Advanced Vascular Imaging: Pulsatile Tinnitus

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The Objectives of this presentation are to:
- Review the differential diagnosis of pulsatile tinnitus
- Discuss the multiple MRI/MRA imaging options and innovations
- Show examples of vascular causes of tinnitus
- Discuss how the combination of temporal bone CT and MRI/MRA are complementary in the work up of pulsatile tinnitus

Disclosures

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Pulsatile Tinnitus

- Common symptom, affecting up to 10% general population
- Prevalence increases with age, more common in men
- Pulsatile Tinnitus: describes tinnitus that is synchronous with the cardiac cycle
  - Inherently due to vascular etiologies
- Tinnitus is often divided into subjective and objective categories
  - Subjective: perceived only by patient
  - Objective: perceived by patient and examiner as whooshing sound
- Pulsatile tinnitus commonly characterized as objective tinnitus.
- More likely to find a cause of objective tinnitus, imaging is higher yield in this patient population

Lockwood et al, New England Journal of Medicine, 2002

Pulsatile Tinnitus: Differential Diagnosis

- Dural and Intracranial Vascular Lesions
  - Dural Arteriovenous Fistula (DAVF)
  - Arteriovenous Malformation (AVM)
  - Dural sinus stenosis
  - Idiopathic intracranial hypertension
- Extradural vascular lesions
  - Carotid artery dissection
  - Fibromuscular dysplasia (FMD)
  - Carotid atherosclerotic stenosis
- Temporal Bone
  - Paragangliomas
  - Aberrant carotid, Persistent Stapedial Art. Aneurysms
  - Jugular bulb anomalies
  - Otosclerosis


Pulsatile Tinnitus: Dural Arteriovenous Fistula

DAVF difficult to visualize on cross sectional imaging

Case 1
Multiple Overlapping Thin Slabs – varying the flip angle combined with thin slabs reduces signal loss due to saturation. Widely used for extracranial and intracranial imaging. Acceleration – parallel imaging, compressed sensing and multiband techniques reduce imaging time (4 min to 1 min).

Ramped rf pulse varies the flip angle across the imaging volume.

Phase Contrast MRA

Moving spins have phase shift

Positive flow encoding gradient applied - spins dephase

Equal negative flow encoding gradient applied — stationary spins rephase.

Bipolar Flow Encoding Gradients

Moving spins—accumulate a net phase shift proportional to velocity (derivatives of velocity, flow, pressure, shear stress)

Velocity Encoding (Venc) — to low will result in aliasing, to high will result in reduced flow signal

Time Resolved Contrast Enhanced MRA

Oversampling of the center of k-space

Artery and Vein

Background Volume

Complex Subtraction

Un-subtracted Volume

Subtracted Volume

Slide courtesy F. Korosec
Acceleration achieved by radial undersampling projection reconstruction

High SNR, less artifacts with preserved dynamic information

**Pulsatile Tinnitus: Dural Arteriovenous Fistula**

Radial TR CE MRA with Projection Reconstruction

Whole brain coverage, frame update time of 0.7s

Case 2

**Pulsatile Tinnitus: Dural Arteriovenous Fistula**

Radial TR CE MRA with Projection Reconstruction

Case 2

**Pseudo Continuous Arterial Spin Label (PCASL) MRA Sequence Design**

Case 3

Radial TR CE MRA with Projection Reconstruction
**Arteriovenous Malformation**

Radial TR CE MRA with Projection Reconstruction

- May rarely present with pulsatile tinnitus
- Added advantage of Radial TR CE MRA with PC MRA is the quantitative flow measurements obtained from the phase contrast scan. (Markl et al, J Mag Res Imaging, 2013, Chang, Turski et al, AJNR 2015)

**Left Dural AVF - 4D Intracranial Angiography using Radial PCASL**

<table>
<thead>
<tr>
<th>DAIF 033012</th>
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<td>200 ms</td>
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- Excellent delineation of the occipital artery feeder
- Early signal within the transverse sinus

**Idiopathic Intracranial Hypertension (IIP)**

- Most commonly present with headache and blurred vision
- Can present with pulsatile tinnitus or venous murmur
- Often associated with venous sinus stenosis which may be induced by high CSF pressure
- Alternatively, venous stenosis may lead to high CSF pressure
- 4DFlow MR imaging has added benefit of providing added quantitative flow data

**Pulsatile tinnitus: Venous obstruction dural dehiscence, increased intracranial pressure and encephalocele**

| Pulsatile tinnitus: Venous obstruction dural dehiscence, increased intracranial pressure and encephalocele |

**Treatment Options**

- **Endovascular**
  - Transarterial (nBCA, Onyx)
  - Transvenous (coils, nBCA, Onyx)
- **Surgery**
  - Skeletonization, resection of dura
  - Radiation Therapy – 30 Gy
  - RT - Low obliteration rates (50%)
  - When combined with endovascular (90%)
Idiopathic Intracranial Hypertension
Venous Sinus Stenosis

32 year old female with headache, tinnitus (venous murmur), elevated ICP

10 – 25% present with pulsatile tinnitus; (16/136 patients in one series)

Headache, neck pain, Horner’s, sequelae of ischemia

Etiology: Traumatic, mild trauma (cervical manipulation), spontaneous (connective tissue disorders, FMD)

Pulsatile Tinnitus: Arterial Dissection

Pulsatile Tinnitus after bicycle accident

Pulsatile tinnitus after bicycle accident

Pulsatile Tinnitus: Fibromuscular Dysplasia

1/3 symptomatic FMD patients endorse pulsatile tinnitus

String of beads, vascular ectasia

Bilateral, multifocal, affecting medium size vessels (carotids, vertebral and renal arteries)

TRICKS MRA showing multifocal areas of narrowing (arrows) in the cervical internal carotid artery bilaterally in a patient with FMD.

Pulsatile Tinnitus: Arterial Dissection

ASVD - Arterial Stenosis

Narrowing of the internal carotid artery for any reason results in turbulent flow, which can be transmitted to the inner ear and cause pulsatile tinnitus

The closer the stenosis to the skull base, the more likely a patient is to have pulsatile tinnitus

From: Disappeared Pulsatile Tinnitus Related to Pericranial Segment Stenosis of the ICA after Stenting
Im et al JCAT, Neuro 2013; 31(5): 93-101
**Congenital Vascular Anomalies**
- Aberrant ICA
- Laterally displaced ICA
- Persistent stapedial artery
- Jugular dehiscence

**Paragangliomas**
- Glomus tympanicum
- Glomus jugulare
- Glomus jugulotympanicum

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**Retrotympanic Mass**

- May be detected on exam as a retrotympanic mass
- High Riding Jugular Bulb. Axial and coronal CT images demonstrate an abnormal lateral course.
- May be detected on exam as a retrotympanic mass
- CT is diagnostic
- Important to distinguish from paraganglioma to avoid injury at myringotomy or biopsy

**Fenestral otosclerosis. Axial and coronal temporal bone CT showing loss of normal enchondral bone at the fissula ante fenestrum (arrows).**

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**Otosclerosis**

- Cause of conductive or mixed conductive or sensorineural hearing loss in adults in the 2nd through 4th decades, more common in women, often bilateral
- Patients can present with pulsatile tinnitus
- Also referred to as otospongiosis, because involves replacement of normal enchondral bone with spongy vascular bone
- Temporal bone CT is imaging study of choice for evaluation

**Fenestral otosclerosis. Axial and coronal temporal bone CT showing loss of normal enchondral bone at the fissula ante fenestrum (arrows).**

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**Paraganglioma**

- Glomus tympanicum tumor
- Occur in inferior temporal bone near cochlear promontory
- Arise from paraganglia along Jacobson’s nerve
- Does not typically cause osseous destruction
- Evaluated by temporal bone CT

**Carotid Body Paraganglioma**

Case courtesy Dr. Kennedy

**Paraganglioma**

- Glomus Jugulare
- Glomus jugulotympanicum
- Arise in jugular foramen from Jacobson’s or Arnold’s nerve
- Extension into middle ear defines jugulotympanic tumors
- Osseous erosion

Case courtesy Dr. Kennedy
Summary

- For patients with objective pulsatile tinnitus a combination of CT temporal bone and MRI/MRA may be necessary for diagnosis

- Consider adding Time Resolved CE MRA to the MRA protocol in these patients

- Current vendor supported innovations include parallel imaging, compressed sensing and multiband imaging