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AJNR Am J Neuroradiol 1994, 15 (5) 890-892

<http://www.ajnr.org/content/15/5/890.citation>

This information is current as
of June 5, 2025.

Imaging of Pulsatile Tinnitus: Basic Examination versus Comprehensive Examination Package

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Tinnitus is a common clinical syndrome with rare radiologic findings. This human malady may exist in two forms, namely objective or subjective. Objective tinnitus is a real sound produced *outside* the inner ear, which is heard by the patient and also by the examining physician. Subjective tinnitus is heard only by the patient and involves the neural mechanisms of the ear or auditory pathways. These pathways extend from the tectorial membrane and hair cells of the inner ear through the organ of Corti, cochlear nerve, cochlear nucleus, brain stem, midbrain, and auditory cortex. In some patients, the tinnitus is described as pulsatile, a sound that is synchronous with the cardiac pulsations. Pulsatile tinnitus is often subclassified as objective (which the examining physician can hear) or subjective (which only the patient can hear).

The neurotologic work-up of patients with tinnitus includes complete clinical evaluation including tympanometric, audiometric, and auditory evoked potential investigations. A specific tinnitus evaluation is also performed to match the pitch and intensity of the sounds, which helps to indicate the likely source. The clinical evaluation may demonstrate a mechanical type of tinnitus (muscle myoclonus) or a plug of cerumen or hair in the external auditory canal. Such patients require few tests and are often treated by section of the tendon of the offending muscle or removal of the debris from the external auditory canal. If the problem is not solved by clinical examination or neurotologic tests, the patient is then referred for radiologic evaluation (1).

In this issue of the *American Journal of Neuroradiology*, Dietz et al describe the use of magnetic resonance (MR) and MR angiography (MRA) in the evaluation of patients with pulsatile tinnitus (2). The authors show that MR and MRA may

serve as substitutes for computed tomography (CT) and conventional angiography in patients with *objective* pulsatile tinnitus. Evaluation of patients with *subjective* pulsatile tinnitus remains problematic. The authors studied 49 patients, 28 of whom had positive radiologic findings. Of these 28 patients, 16 had objective pulsatile tinnitus and 12 patients had subjective pulsatile tinnitus. In the 28 positive studies, 10 cases had CT and 17 cases had conventional angiography. The remaining 21 patients with normal MR/MRA findings all had subjective pulsatile tinnitus and a normal clinical examination. Of these 21 patients, only 1 patient had conventional angiography and none had a CT scan. The authors do not discuss the need for high-resolution temporal bone CT or conventional angiography in patients with normal MR/MRA studies. Thus, the value of a normal MR/MRA examination is not known.

A portion of the article describes the value of MRA in the work-up of patients with dural fistulas (extracranial shunts) and/or arteriovenous malformations (AVMs) (both intracranial and extracranial shunts). The subpial variety of AVMs is quite common. A less common type of AVM is the dural variety, which derives its blood supply primarily from the external carotid artery with venous drainage outside or inside the brain. The direction of venous drainage is the determinant of the clinical symptoms. The presenting symptoms may include pulsatile tinnitus and/or an audible bruit in patients with extracranial drainage of subpial AVMs or dural fistulas (3). Conventional MR may not detect dural fistulas or purely dural AVMs, unless the venous drainage extends into the intracranial cavity or into the scalp (4). As clearly shown by the authors, the addition of an MRA examination is invaluable. Another valuable point in the article describes the use of MRA in

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Index terms: Magnetic resonance angiography (MRA); Magnetic resonance, comparative studies; Hearing; Commentaries

AJNR 15:890-892, May 1994 0195-6108/94/1505-0890 © American Society of Neuroradiology

cases of transverse sinus stenosis. Whether such stenosis is caused by a thrombosed dural AVM, an isolated intraluminal thrombus, or a tumor within the sinus is not clear. From a practical standpoint, noninvasive documentation of such transverse sinus stenosis seems helpful.

Besides AVMs, another group of congenital or developmental vascular anomalies (both arterial or venous) may be present in the middle ear cavity and cause pulsatile tinnitus. Careful otoscopic examination may demonstrate a pulsating reddish mass in the anterior inferior quadrant of the middle ear behind an intact tympanic membrane in patients with arterial anomalies (5–7). The otoscopic examination may demonstrate a nonpulsatile bluish mass in the inferior posterior quadrant of the middle ear behind an intact tympanic membrane in patients harboring certain venous anomalies (5–8). High-resolution CT is often used as the primary diagnostic modality to differentiate these vascular anomalies of arterial origin from those of venous origin. The venous anomalies are more common and are typically caused by variations in the position of the jugular bulb in relation to the hypotympanum (8). The most common venous anomaly is a high jugular bulb protruding into the middle ear cavity. With CT, a high-riding jugular bulb appears as a mass in the middle ear with or without a covering bony shell. The jugular bulb may be dehiscent with a protruding mass that fills the entire middle ear. A diverticulum or diverticula may extend from the apex of the jugular bulb. The space between the descending facial nerve canal and the dehiscent jugular bulb may be narrowed. The bony outline is smooth with regular margins, which helps to differentiate the dehiscent bulb from a neoplasm or aggressive infection. Surgical correction of the dehiscence consists of placement of a bony or dural plug to prevent further exposure of the bulb within the tympanic cavity (5, 8, 9).

Arterial anomalies within the middle ear may be related to anomalous development of the stapedia-hyoid artery. Examples are a persistent stapedia-hyoid artery, an altered course of the internal carotid artery through the middle ear with or without a persistent stapedia artery, and an anomalous pharyngostapedial artery (10). An aberrant or intratympanic course of the carotid artery, without an associated stapedia artery, will show a reduced caliber carotid canal through the temporal bone. The covering of the carotid canal will appear absent as the vessel traverses through the middle ear. In such cases, the bony canal

takes a course anterior to the jugular bulb, below and against the cochlear promontory, and inferior and anterior to the stapes, where it joins the normal horizontal portion of the carotid canal. High-resolution CT will demonstrate not only the narrowed bony canal, but also the erosion of the cochlear promontory and the enlargement of the inferior tympanic canaliculus, which forms the pathway for the inferior tympanic branch of the ascending pharyngeal artery connecting the primitive hyoid artery to the distal precavernous internal carotid artery (11). Persistence of the stapedia artery is also readily identified by high-resolution CT. The stapedia artery enters with the facial nerve through the lateralmost orifice of the fallopian canal. The fallopian canal appears dilated distal to the geniculate ganglion. After passage through the tympanic portion of the fallopian canal, the stapedia artery continues intracranially as the dural supply to the posterior cranium (5). As shown by the authors, MR/MRA may also document an anomalous course of the internal carotid artery through the middle ear (2, 9). The course of the stapedia artery or other variants has not yet been documented by MR or MRA.

The MR/MRA examination package seems to be particularly useful in patients with vascular tumors, typically paragangliomas. Some of these patients present with otoscopically visible intratympanic masses; some patients may have cranial nerve deficits or a palpable cervical mass and/or pulsatile tinnitus. Nearly all these vascular neoplasms, whether metastatic from renal or thyroid origin or primary paragangliomas, will show a dramatic enhancement on postcontrast MR. Such tumor enhancement is much easier to identify with MR than with CT (12, 13). The MRA examination may be a useful adjunctive procedure to demonstrate the vascular pedicles. In addition, one can measure the enhancement and time patterns with fast imaging techniques. Gradient-echo sequences are repeated in a standardized pattern, with measurements of the degree of enhancement and its time dependence. Typically, vascular tumors will show a rapid take-up of contrast immediately after injection of the paramagnetic contrast medium and a gradual decrease at the end of several minutes. The peak enhancement occurs at approximately 1.5 minutes. The enhancement and time patterns with the prompt washout effect may help to differentiate highly vascular neoplasms from less vascular tumors such as meningiomas and schwannomas,

which show slow uptake and delayed washout of contrast (13). Relying exclusively on the characteristic MR appearance without the benefit of contrast enhancement and/or MRA makes it difficult to differentiate some vascular tumors from AVMs.

The authors are to be congratulated for the large number of patients they examined for pulsatile tinnitus. The quality of the MR/MRA examinations is clearly an indication of the value of these procedures, which often serve as a substitute for conventional angiography, in experienced hands. The MR/MRA techniques may be used as primary screening modalities in patients with objective pulsatile tinnitus or in patients without additional findings of an otoscopically visible intratympanic mass, cranial nerve deficits, or palpable cervical lesions. Evaluation of patients with subjective pulsatile tinnitus remains problematic, although CT can serve as the definitive examination in patients with otoscopically visible intratympanic lesions.

One can consider a basic examination consisting of high-resolution CT in patients with otoscopically positive findings. Congenital or developmental vascular anomalies may be surgically treated or incidentally noted as indicated. Patients with normal otoscopic findings, particularly those with objective pulsatile tinnitus, may be examined by a comprehensive examination package consisting of MR/MRA followed by therapeutic angiography (patients with dural fistulas or AVMs) or a combination of treatment options (patients with vascular tumors).

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