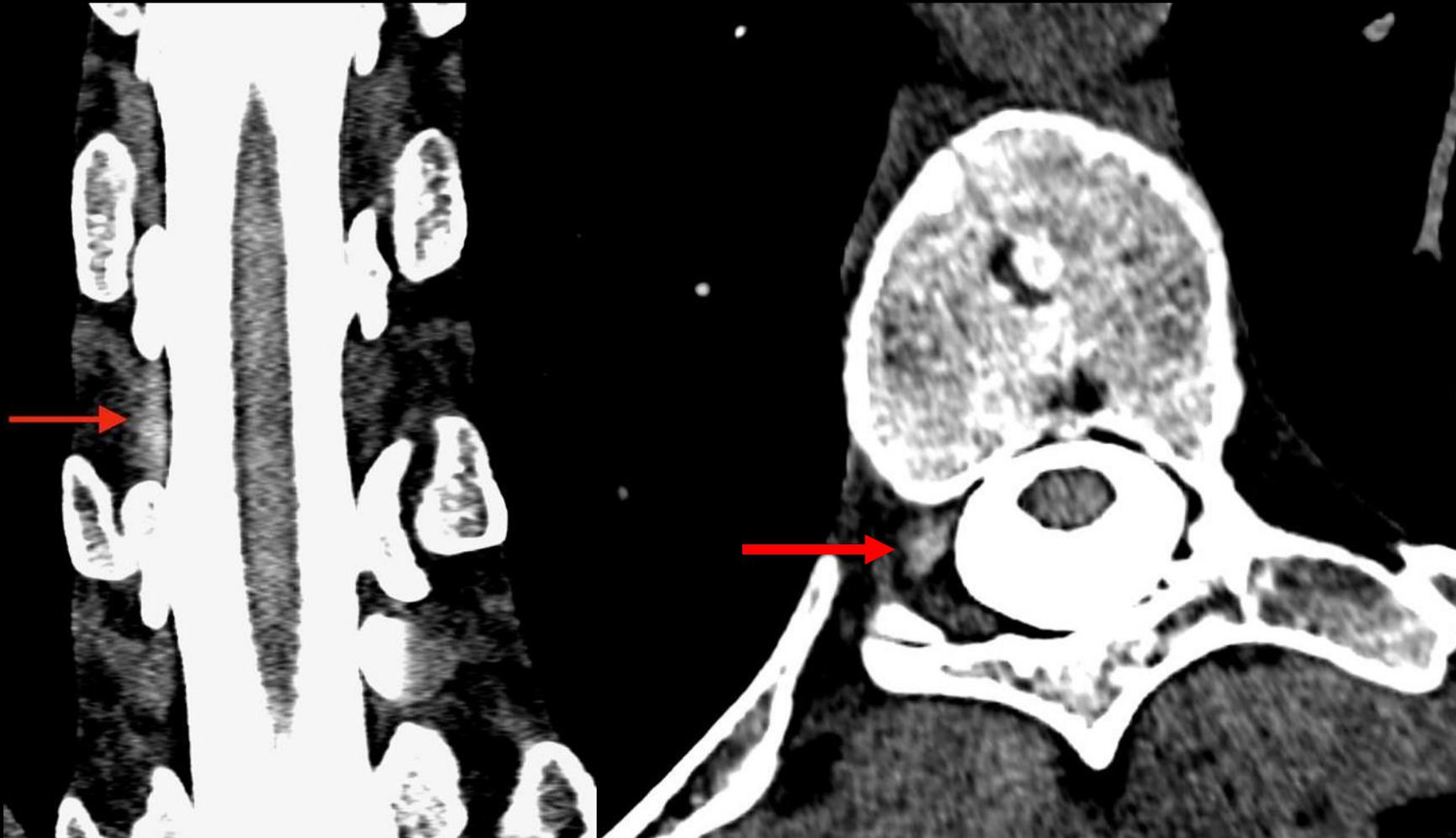
Can MRI help **RULE IN CVF?**



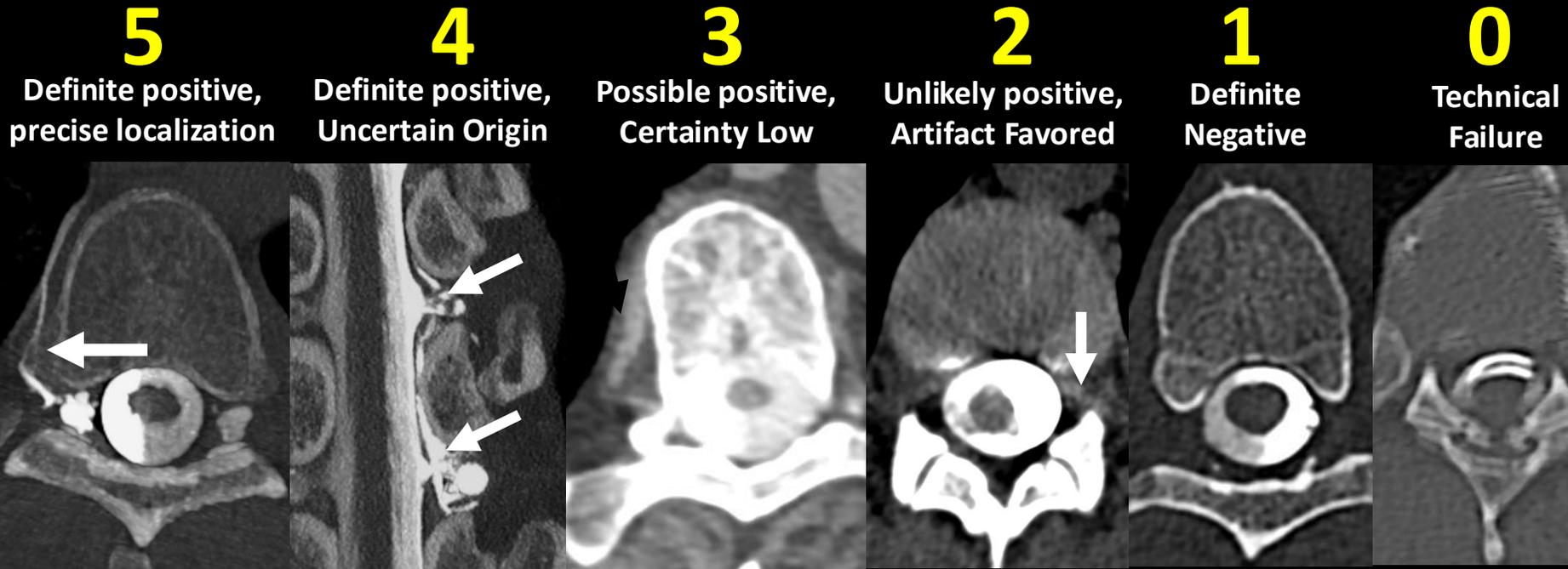
dCTM
(immediate phase)

Is this a CVF?

How should we communicate this?



SIH RADS :

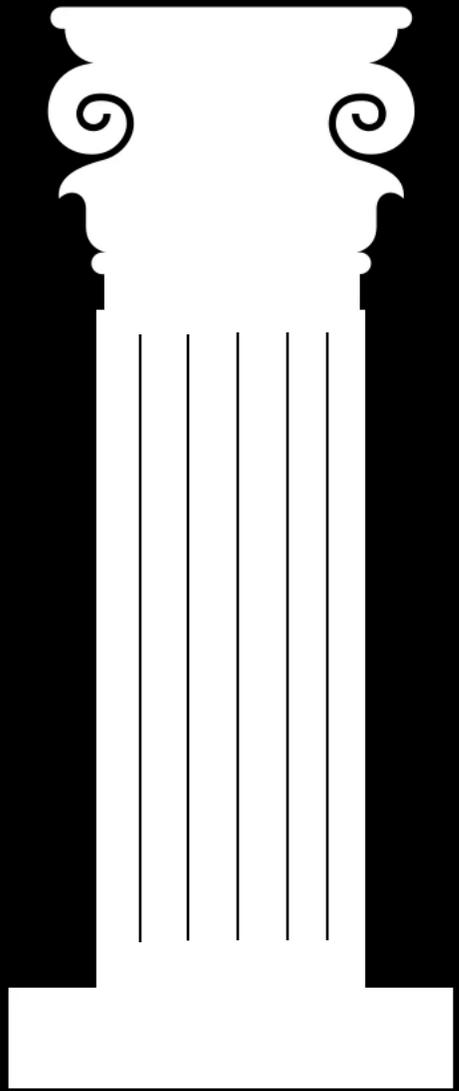


70% of patients incompletely understood their myelography report
46% of reports contained “uncertain, or possible but not definite” findings
77% of patients and 92% providers would prefer structured report

AJNR Enhancing Clarity in Dynamic Myelography Reporting:
Results of a Survey of Patients and Referring Providers
Evaluating a Standardized Reporting System in the
Myelographic Work-Up of Patients with Suspected
Spontaneous Intracranial Hypotension

© Andrew L. Callen, Samantha L. Pisani Petrucci, © Debayan Bhaumik, Peter Lennarson, © Marius Birlea, © Jennifer MacKenzie,
© Jodi Ettenberg, and © Lalani Carlton Jones

TECHNIQUE



1. Density
2. Positioning
3. Timing
4. Pressurization
5. Respiration
6. Scanner Technology

PRIORITY #1

AJNR

Density and Time Characteristics of CSF-venous fistulas on CT myelography in Patients with Spontaneous Intracranial Hypotension

Diogo G.L. Edelmuth, Timothy J. Amrhein and Peter G. Kranz

Lateral Decubitus: As Dense as Possible



Lateral Decubitus: Dense as Possible

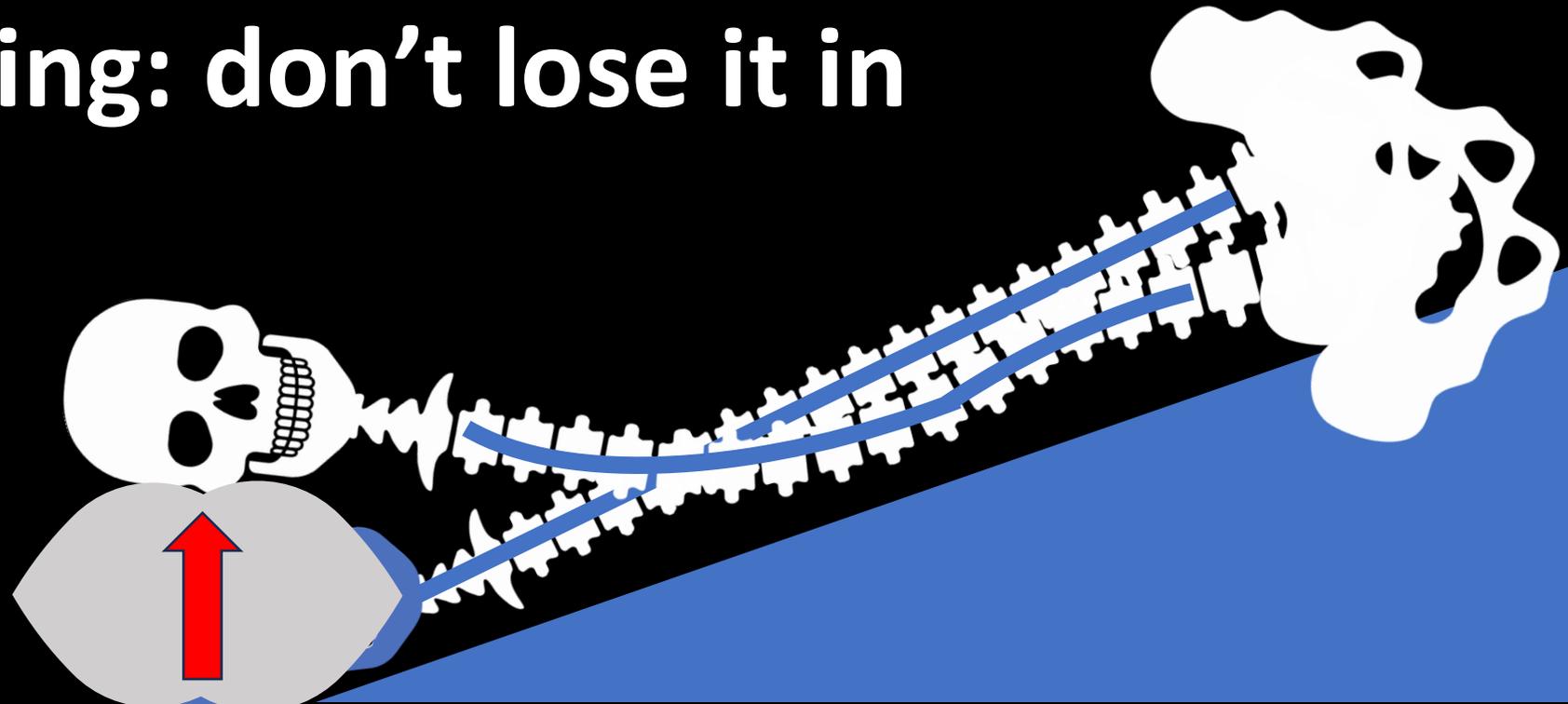
1. Contrast (M300): up to 20 mL total

AJNR

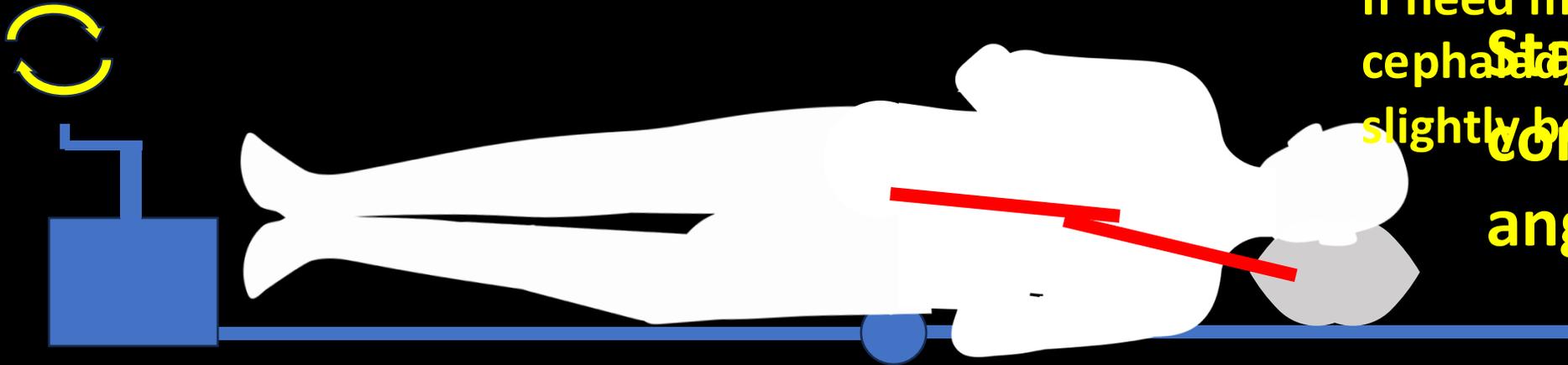
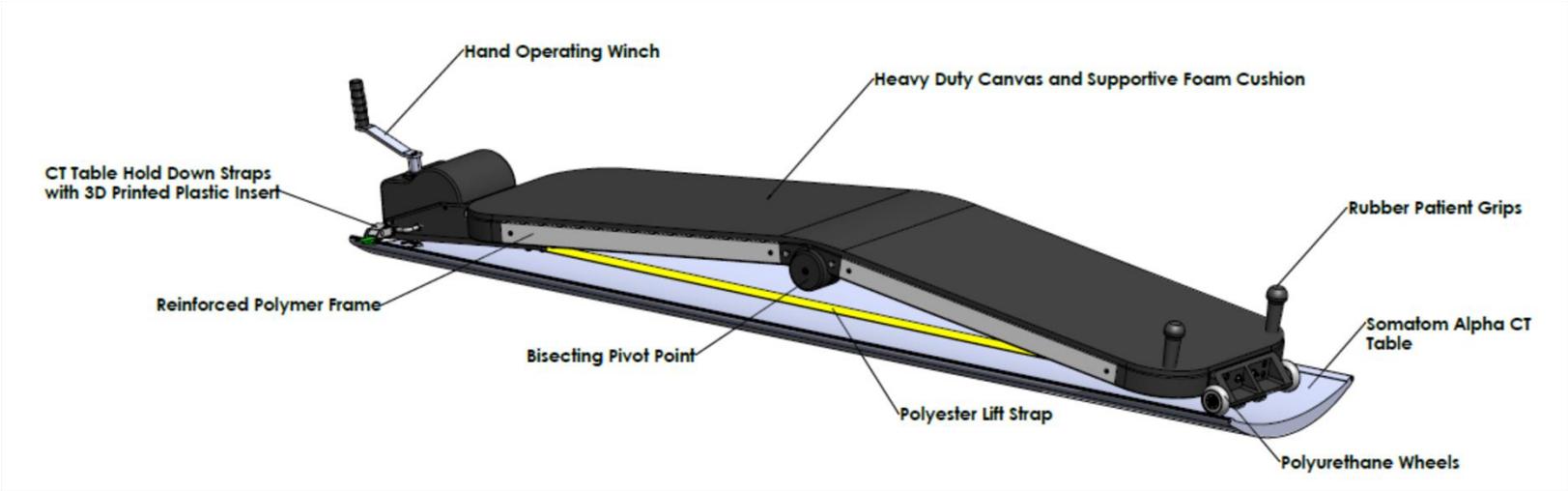
**Safety and Technical Performance of
Bilateral Decubitus CT Myelography Using
Standard versus Increased Intrathecal
Iodinated Contrast Volume**

Diogo G.L. Edelmuth, Renata V. Leão, Eduardo N.K. Filho,
Marcio N.P. Souza, Marcelo Calderaro and Peter G. Kranz

2. Positioning: don't lose it in
the head



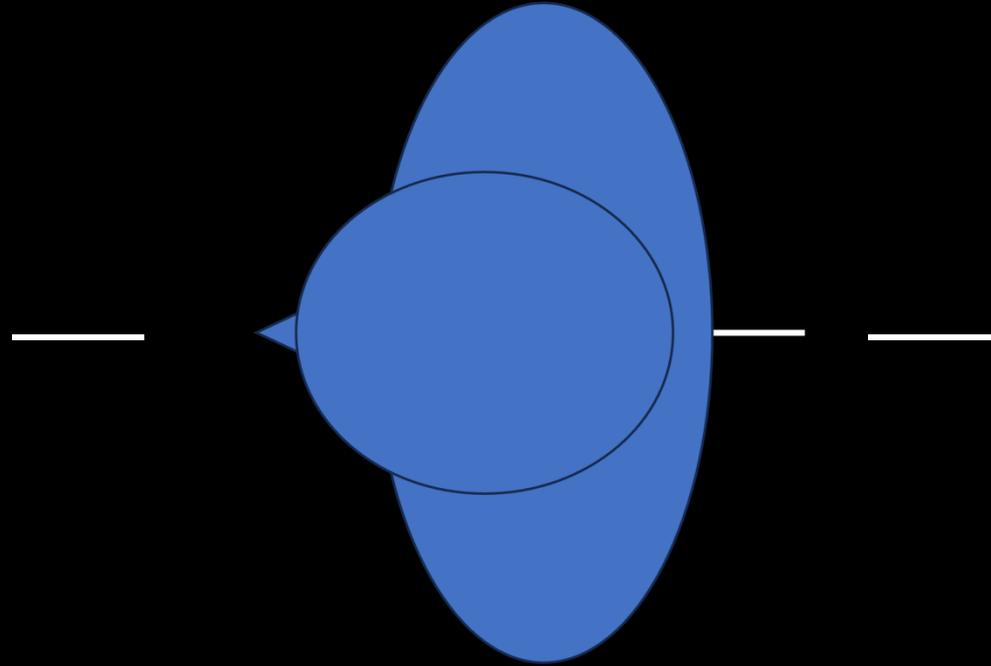
Control the Contrast



If need more contrast
Start with angle
slightly between scans
conservative
angulation



Studying the other side:



**Option 2:
Carlton Jones Spin**

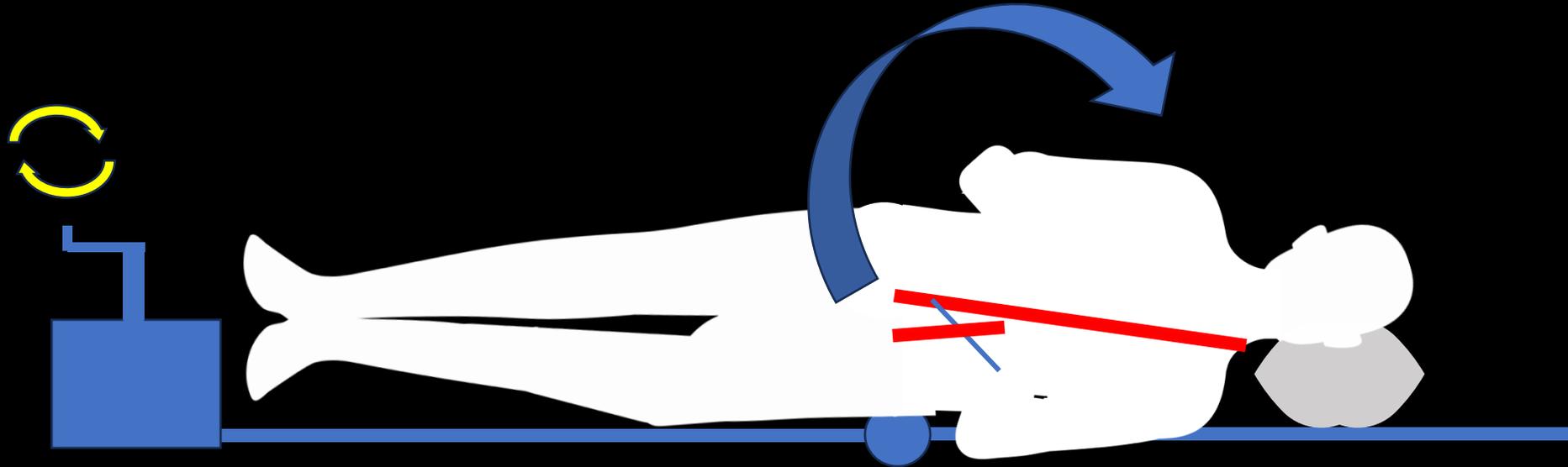
**Same-Day Bilateral Decubitus CT Myelography for Detecting
CSF-Venous Fistulas in Spontaneous Intracranial
Hypotension**



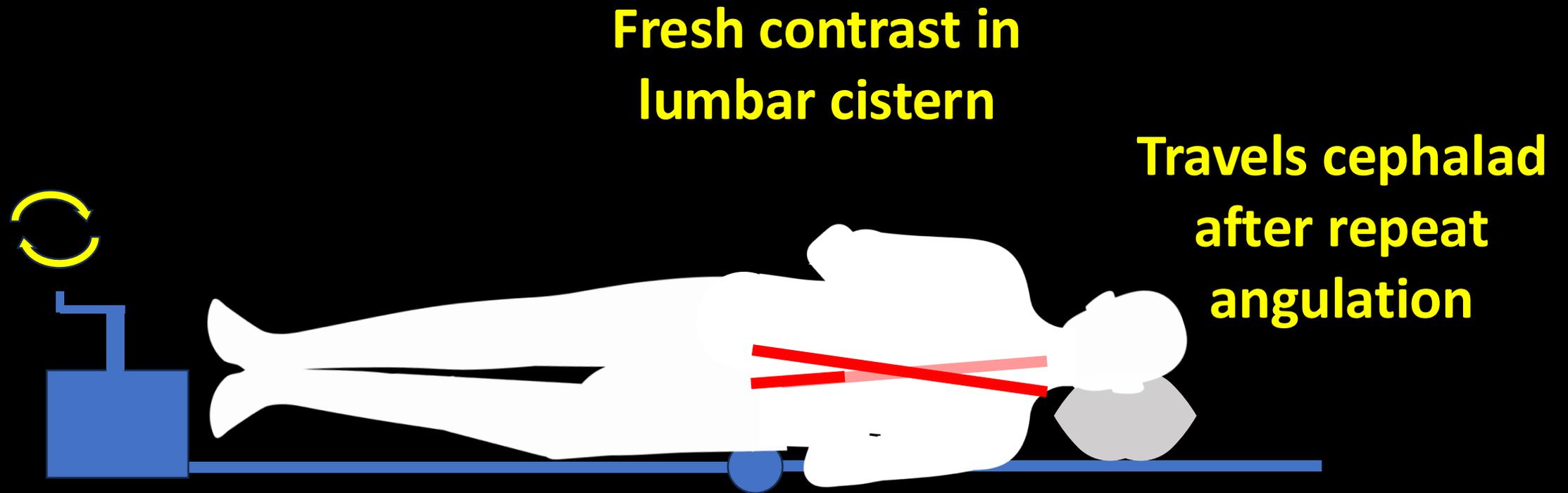
^{id} L. Carlton Jones and ^{id} P.J. Goadsby

How I Do it

Remove needle, rotate
Puncture while
into pleural space
horizontal/scan
coronary/scan
decurtatus



How I Do it



Additional Maneuvers:

Pressurization

Resisted Inspiration

Timing

Pressurization

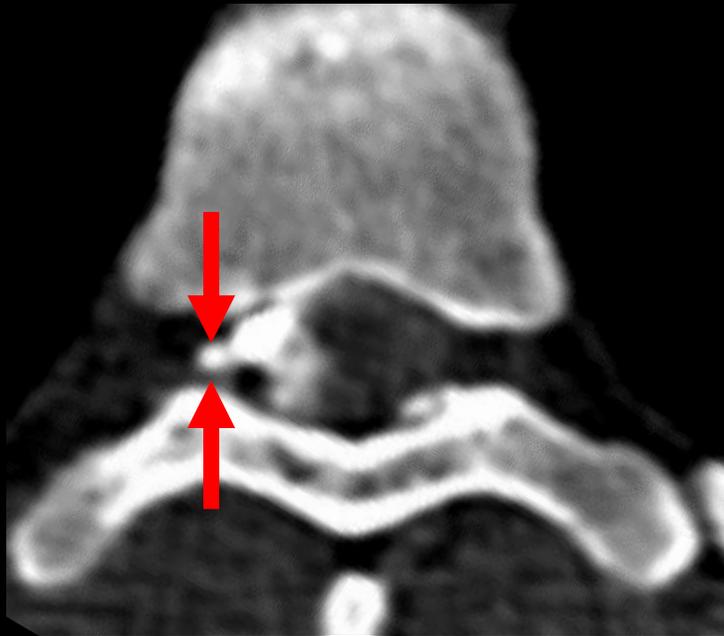
Nerve Root Distention/Penetration

AJNR

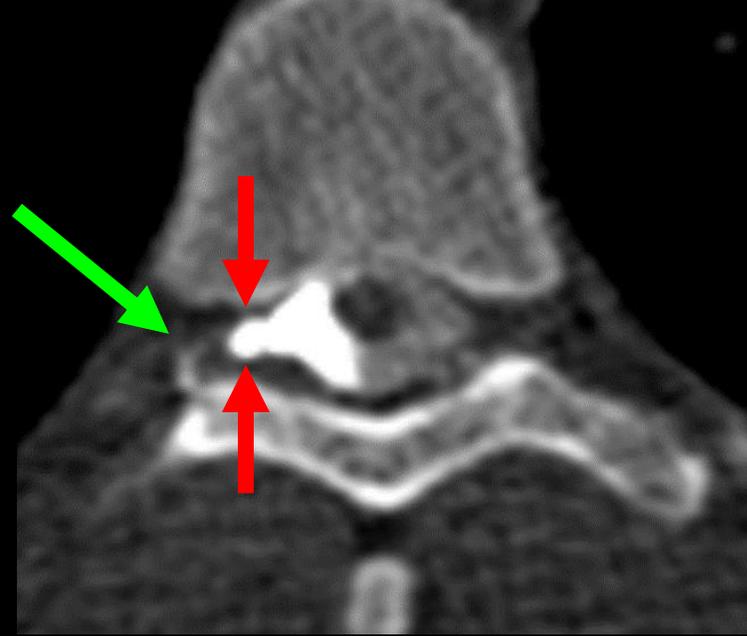
CLINICAL REPORT

**Improved Conspicuity of CSF-Venous Fistulas with Saline
Pressure Augmentation: A Multi-Institutional Case Series**

Ajay A. Madhavan, Lalani Carlton Jones, Michelle L. Kodet, Federico Cagnazzo, and Niklas Lutzen



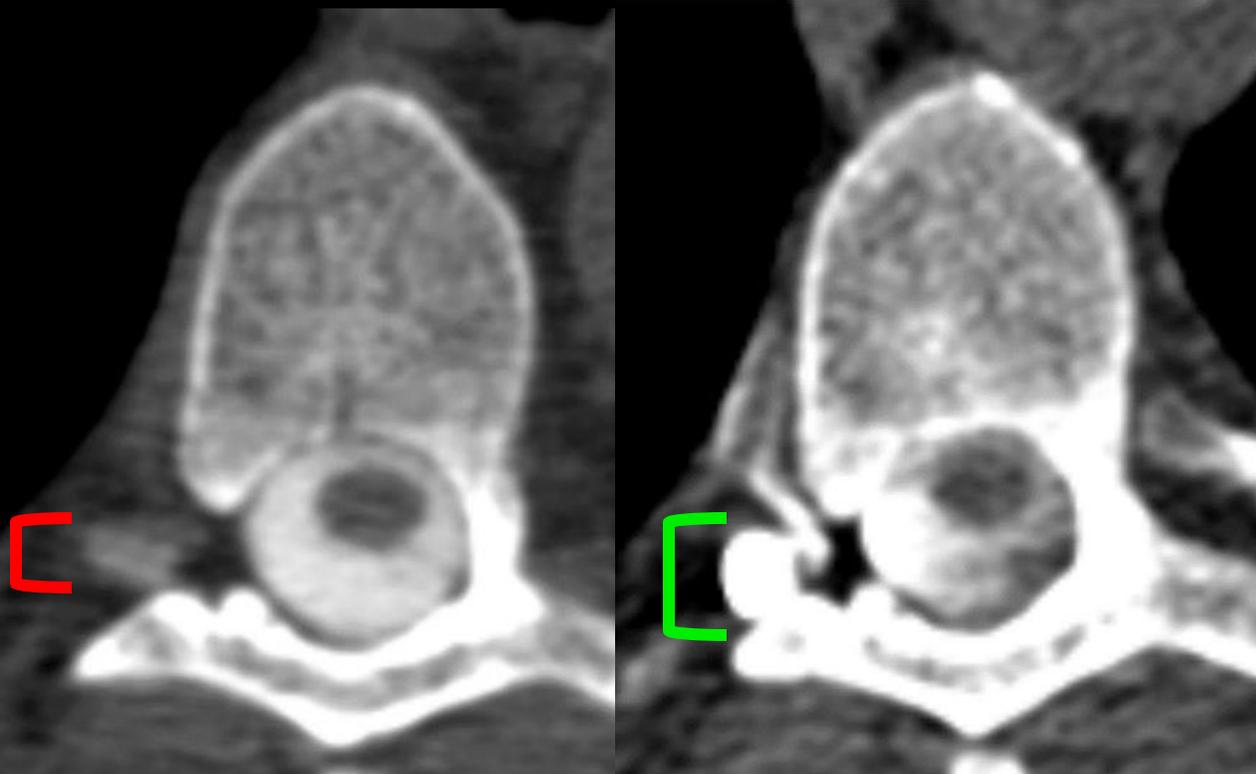
No Pressure
Augmentation



+ Pressure Augmentation to
23 cm H₂O



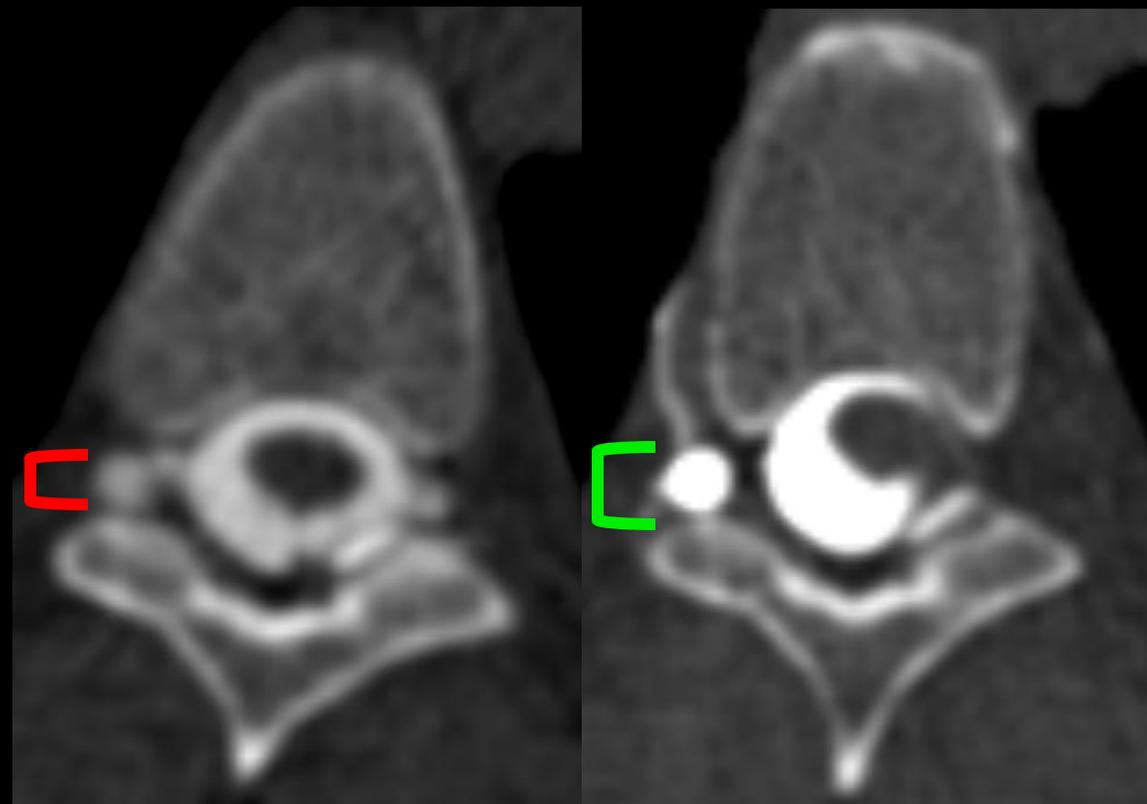
Patient 1



Supine
Conventional
CTM

Lateral
Decubitus
dCTM

Patient 2



Supine
Conventional
CTM

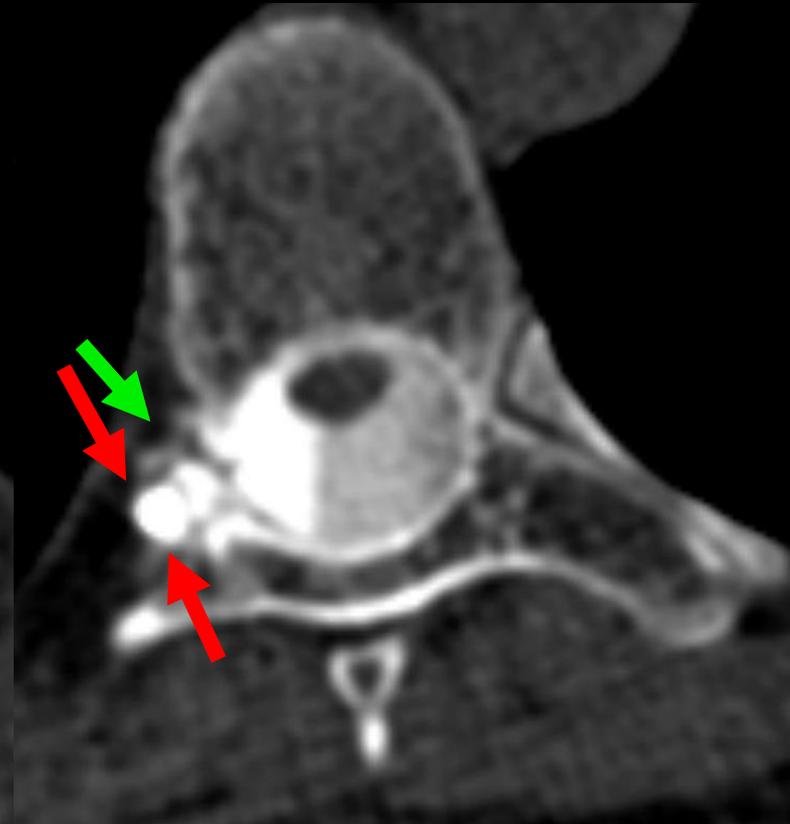
Lateral
Decubitus
dCTM

Resisted Inspiration

↓ P_{venous} and ↑ P_{CSF}



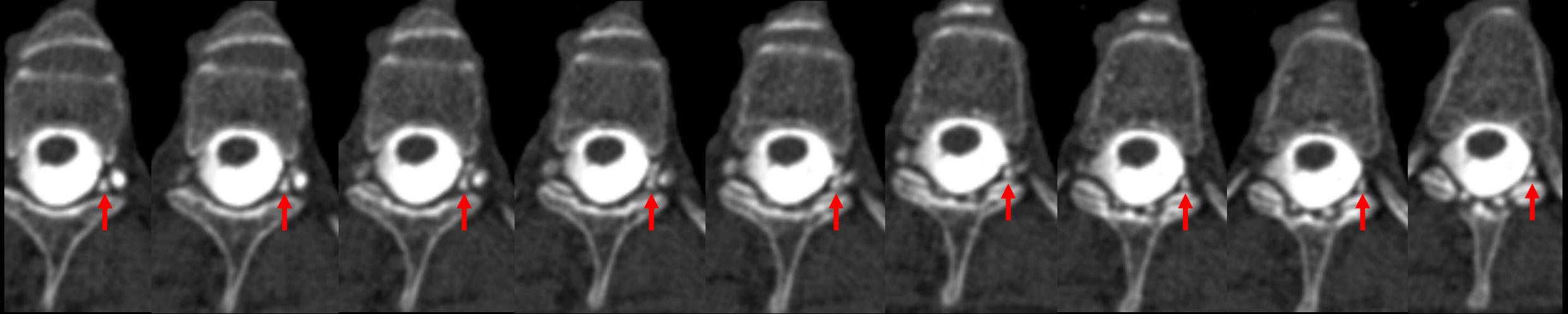
Without Resisted Inspiration



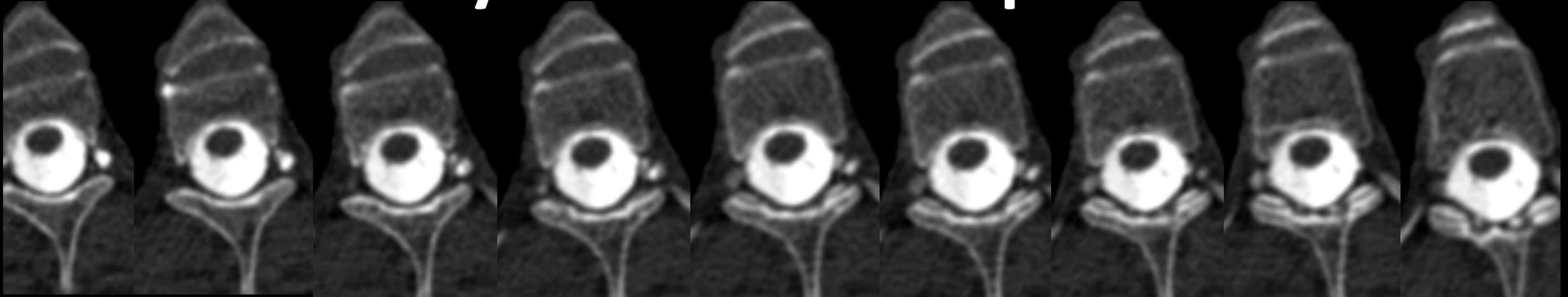
With Resisted Inspiration

Timing

Immediate Run: No Resisted Inspiration



4 minute delay: + Resisted Inspiration



**Left Decubitus:
Immediate**

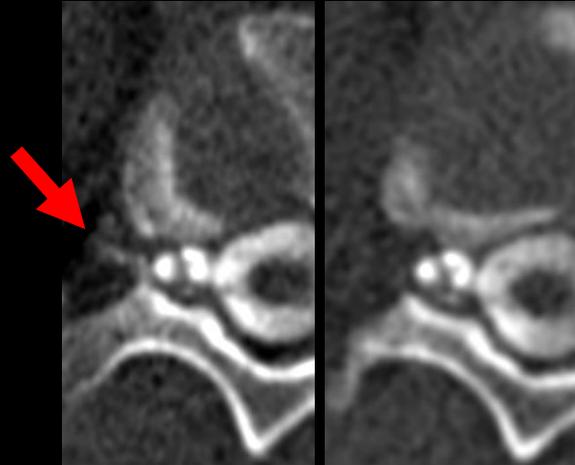


**Left Decubitus: 60 sec
delay, + inspiration**

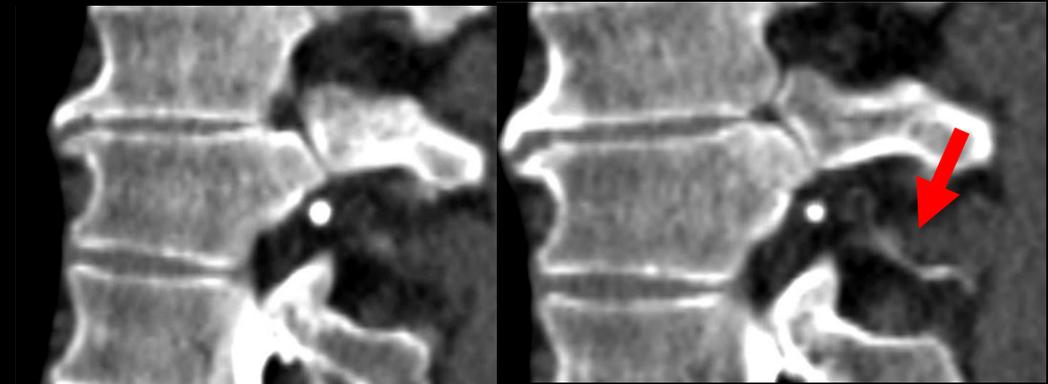


~1 in 8 seen only on early or delay, but not both

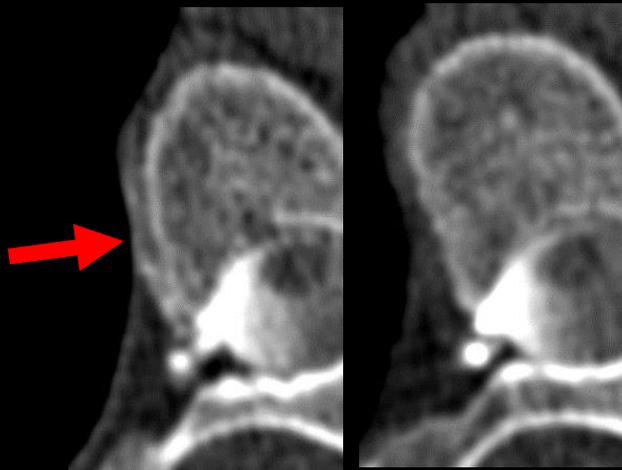
Early ← ~30 sec → Delay



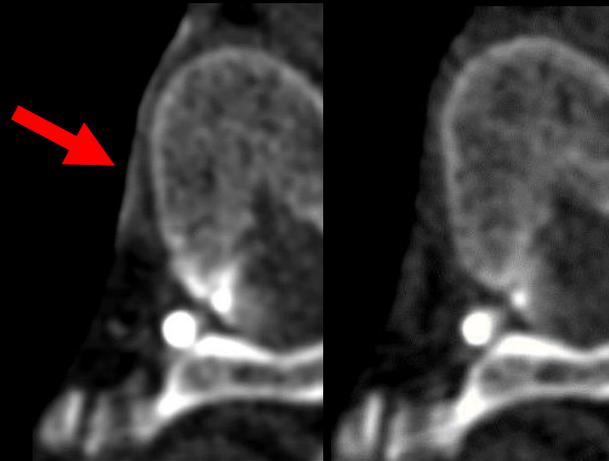
Early ← ~30 sec → Delay



Early ← ~30 sec → Delay



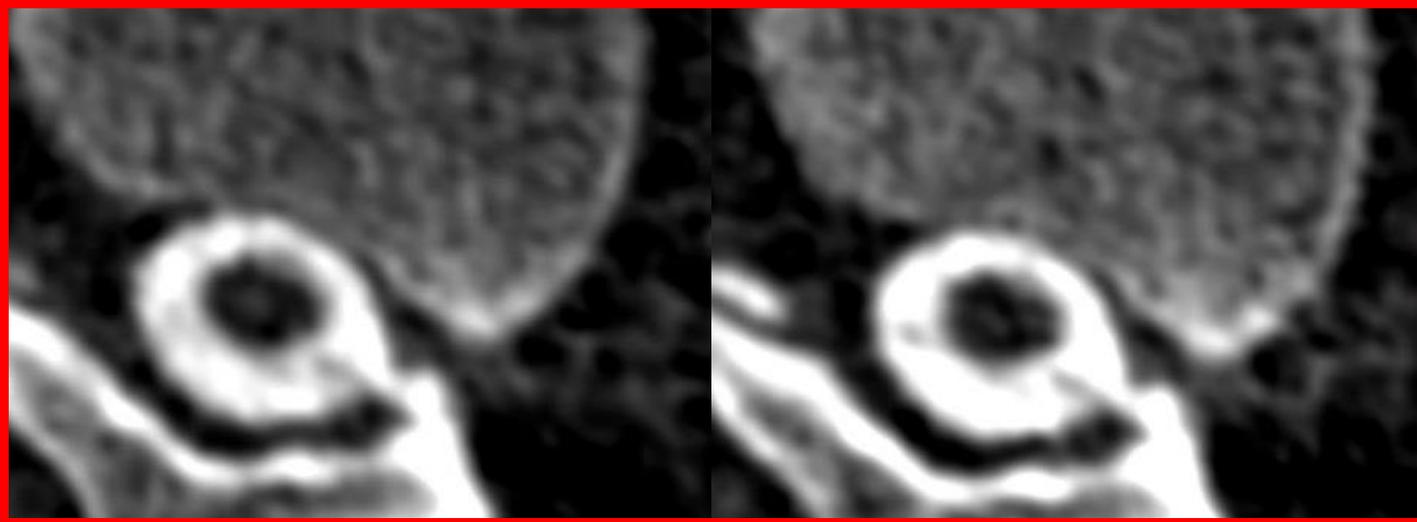
Early ← ~30 sec → Delay



Temporal Characteristics of CSF-Venous Fistulas on Dynamic Decubitus CT Myelography: A Retrospective Multi-Institution Cohort Study

© Andrew L. Callen, Mo Fakhri, © Vincent M. Timpone, © Ashesh A. Thaker, © William P. Dillon, and © Vinil N. Shah

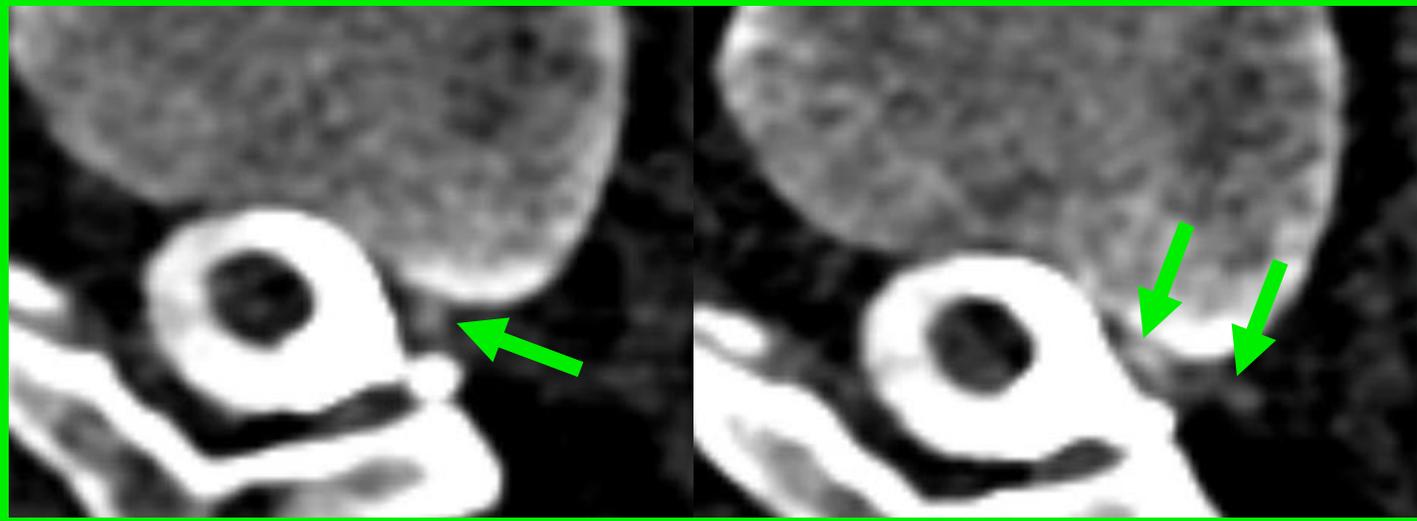
PCCT for Internal Plexus CVF



EID CT

Lower detail

Higher Noise

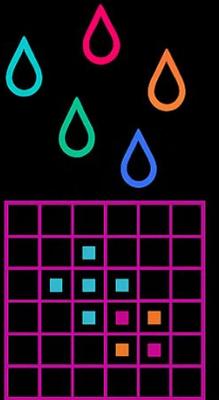


PCCT

Sharper detail

Better Contrast

Lower Dose



Photon Counting CT



EID CT: Sums Energy
Lower detail
Higher Noise



Detector Physics

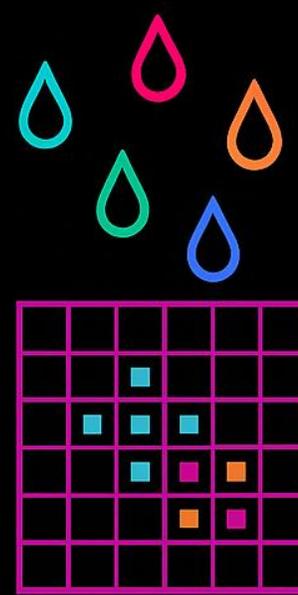
Semiconductor pixels log each photon/energy individually :
↓ noise, 0.2 mm voxels

Spectral Advantage

Multi energy data → ↑ contrast,
mono-energetic views, ↓ artifact

Clinical Payoff

↑ contrast/noise ratio
at equal/lower dose



PCCT: Counts Each Photon
Sharper detail
Better Contrast
Lower Dose

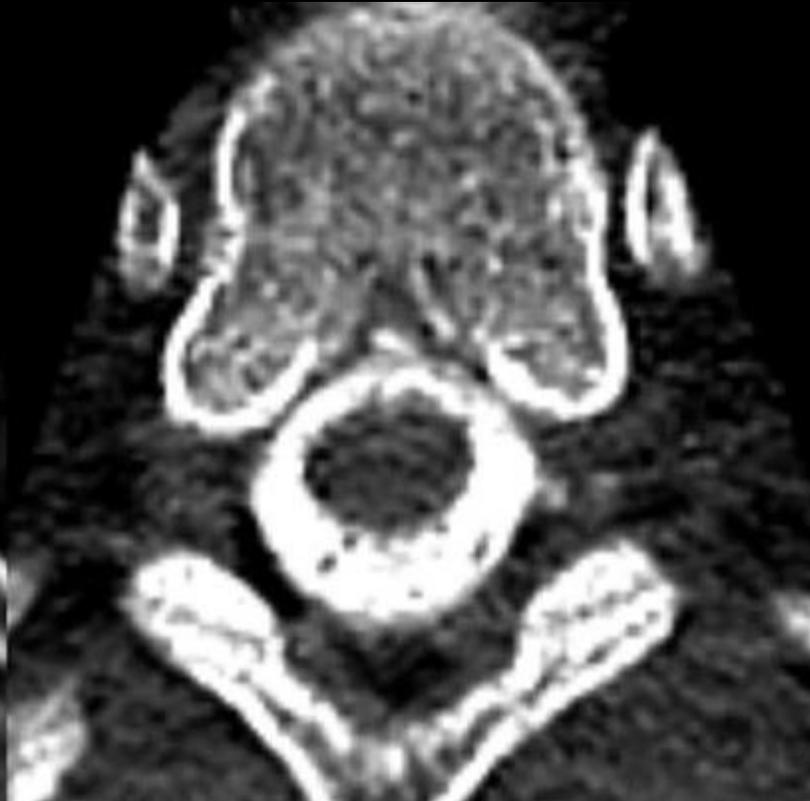


PCCT for Internal Plexus CVF

PCCT



EID CT

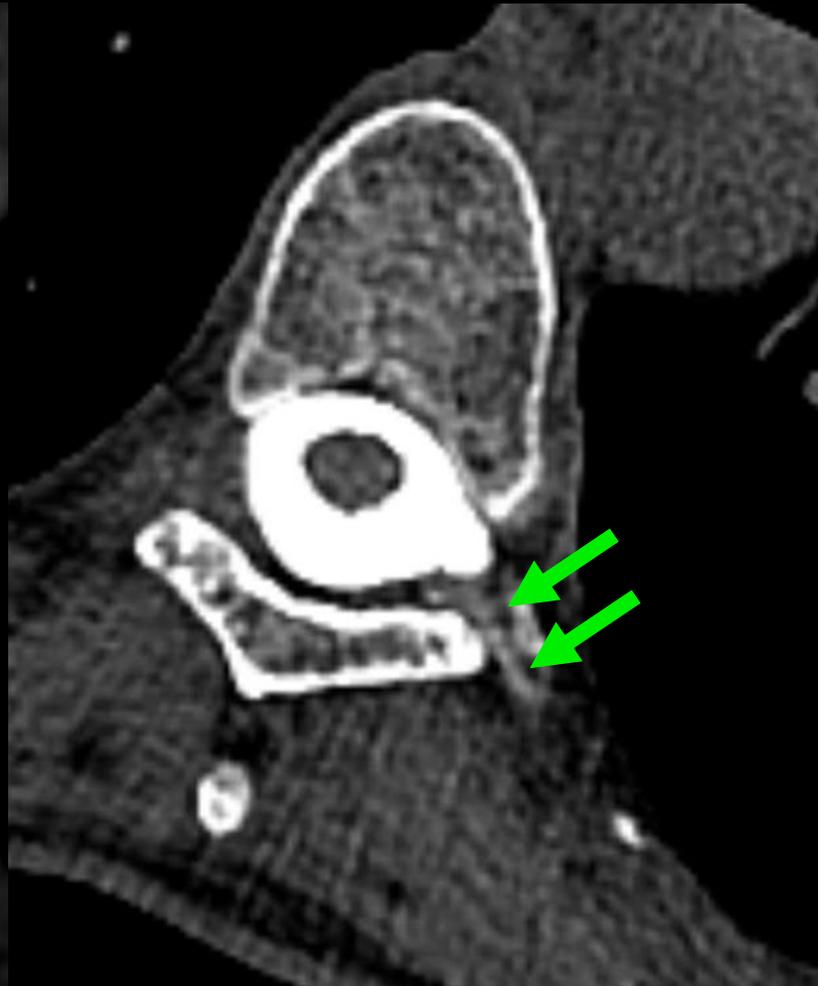


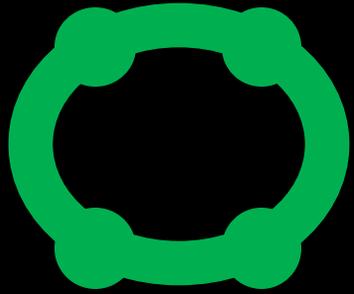
PCCT For Larger CVF

EID CT

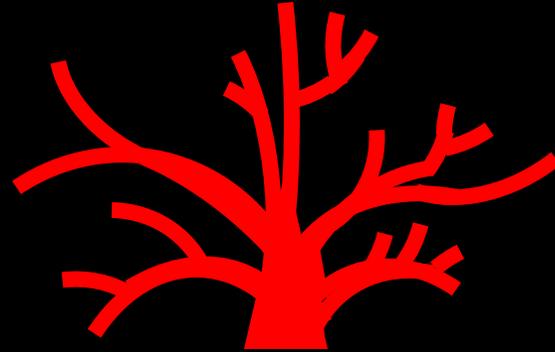


PCCT





Conclusions



- 1. We are still learning so much about CVFs. Stay tuned!**
- 2. CVFs are not just dense paraspinal veins:
spinal venous anatomy dictates search pattern.**
- 3. Myelography for CVFs =
interactive exam requiring real time troubleshooting.**

Thank You!

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