Pulsatile Tinnitus

UB NS
UNIVERSITY AT BUFFALO
NEUROSURGERY

Tinnitus
(Latin word ‘tinnire’ – ringing or tinkling)

- When we are talking about “tinnitus”, important to differentiate:

Subjective tinnitus – perceived auditory sensation

Objective tinnitus – sound detected at examination and/or auscultation

Also *pulsatility* – pulsatile (heartbeat) or non-pulsatile (constant noise)

Long list of differential diagnoses for Tinnitus!

Non-otologic differential diagnoses:

- Dural arteriovenous fistula
- Arteriovenous malformation
- Sigmoid sinus dehiscence and/or diverticulum
- Carotid-cavernous fistula
- Enlarged/dilated mastoid emissary vein
- Carotid stenosis
- Cerebral venous sinus thrombosis
- Transverse sinus stenosis
- Fibromuscular dysplasia
- Aberrant carotid artery/persistent stapedial artery

Table. Causes of Pulsatile Tinnitus: Groups[a]

Group	Cause	Diagnosis
Structural	Neoplasm	Paraganglioma
		Schwannoma
		Skull base meningioma
		Endolymphatic sac neoplasm
		Skull base vascular metastasis
	Temporal bone pathologic abnormality	Semicircular canal dehiscence
		Sigmoid plate dehiscence
		Otospongiosis
		Carotid canal dehiscence
Metabolic	Ototoxic medications	Aminoglycosides
		Cisplatin
	Vitamin toxic effects	Vitamin B6
	Myoclonus	Tensor tympani
		Stapedius
		Soft palate
	High cardiac output	Hyperthyroidism
		Anemia
		Valvular heart disease
Vascular	Venous	Idiopathic intracranial hypertension
		Dural venous sinus stenosis
		Jugular vein stenosis
		Dural venous sinus diverticulum
		Jugular bulb diverticulum
		High-riding jugular bulb
	Arterial	Dural arteriovenous fistula
		Carotid-cavernous fistula
		Arteriovenous malformation
		Aneurysm
		Dissection
		Fibromuscular dysplasia
		Carotid stenosis
		Aberrant arterial course
		Dolichoectasia

[a] Causes of pulsatile tinnitus organized into groups. This organization facilitates practical evaluation, referral, and treatment in patient-centered fashion rather than focusing on anatomic compartments.

Proposed algorithm for work up for Pulsatile Tinnitus

- Important differentiation – if pulsatile tinnitus attenuates with jugular compression
- Arterial vs Vascular etiology of tinnitus
- Venous: lower pitched “whooshing” sound alleviated by neck maneuvers

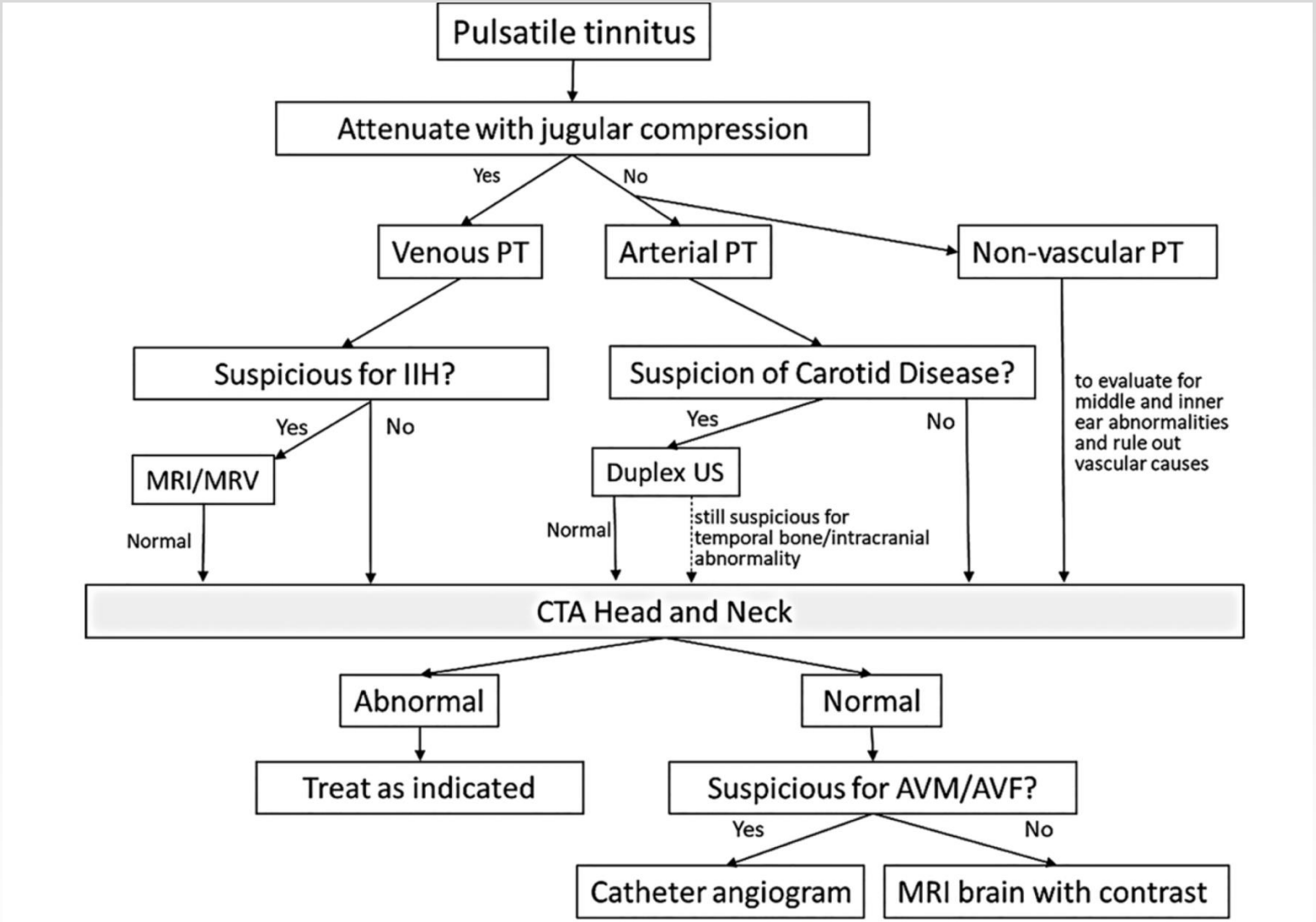

Figure 1: Diagnostic imaging algorithm for patients with unilateral pulsatile tinnitus (PT). AVM = arteriovenous malformation, AVF = arteriovenous fistula, CTA = CT angiography, IIH = idiopathic intracranial hypertension, MRA = magnetic resonance angiography, MRV = MR venography.

Why should patients undergo diagnostic cerebral angiogram or venogram for tinnitus?

And when?

Arterial etiology of pulsatile tinnitus

PLAGH
Chinese PLA General Hospital

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Journal of Otology

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Role of cerebral digital subtraction angiography in the evaluation of pulse synchronous tinnitus

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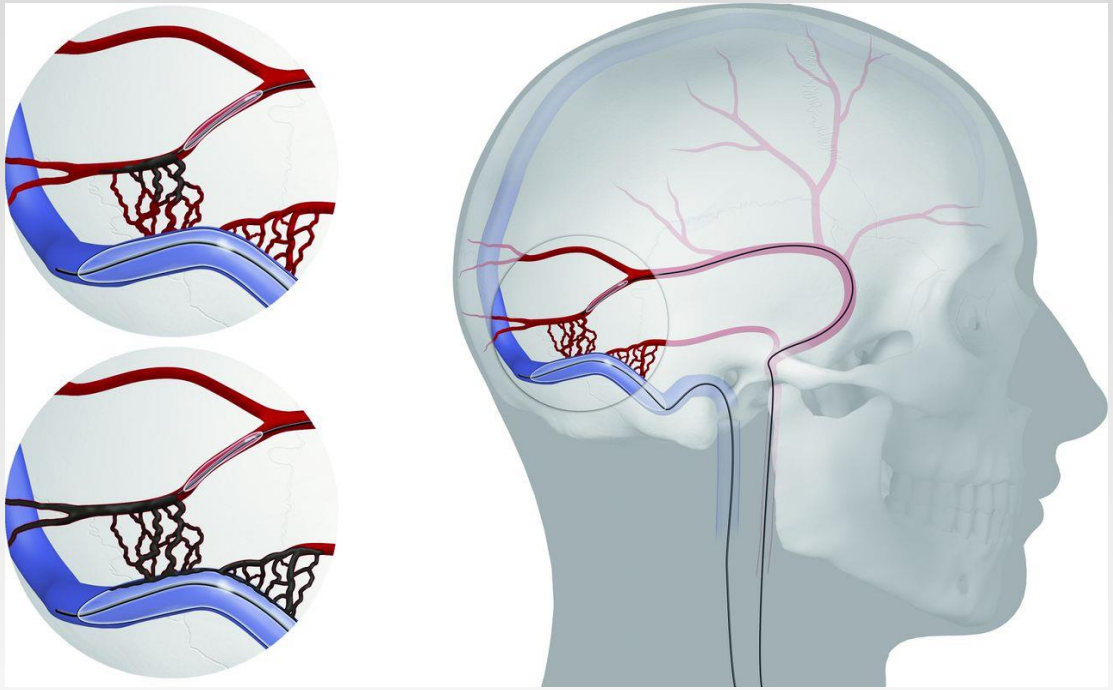
ABSTRACT

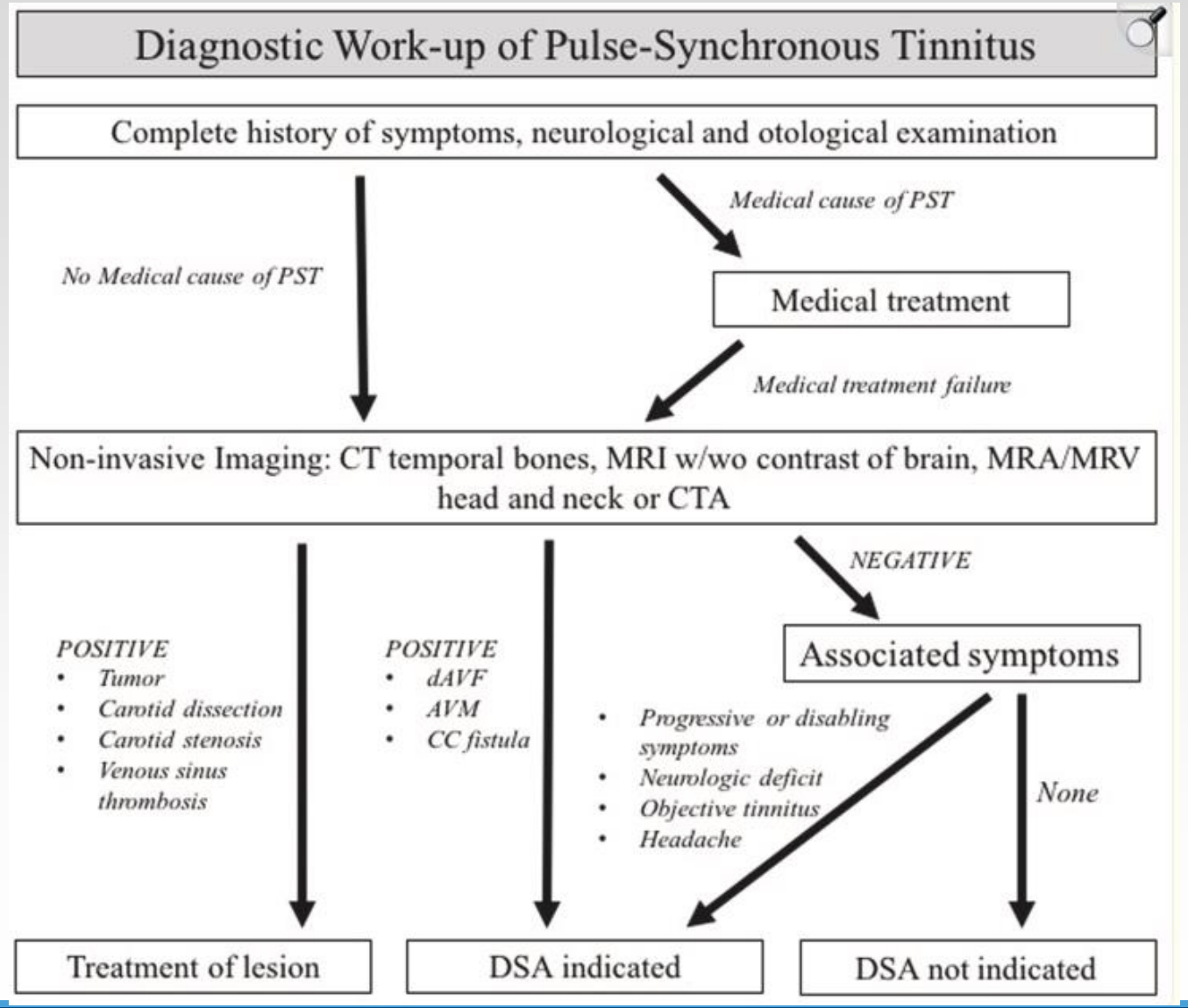
Objectives: The aim of this study was to evaluate the value of digital subtraction angiography (DSA) in the diagnostic evaluation of a highly selected patient population presenting with pulse-synchronous tinnitus (PST).
Methods: We retrospectively reviewed the charts of all patients referred for evaluation of possible vascular etiology of pulsatile tinnitus. Patients were evaluated with regards to presenting signs, comorbidities, non-invasive imaging results, angiographic findings and outcomes.
Results: Fifteen patients underwent cerebral DSA. Dural arteriovenous fistula (dAVF) was identified in six patients, and five patients had other significant vascular pathology identified on DSA. Seven patients with 'negative' non-invasive imaging were found to have significant pathology on DSA.
Conclusions: Catheter angiography may have a significant yield in appropriately selected patients presenting with pulse synchronous tinnitus.



Piechowiak et al. 2017

Dural arteriovenous fistula is high on the differential

Diagnostic algorithm prior to DSA

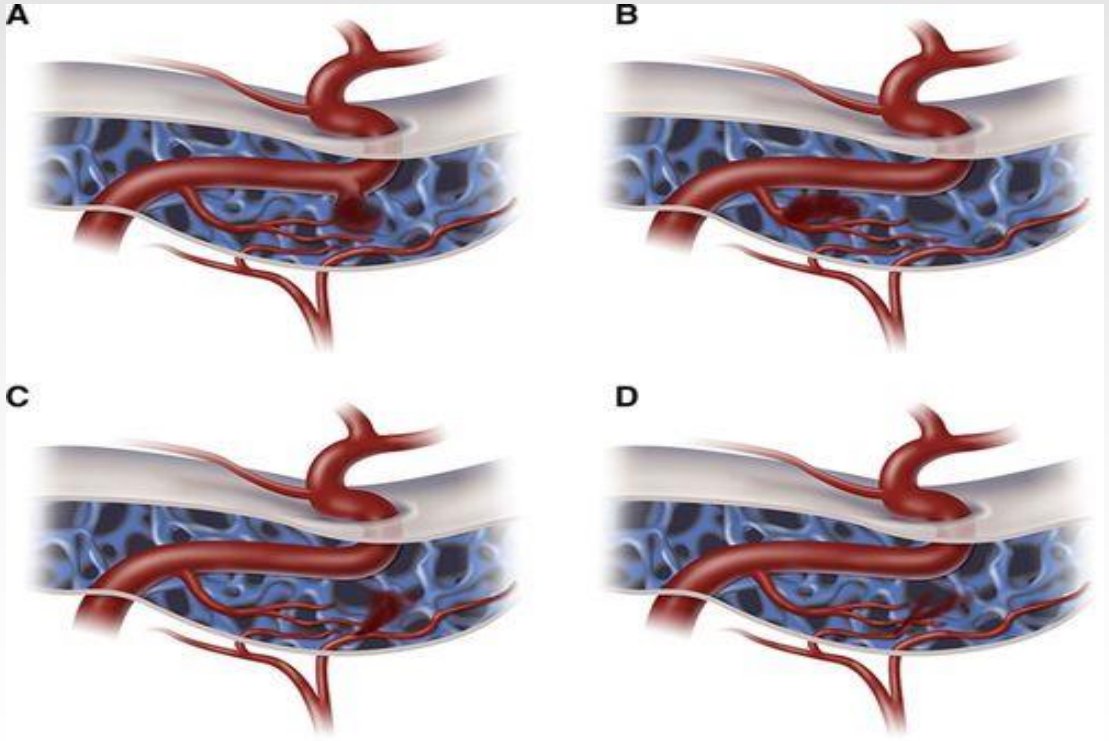


Dural arterio-venous fistula

Can account for up to 2-20% of pulsatile tinntius

Abnormal connections between dural arterial branches and venous sinuses/veins

May present with other symptoms: headache, diplopia, intraparenchymal hemorrhage

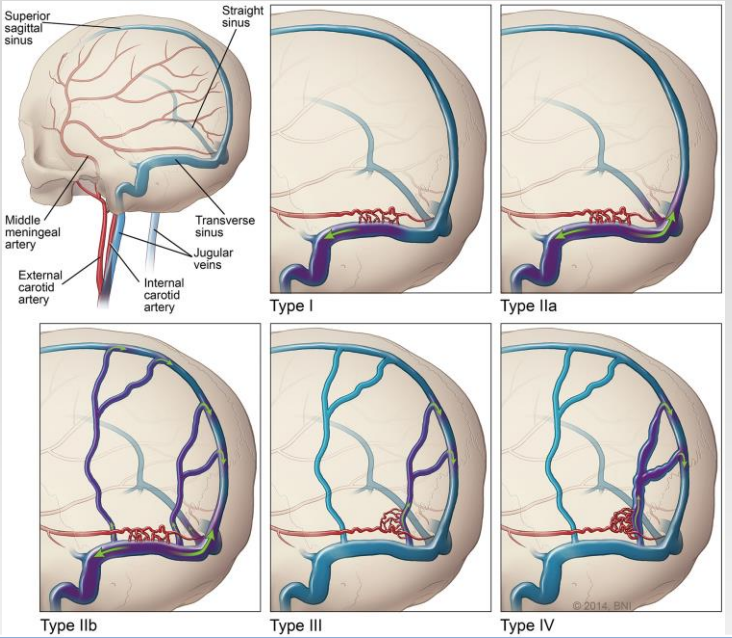


Reynolds 2017

Classification of arterio-venous fistula

Borden Classification

I. Venous drainage directly into dural venous sinus or meningeal vein
II. Venous drainage into dural venous sinus with CVR
III. Venous drainage directly into subarachnoid veins (CVR only)



Cognard Classification

I. Venous drainage into dural venous sinus with antegrade flow
IIa. Venous drainage into dural venous sinus with retrograde flow
IIb. Venous drainage into dural venous sinus with antegrade flow and CVR
IIa+b. Venous drainage into dural venous sinus with retrograde flow and CVR
III. Venous drainage directly into subarachnoid veins (CVR only)
IV. Type III with venous ectasias of the draining subarachnoid veins

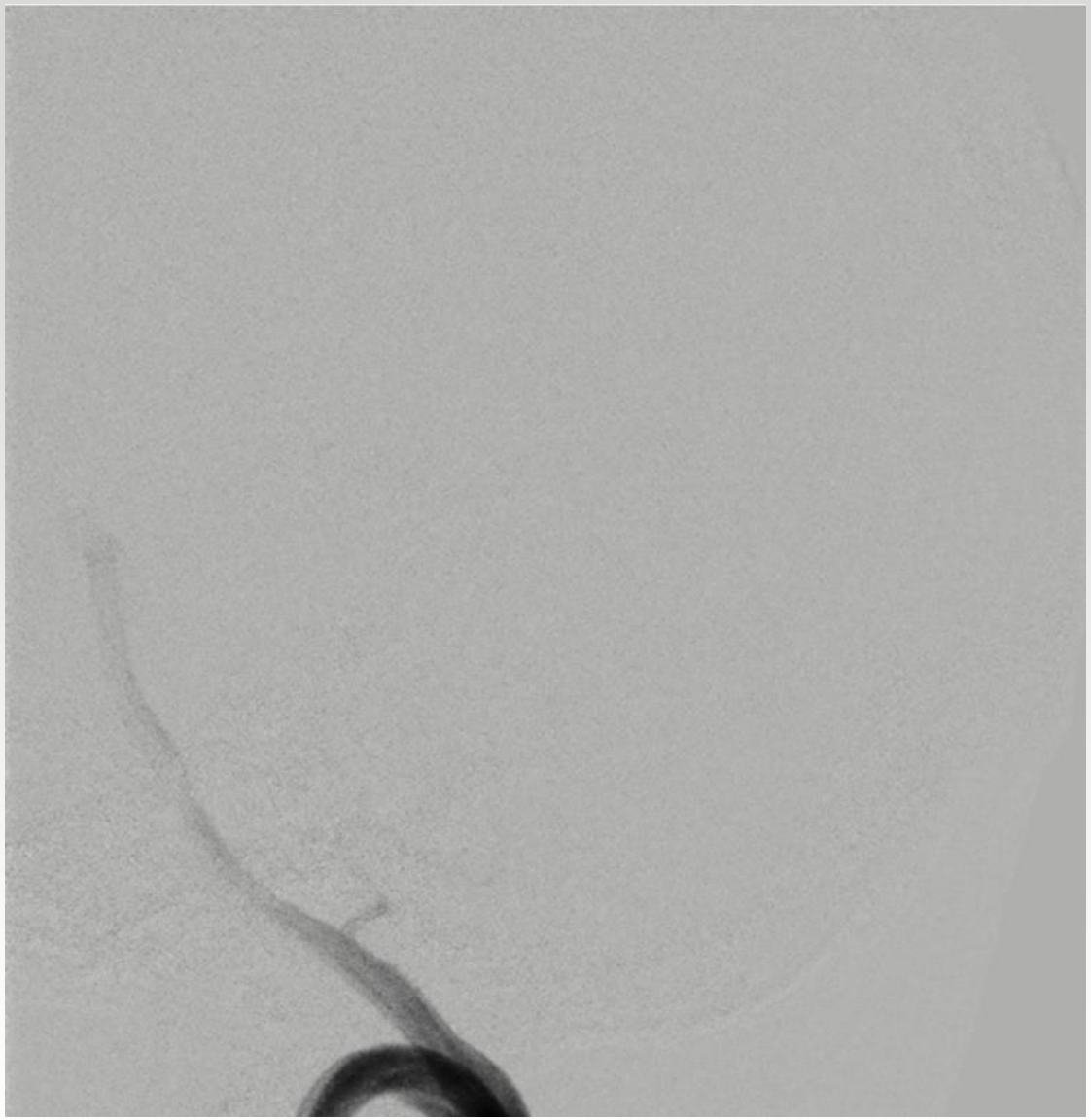
Case 1. Story

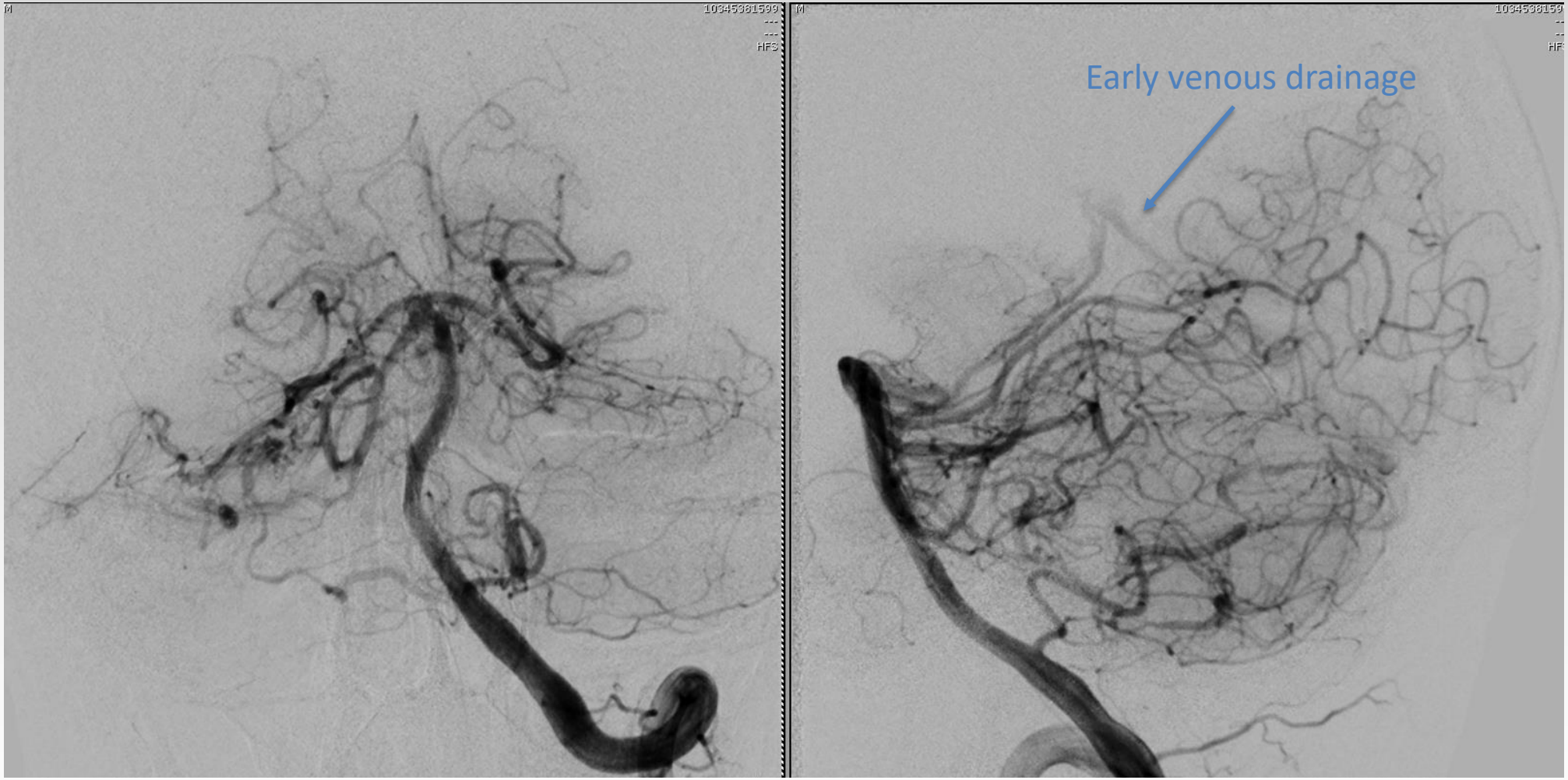
A man in his 60s presented to ENT clinic for progressive asymmetric hearing loss, fullness in his ears, and tinnitus

Audiogram done in clinic with sudden sensorineural hearing loss that resolved spontaneously.

MRI was suggested as next step in work up

MR/MRA did not find any masses or intracranial abnormalities but concerned about an anterior communicating artery aneurysm vs infundibulum.




Early venous drainage

Case 1 cont.

Did not find aneurysm – but did find early venous drainage likely fed by right PICA. Vessel calibers and target small to embolize.

Patient was referred for gamma radiation for the fistula and tinnitus improved.

Important learning point from case:

- Dural AVF is a common arterial cause for tinnitus
- MRI did not find abnormality, but confirmed with diagnostic cerebral angiogram.

DSA remains the gold standard for evaluation if non-invasive imaging work up is negative

Not just arterial etiology...pulsatile tinnitus can be from venous etiology

Pathophysiology: turbulence within normal veins/sinuses, or abnormally enlarged/located veins in close proximity to conductive auditory pathway

Turbulence transmitted to the cochlea through skull base and mastoids, resulting in auditory pulsations.

Increasing awareness of venous stenosis as a common cause for pulsatile tinnitus

Stroke: Vascular and Interventional Neurology
Volume 2, Issue 4, July 2022
https://doi.org/10.1161/SVIN.121.000154

American Heart Association.

ORIGINAL RESEARCH

Emergence of Venous Stenosis as the Dominant Cause of Pulsatile Tinnitus

Eytan Raz, MD, PhD, Erez Nossek, MD, Daniel Jethanamest, MD, Vinayak Narayan, MD, Aryan Ali, MD, Vera Sharashidze, MD, Tibor Becske, MD, Peter K. Nelson, MD, and Maksim Shapiro, MD

Table 2 Final Diagnoses (Table view)

	All		Women	
Diagnosis	n	%	n	%
Sinus stenosis	75	34	69	43
Unclear	61	28	43	27
Dural fistula	19	9	11	7
Mixed pulsatile/nonpulsatile	18	8	6	4
Carotid loop	9	4	5	3
Carotid dissection	8	4	7	4
Periodic nonpulsatile tinnitus	5	2	3	2
Carotid pulsations	4	2	4	3
Vertebral fistula	2	1	1	1
Superior semicircular canal dehiscence	2	1	0	0
Presumed venous, no anatomic issue	3	1	3	2
Meniere disease	2	1	0	0
Jugular stenosis	2	1	2	1
Hyperdynamic state	2	1	2	1
Trauma/Fracture	1	0	0	0
Sinus thrombosis	1	0	1	1
Sinus diverticulum	1	0	1	1
Otosclerosis	1	0	0	0
High-riding jugular bulb	1	0	0	0
Carotid stenosis	1	0	1	1

Over 90% of patients with venous stenosis are women. In other groups, sex seems to play no significant role or the overall number is too small to adjudicate.

Exam findings in venous sinus stenosis

Neck/ jugular venous compression is a reliable bedside examination with positive and negative predictive value

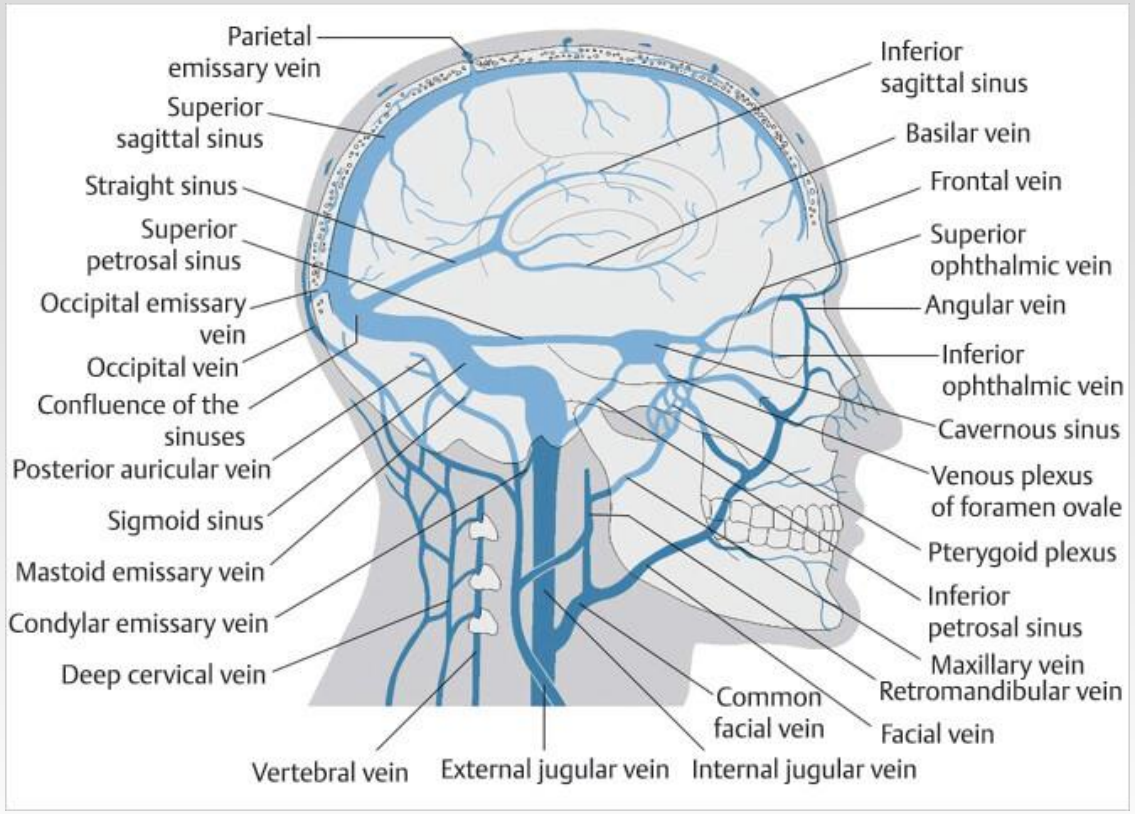
TABLE 3 Ipsilateral Jugular Compression Effects in Patients with Venous Sinus Stenosis as Cause of Pulsatile Tinnitus

Sinus stenosis	n	%
Neck compression completely stops sound	57	76
Neck compression reduces sound intensity	10	13
Unclear	2	3
Sound too intermittent to establish neck compression efficacy	2	3
No change	4	5
Total	75	100

TABLE 4 Quantification of Jugular Compression Effect in Patients With Final Diagnosis of VSS as Cause of PT

VSS	Jugular compression completely stops sound	Jugular compression completely stops or significantly diminishes sound
Sensitivity	76	89
Specificity	95	90
Positive predictive value	89	83
Negative predictive value	88	94

Venous anatomy – Cerebral venous sinuses



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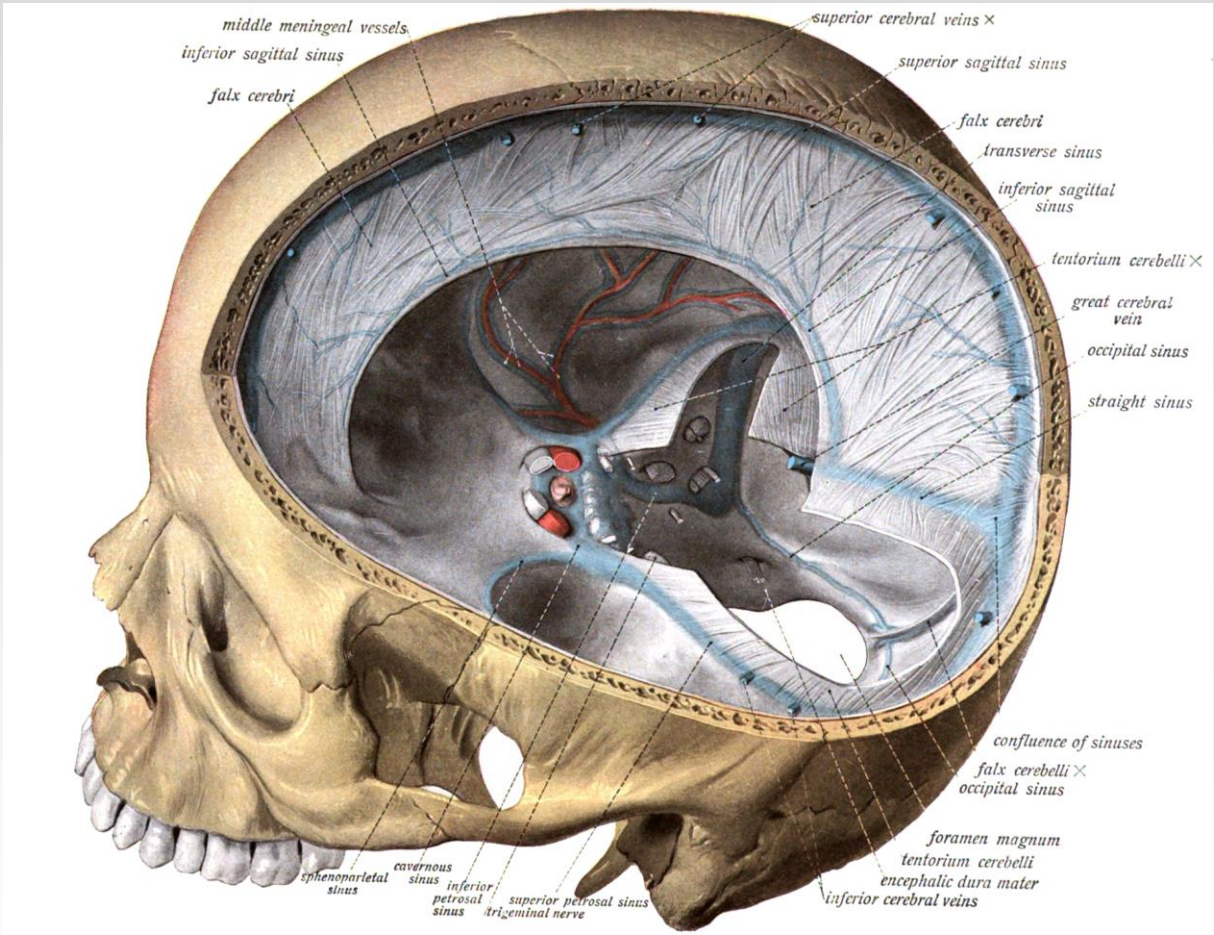
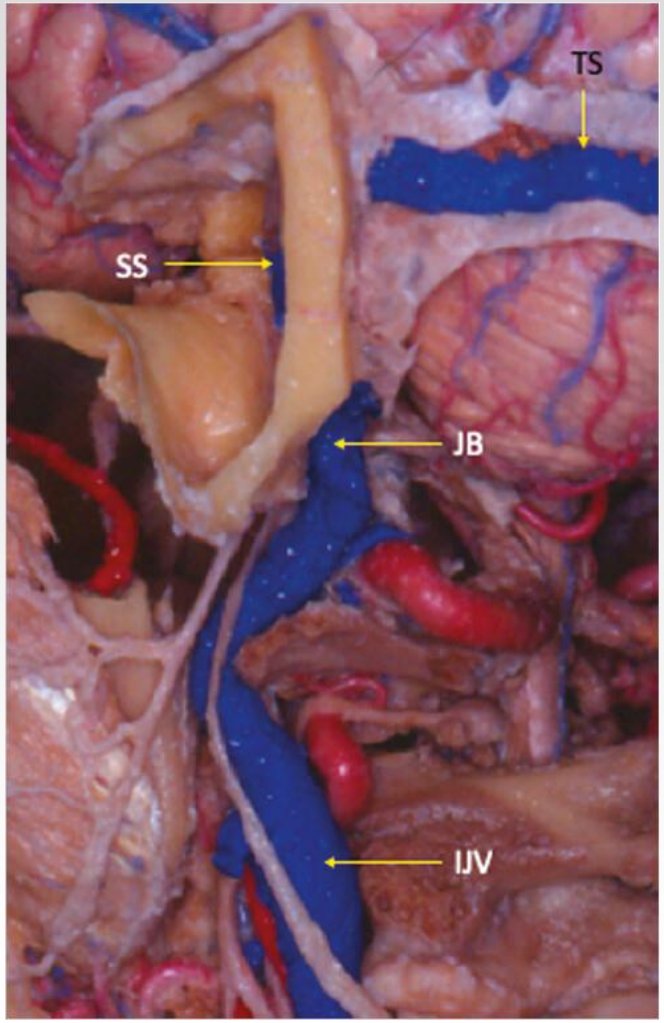
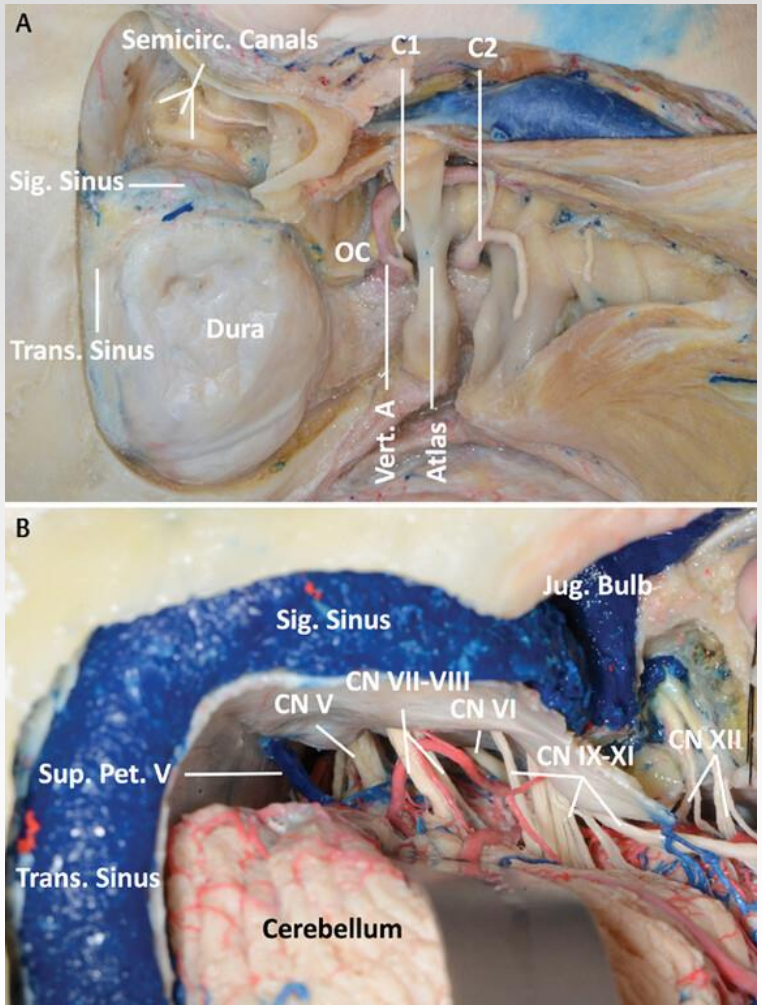
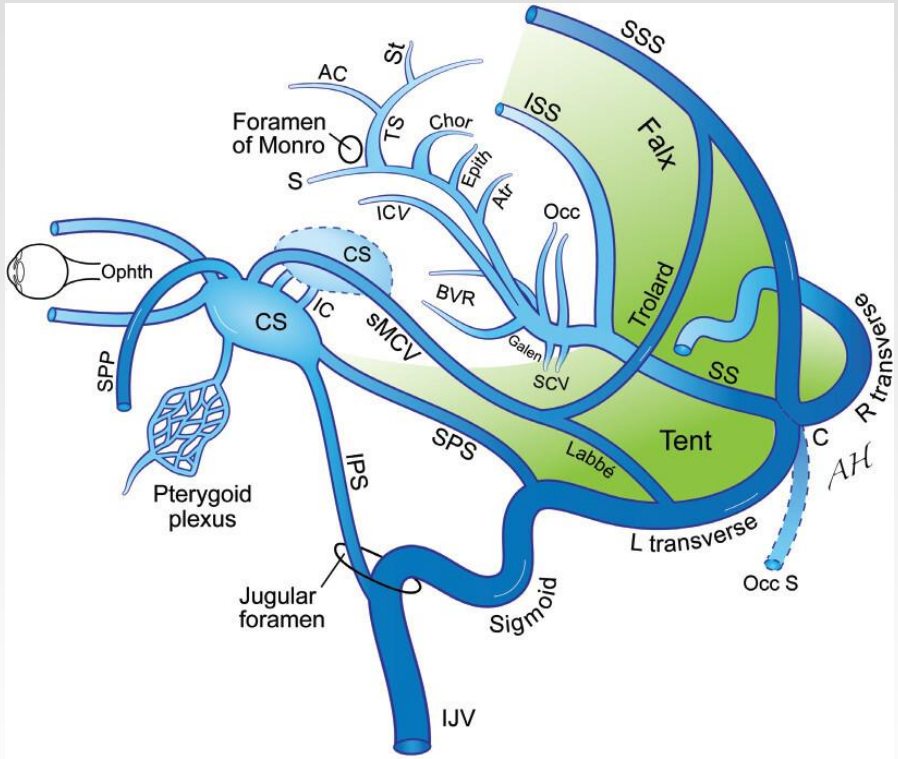


Dural venous sinuses – blood channels that drains venous blood from cranial cavity between endosteal and meningeal layers of dura mater

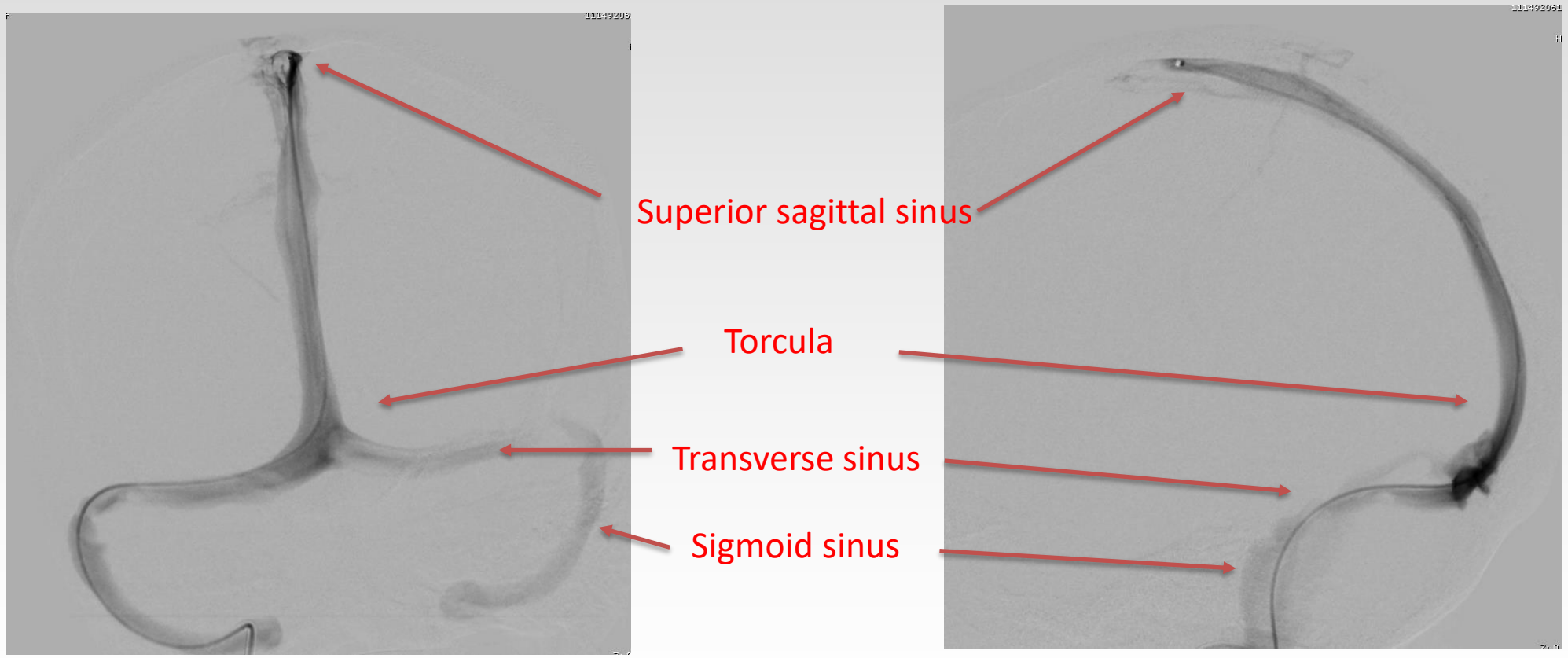
Transverse/Sigmoid Sinus







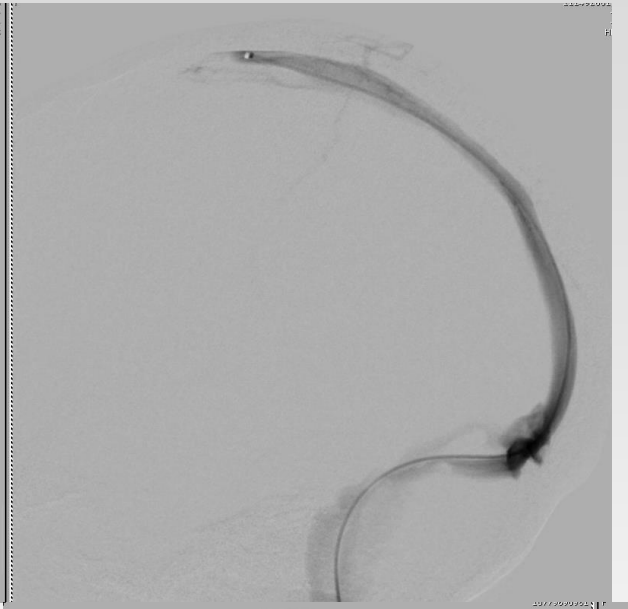
Angiographic anatomy for venous sinus

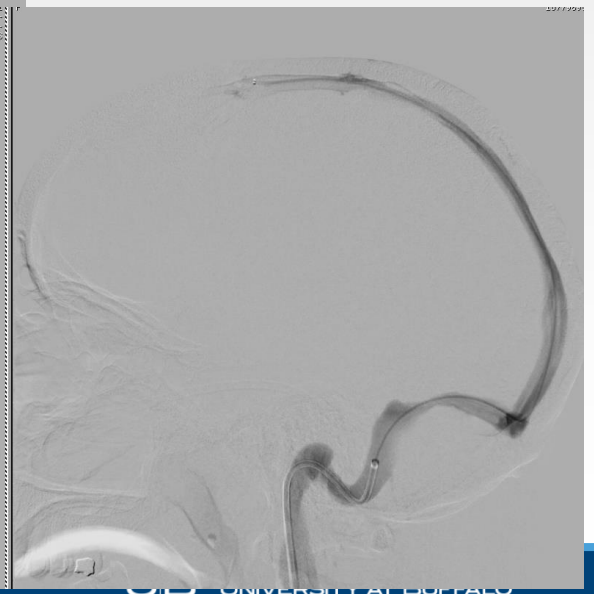


AP venogram

Lateral venogram

Anatomical variances : Venous system can be dominant on the right side, left side, or co-dominant.





Angiographic Anatomy

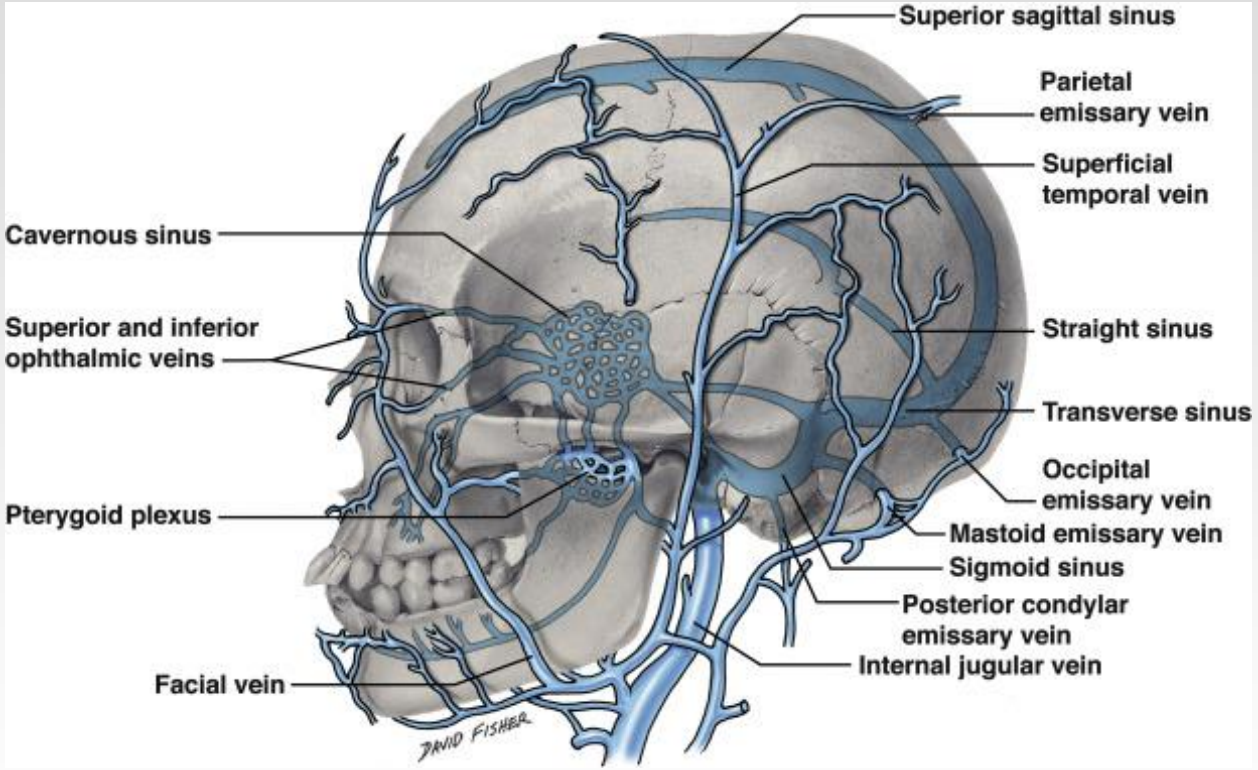
Aberrant sinus – Falcine sinus

Diagnostic cerebral venogram is important in evaluating underlying anatomy!

Comprehensive Management of Skull Base Tumor
Journal of Neurological Surgery Part B Skull base 06/2021 (Guanfu et al. 2021

Categorization of venous etiology of pulsatile tinnitus by anatomical location

1. Lateral sinus (sigmoid/transverse)
    1. Transverse sinus stenosis
    2. Sigmoid sinus plate dehiscence
    3. Sigmoid sinus diverticulum
2. Emissary vein
3. Jugular vein or bulb



Anatomy, Imaging and Surgery of the Intracranial Dural Venous Sinuses

Transverse sinus stenosis

Computational modeling of venous sinuses show increased blood flow and wall shear stress in patients with transverse sinus stenosis and increased intracranial hypertension

May result in tinnitus affecting CSF reabsorption – alteration in normal CSF homeostasis between intracranial and labyrinthine fluids

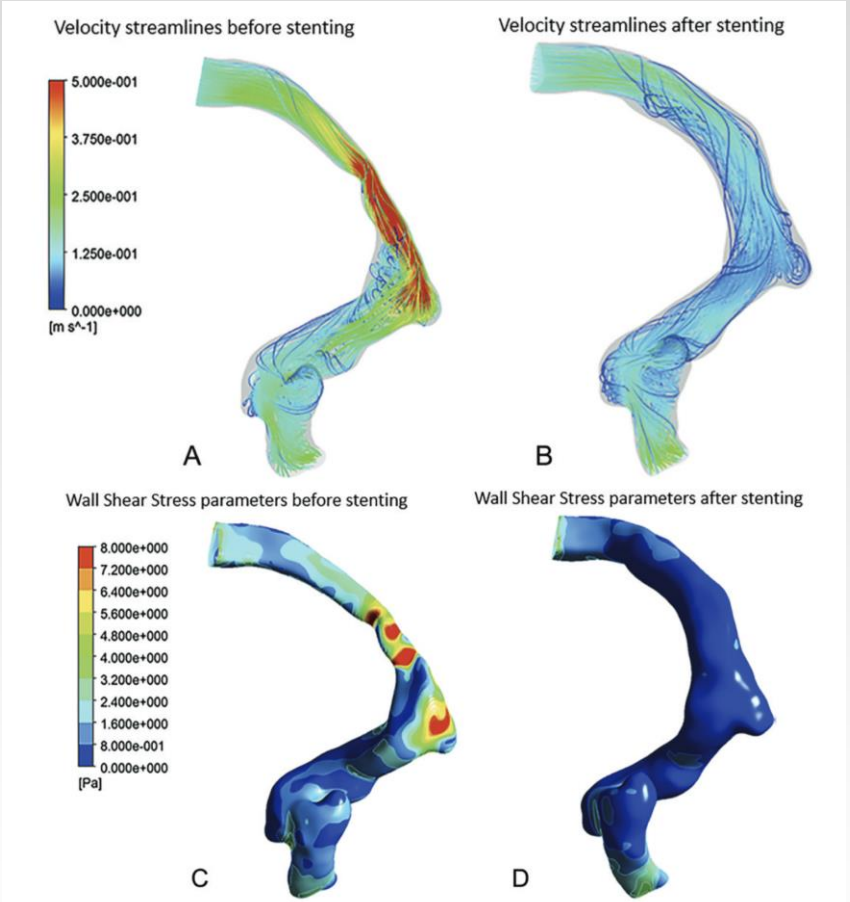


Figure 2: Computational fluid dynamic simulation images in a 54-year-old patient with pulsatile tinnitus secondary to left transverse sinus stenosis and sigmoid sinus diverticulum. Computational fluid dynamic (CFD) simulation with, *A, B,* wall shear stress parameters and, *C, D,* velocity streamlines before and after stent placement. *A, C,* Before stent placement, blood flow was faster and turbulent with, *A,* increased twisting and curling, and the, *C,* wall shear stress was increased in the stenotic region and the opening of the diverticulum. *B, D,* After stent placement, the flow pattern became, *B,* smoother and more regular, and the wall shear stress was, *D,* reduced markedly and distributed uniformly. (Reprinted, with permission, from reference 20.)

Meta-analysis of venous sinus stenting for intractable pulsatile tinnitus

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SNI: Neurovascular

Editor
Kazuhiro Hongo, MD
Shinshu University, Matsumoto, Japan

SNI
Open Access

Review Article

Venous sinus stenting for intractable pulsatile tinnitus: A review of indications and outcomes

Brian Fiani[1], Athanasios Kondilis[2], Thao Doan[3], Juliana Runnels[4], Nicholas J. Fiani[5], Erika Sarno[6]

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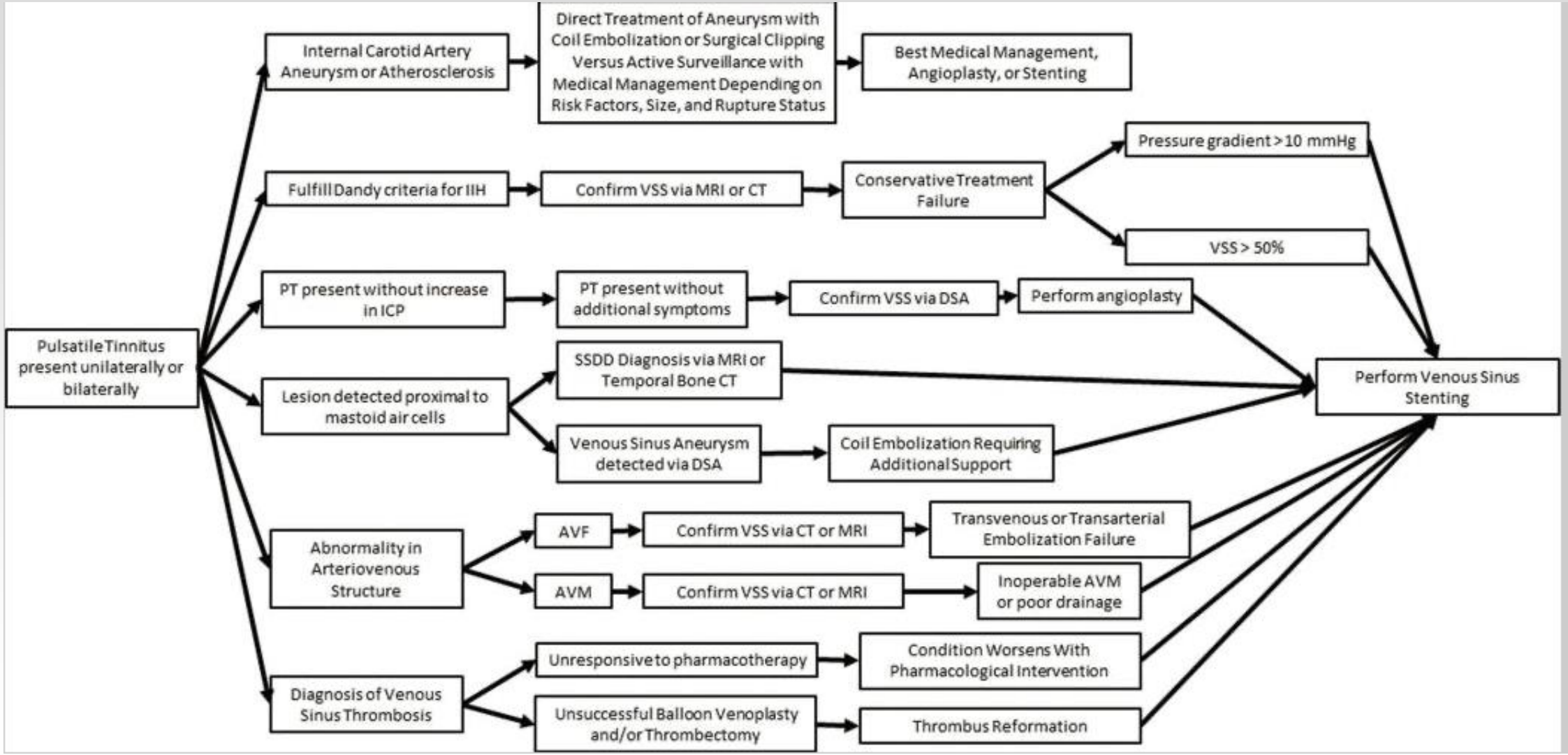
Patients with intractable pulsatile tinnitus

All roads lead to venous sinus stenting



Extensive evidence base for efficacy of venous sinus stenting for pulsatile tinnitus

Resolution most commonly occurs on day of procedure

Results appear to be durable at several years of follow up

Studies evaluating pulsatile tinnitus following venous sinus stenting.

Study	Year	*n*	Resolution of pulsatile tinnitus (%)
Donnet *et al.*[12]	2008	5	5/5 (100)
Ahmed *et al.*[2]	2011	17	17/17 (100)
Fields *et al.*[16]	2013	14	11/14 (79)
Radvany *et al.*[41]	2013	12	12/12 (100)
Baomin *et al.*[5]	2014	46	46/46 (100)
Goodwin *et al.*[20]	2014	15	15/15 (100)
Teleb *et al.*[48]	2015	5	4/5 (80)
Boddu *et al.*[6]	2016	29	28/29 (97)
Aguilar-Pérez *et al.*[1]	2017	9	9/9 (100)
Asif *et al.*[3]	2017	19	10/19 (53)
Dinkin *et al.*[11]	2017	13	13/13 (100)
Lenck *et al.*[30]	2017	21	21/21 (100)
El Mekabaty *et al.*[14]	2018	19	18/19 (95)
Funnell *et al.*[19]	2018	7	7/7 (100)
Oh *et al.*[37]	2019	5	5/5 (100)
Kulhari *et al.*[29]	2020	4	4/4 (100)
Total		240	225/240 (94)

Sigmoid sinus diverticulum or dehiscence (SSDD)

Rare cause for tinnitus

Dehiscence of the sigmoid plate

CT temporal bone recommended for evaluation

Endovascular stenting provides

relief of tinnitus symptoms

Interventional Neurology

Intervent Neurol 2016;5:76–80
DOI: 10.1159/000444507
Published online: May 12, 2016

1664–9737/16/0052–0076$39.50/0
www.karger.com/ine

Original Paper

Endovascular Management of Sigmoid Sinus Diverticulum

Srinivasan Paramasivam[a] Sunil Furtado[a] Tomoyoshi Shigamatsu[a]
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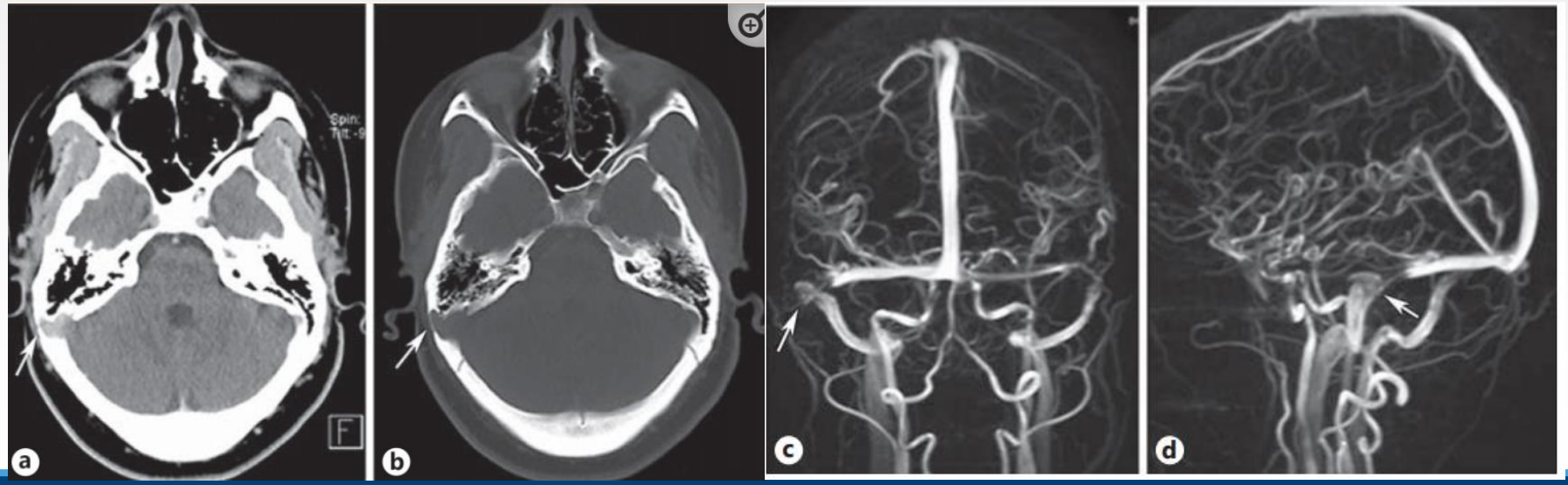
[a]Center for Cerebrovascular Surgery, Department of Neurosurgery, and [b]Department of Otolaryngology, Mount Sinai Hospital, New York, N.Y., USA



Otolaryngology--Head and Neck Surgery
Volume 150, Issue 5, May 2014, Pages 841-846

https://doi-org.gate.lib.buffalo.edu/10.1177/0194599813520291

Otology and Neurotology

Imaging Prevalence of Sigmoid Sinus Dehiscence among Patients with and without Pulsatile Tinnitus

Stephen Schoeff[1], Brian Nicholas, MD[2], Sugoto Mukherjee, MD[3], and Bradley W. Kesser, MD[1]

Objective Define the radiographic prevalence of sigmoid sinus diverticulum or dehiscence (SSDD) in patients with and without pulsatile tinnitus (PT).

Study Design Case series with chart review.

Setting Tertiary care university medical center.

Subjects Patients imaged between January 1, 2003, and December 31, 2012.

Methods Two groups were evaluated for SSDD. The first ("PT") included patients whose radiology report indicated a clinical history of PT (n = 37 symptomatic ears in 30 patients). The second ("non-PT") included all patients undergoing temporal bone high resolution CT (HRCT) between November 2011 and November 2012 (n = 308 ears in 164 patients) for reasons other than pulsatile tinnitus. Primary outcome measure was the radiographic presence of SSDD. Covariates including age, gender, body mass index (BMI), and audiometric data were analyzed by independent *t* tests and Fisher's exact test.

Results Within the PT group, SSDD was identified in 24% of ears (9/37) and 23% of patients (7/30); all SSDD patients were female ($P = .024$). Patients with SSDD were significantly younger ($P = .037$). SSDD more frequently caused objective tinnitus ($P = .016$). There was no difference in average BMI between those with and those without SSDD. In the non-PT group, SSDD was identified in 2 (both female) of 164 patients (1.2%; 0.6% of ears). The difference in SSDD prevalence between groups was significant ($P < .0001$).

Conclusions The prevalence of SSDD in patients with PT was 23%. Among patients with PT, those with SSDD were younger, exclusively female, and presented with objective tinnitus. The prevalence of SSDD among asymptomatic patients in 1 year was 1.2%.

Presence of SSDD in patients with pulsatile tinnitus up to 20%+

Associated with younger, female with objective tinnitus

Sigmoid Sinus Diverticulum
Endovascular versus surgical management

Systematic reviews and Meta-analysis Articles

INR INTERVENTIONAL NEURORADIOLOGY

Endovascular vs surgical treatment of sigmoid sinus diverticulum causing pulsatile tinnitus: A systematic review

Anvitha Sathya[1], Thanh N Nguyen[1,2,3], Piers Klein[1], Stephanos Finitsis[4], Bindu N Setty[1], Adam A. Dmytriw[5,*], Kyle M Fargen[6], Ferdinand K Hui[7], Peter Weber[8], Matthew R Amans[9] and Mohamad Abdalkader[1]

Interventional Neuroradiology
1–10

DOI: 10.1177/15910199241231325
journals.sagepub.com/home/ine
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Table 2. Descriptive statistics and associated characteristics of endovascular and surgical-treated sigmoid sinus diverticula.

Variable	Endovascular (n = 27)	Surgical (n = 107)	Overall (n = 134)
Age (mean)	43.9	40.8	41.3
Gender			
Female	20 (74.1)	82 (76.6)	102 (76.1)
Male	4 (14.8)	7 (6.5)	11 (8.2)
Not reported	3 (11.1)	18 (16.8)	21 (15.7)
Resolution (first treatment)			
Complete	23 (85.2)	83 (77.6)	106 (79.1)
Partial	4 (14.8)	12 (11.2)	16 (11.9)
None	0 (0.0)	12 (11.2)	12 (9.0)
Reoperation required	1 (3.7)	7 (6.5)	8 (6.0)
Resolution (all operations)			
Complete	24 (88.9)	87 (81.3)	111 (82.8)
Partial	3 (11.1)	14 (13.1)	17 (12.7)
None	0 (0.0)	6 (5.6)	6 (4.5)
Any complications	1 (3.7)	10 (9.3)	11 (8.2)

Jugular bulb diverticulum

Optimal imaging tool is CT venography and skull base CT

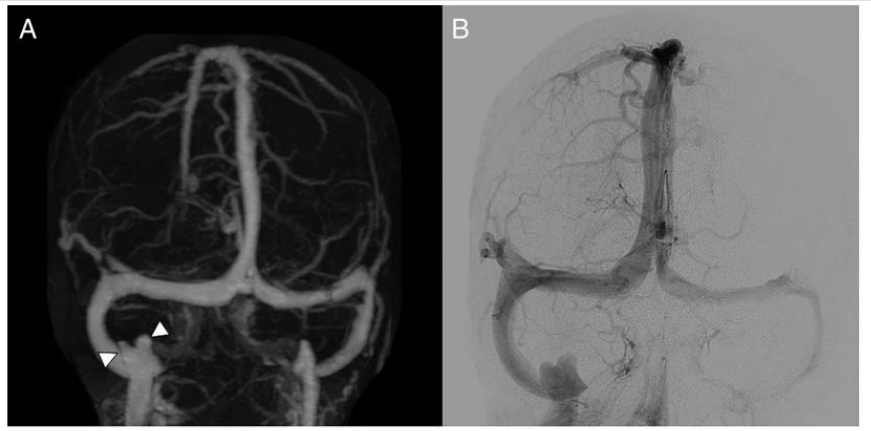
Surgical treatment by mastoidectomy/impaction of bone wax or endovascular approach with coil embolization/stenting

Head and neck

CASE REPORT

Endovascular treatment of jugular bulb diverticula causing debilitating pulsatile tinnitus

Alex M Mortimer, Tim Harrington, Brendan Steinfort, Ken Faulder



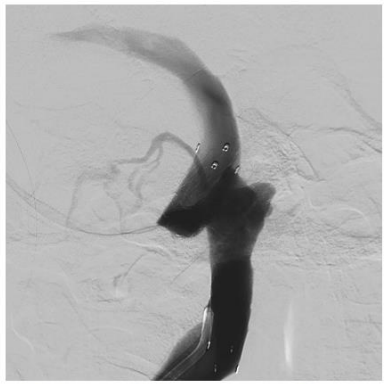


Figure 2 Lateral digital subtraction venogram via right internal jugular vein injection showing stent position.

Figure 3 Frontal digital subtraction venogram via right internal jugular vein injection showing coil embolization of the two diverticula.

Other unusual venous causes of PT

Marginal sinus – dural venous sinus that connects OS posteriorly and basilar venous plexus

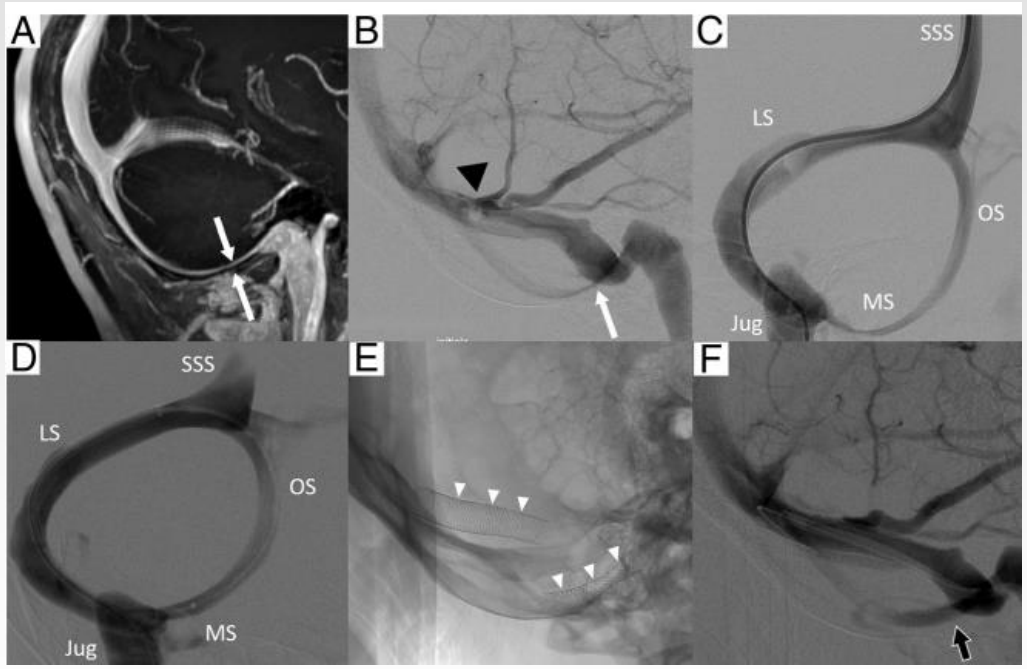
Potential location for dural sinus stenosis

Treatment by endovascular stenting improves PT

ORIGINAL RESEARCH
INTERVENTIONAL

Pulsatile Tinnitus Due to Stenosis of the Marginal Sinus: Diagnosis and Endovascular Treatment

J. Cortese, M. Eliezer, A. Guédon, and E. Houdart



Patients with MS stenosis

No.	Type of PT	Side	Disability[a]	Ipsilateral LS	Sinus Stented	Treatment Efficiency
1	Venous	Right	8	Stenosis	LS then MS	Yes (after the MS stent placement)
2	Venous	Right	9[b]	Normal	MS	Yes
3	Venous	Left	9	Stenosis	LS+MS	Yes
4	Venous	Right	8	Stenosis	LS+MS	Yes
5	Venous	Left	3	Normal	None	
6	Venous	Right	4	Hypoplastic	None	
7	Venous	Left	5	Hypoplastic	None	
8	Venous	Right	9	Hypoplastic	None	

[a]Disability was evaluated on a VAS from 0 (no tinnitus) to 10 (unbearable and extreme tinnitus).
[b]Patient 2 also had IIH, which also resolved after the stent placement.

Unusual Arterial causes of PT

CASE REPORT

Aberrant internal carotid artery causing objective pulsatile tinnitus and conductive hearing loss

YUE-SHUAI SONG[1,2], YONG-YI YUAN[1,3], GUO-JIAN WANG[1,3], PU DAI[1,3] & DONG-YI HAN[1]

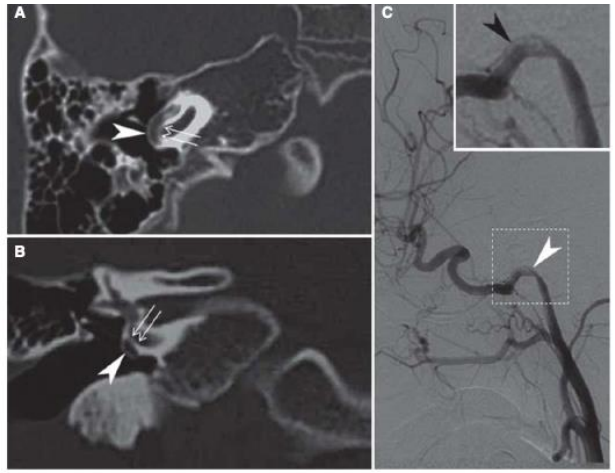


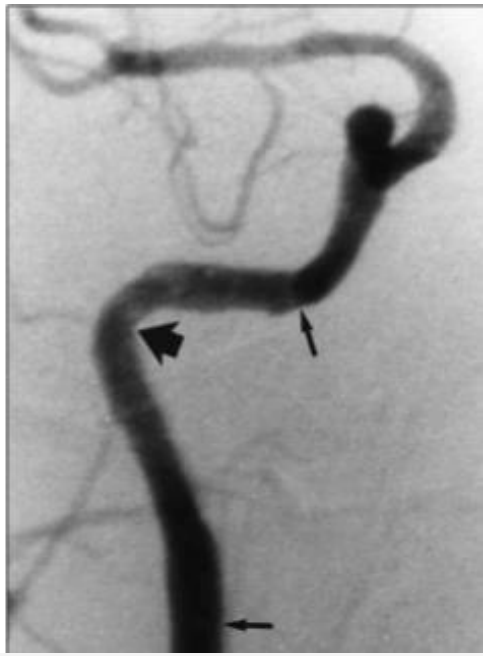
Figure 1. (A) Axial and (B) coronal high-resolution computed tomography (HRCT) showed the course of the aberrant internal carotid artery (ICA) (white arrowheads); a 'third mobile window' of the inner ear was also identified (double white arrows). (C) Angiography of the ICA indicated a small branch of the vessel (black arrowhead).

Interv Neuroradiol. 2022 Jun 3;30(2):293–296. doi: 10.1177/15910199221106036

CLINICAL NOTE

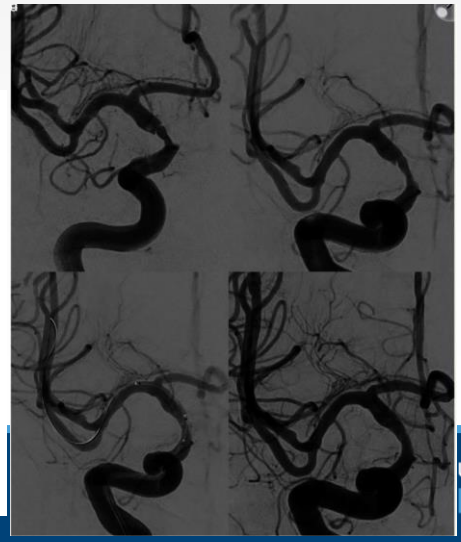
Pulsatile Tinnitus Cured by Angioplasty and Stenting of Petrous Carotid Artery Stenosis

Derek J. Emery, MD; Robert D. G. Ferguson, MD; J. Scott Williams, MD, PhD



Pulsatile tinnitus due to stenosis of the supraclinoid segment of the internal carotid artery: Management with a low-profile self-expanding stent

Carolina Capirossi [1,✉], Antonio Laiso [1], Francesco Capasso [1], Sergio Nappini [1], Leonardo Renieri [1], Nicola Limbucci



Current Vascular Protocol for Tinnitus Work-Up: For patients who present with headache and pulsatile tinnitus

Tinnitus +/- Headache

↓

ENT Consult
Ophthalmology Consult (IIH)

↓

Non-invasive imaging
- CT head
- MRI+c/MRA/MRV

↓

- Diagnostic cerebral angiogram
  - Rule out arterial causes (e.g. fistula)
  - Rule out venous causes (e.g. venous sinus thrombosis, stenosis)
  - With or without venous manometer (for IIH)

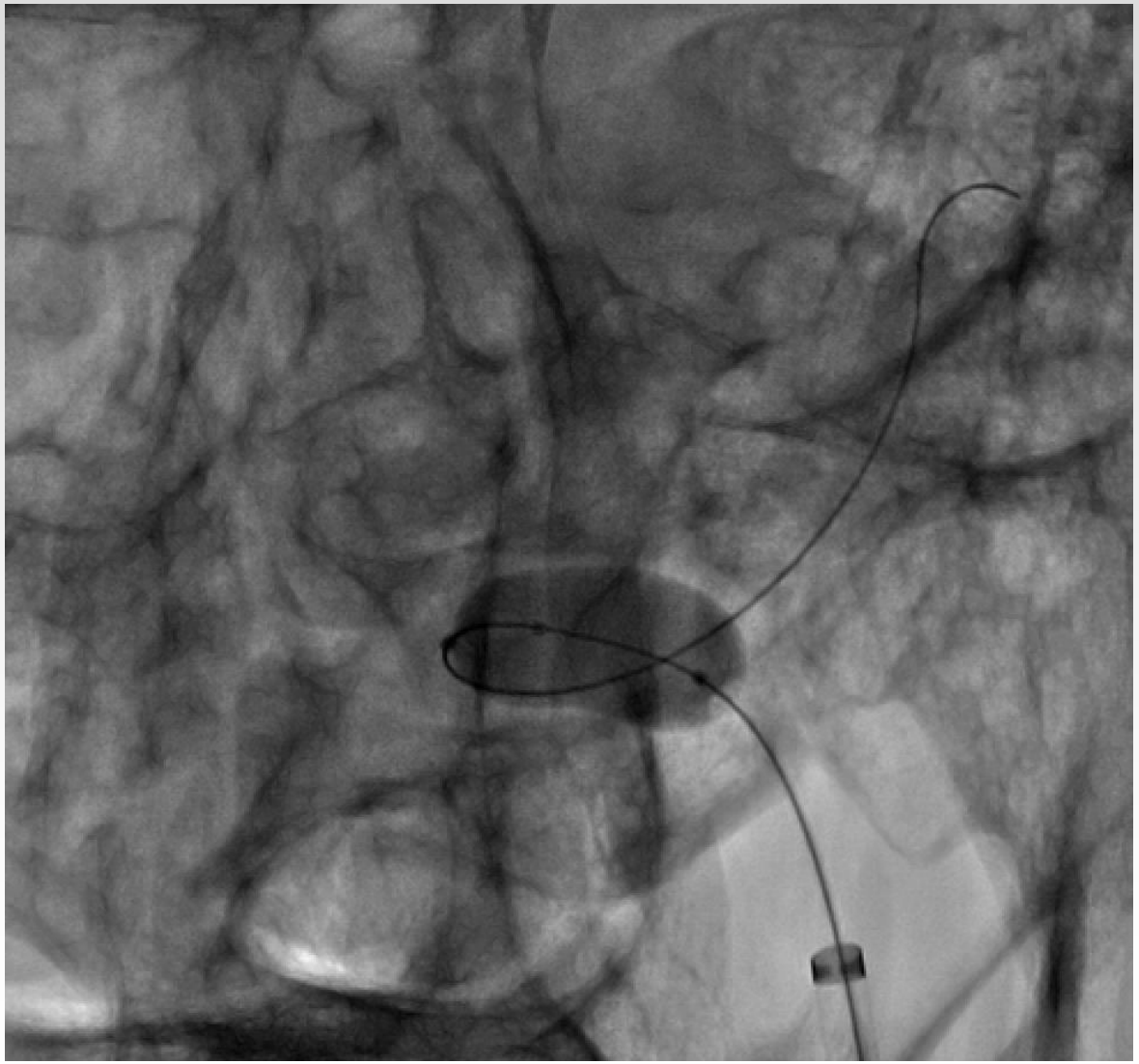
Case 2 : Enlarged mastoid emissary vein as the cause of pulsatile tinnitus

Story

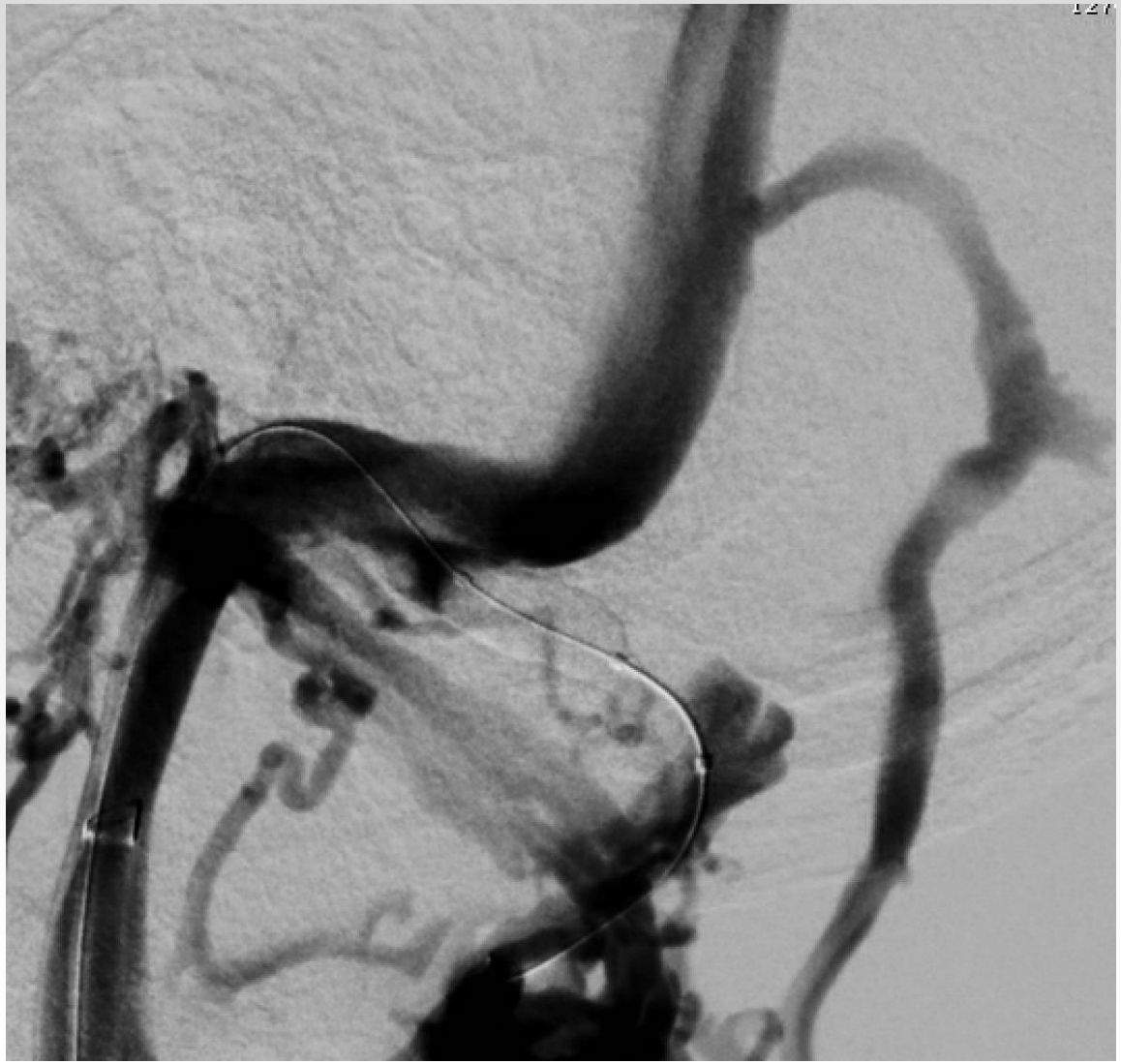
- 60y/M presents with 5 year history of tinnitus with mild headache
- Bilateral but with L>R
- Sudden in onset while he was hiking in the woods
- Aggravated on lying down and with exercise
- Associated with occasional occipital pain
- Exam : Overall unremarkable
- Seen by ENT; no cause identified
- CT scan, MRI : negative
- DSA + venogram : **bilateral prominent mastoid emissary veins**

Cerebral venogram with guide catheter at the jugular bulb with good filling of the left sigmoid sinus, internal jugular vein, and multiple emissary veins

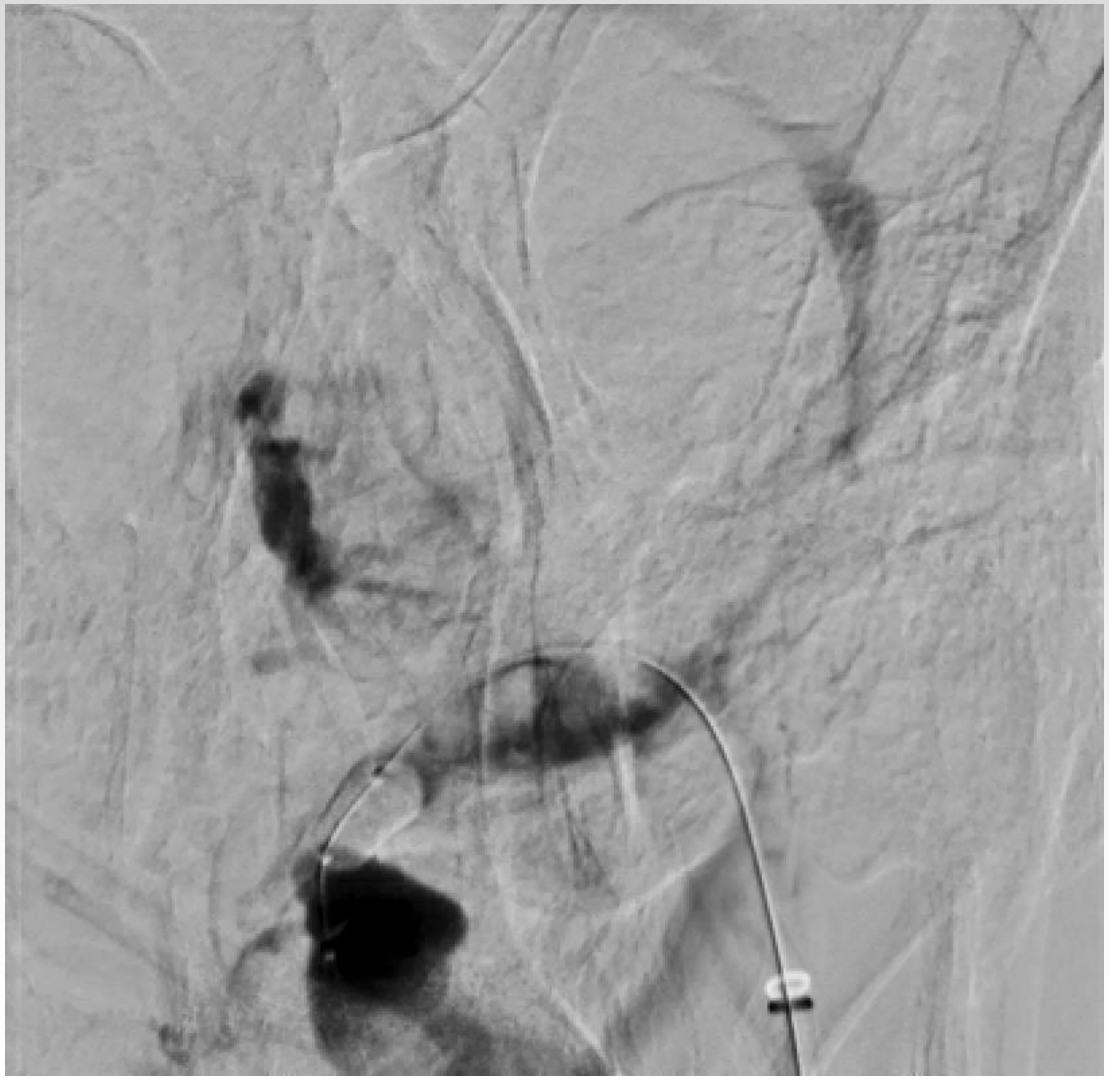
Balloon occlusion of the dural venous sinus at the junction of the jugular bulb and the internal jugular vein



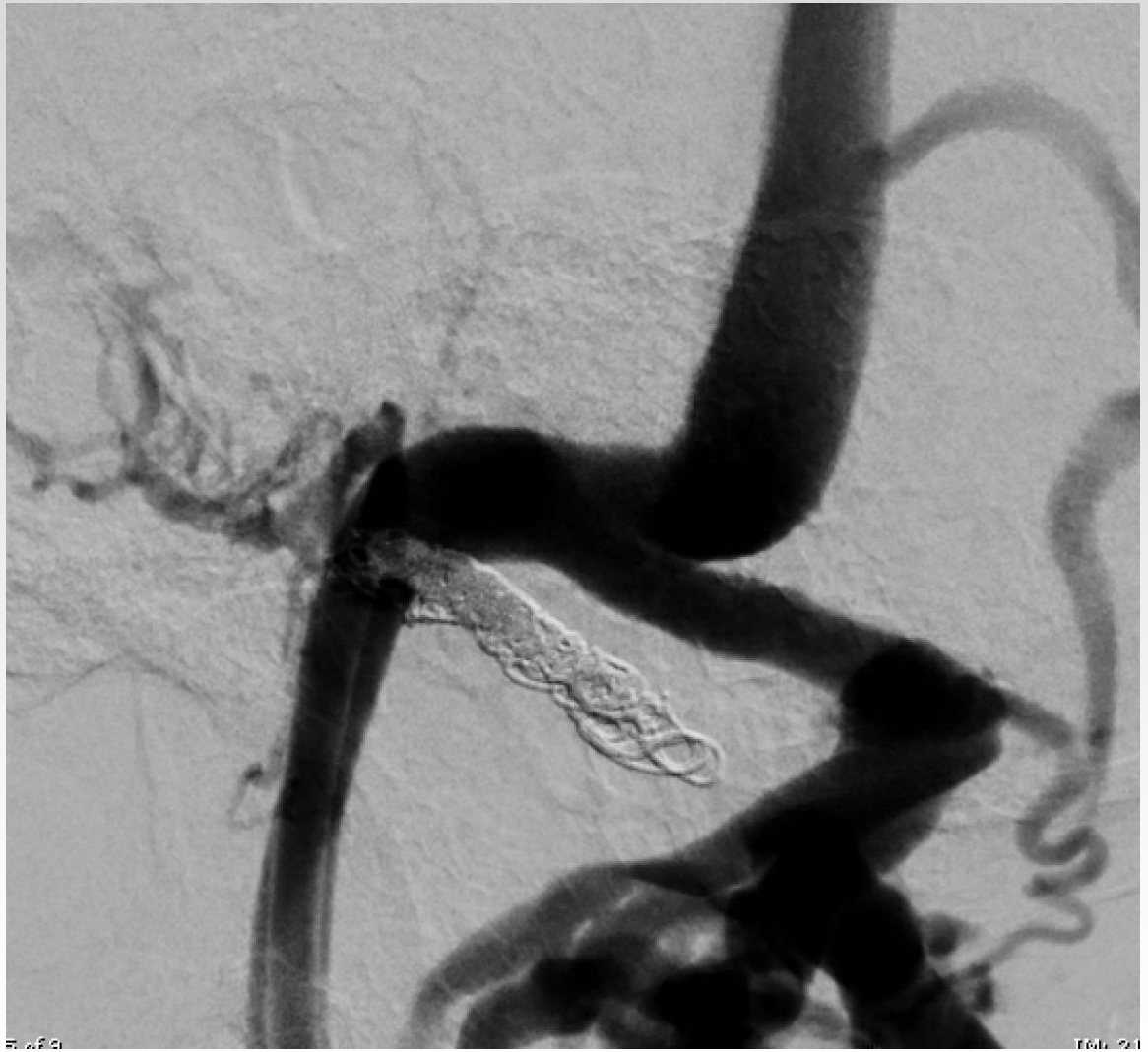
Balloon occlusion of the dural venous sinus at the junction of the sigmoid sinus and jugular bulb.



Balloon occlusion of the smaller emissary vein achieved 80-90% reduction in pulsatile tinnitus



Proceeded with coiling of the smaller mastoid emissary vein



Clinic follow up at 4 week : Almost complete resolution tinnitus of pulsatile

What is next or still unknown?

- Small study cohorts – expand to larger studies
- Durability and long-term resolution of pulsatile tinnitus with stenting
- Stenting for sinus thrombosis? (insufficient data available currently)

Conclusion

- Increasing knowledge on cerebrovascular arterial and venous etiologies for tinnitus
- Tinnitus, with and without headache, may be associated with a wide range of neurologic venous diseases (from intracranial hypotension to intracranial hypertension)
- The gold standard of evaluation for neurologic causes is diagnostic cerebral angiogram (Standard non-invasive imaging may not detect subtle findings)
- Neuroendovascular treatment has proven to be an effective treatment for tinnitus in many of these diseases


Thank You