Preoperative study of the petrous bone with multidetector CT (MDCT): identification of anatomical risky conditions in otosurgery.

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Authors: G. Coniglio, M. L. Lanza, A. uccello, M. Coppolino, A. Montana, G. C. Ettorre; Catania/IT
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Aims and objectives

The aim of this study is to retrospectively analyze a series of temporal bone high-resolution CT scans for the incidence of anatomical variations of both vascular and non-vascular structures, highlighting how these variations may cause important problems in diagnosis and treatment planning.

Methods and materials

We retrospectively searched our radiology database for all temporal bone CT scans performed over a 21-months period from January 2012 through September 2013. Consecutive unenhanced temporal bone CT scans in 174 patients were identified, consisting of axial images acquired with a 16-slice CT scanner (Brilliance-16-MDCT, Philips Healthcare), using a high resolution temporal bone protocol. Multiplanar reconstructed images with 0.70 mm slice thickness were obtained from CT images performed in the axial plane at a separate workstation.

Results

Anatomical variations were observed in 41 patients of 174 (24%). The conditions most often encountered are: high or protruding bulb of the jugular vein 23 (13%), mastoid emissary vein 7 (4%), anterior placed sigmoid sinus 4 (2%), facial nerve dehiscence 4 (2%). Abnormalities of mastoid pneumatization and surgical landmarks are also considered. Below these variants are described; important anatomical variants not encountered in our series are also mentioned.

The **jugular bulb (JB)** is the confluence of the lateral venous sinuses situated in the jugular fossa. It drains extracranially to the internal jugular vein as it passes through the jugular foramen of the posterior cranial fossa. A bony interface, described as the sigmoid plate, separate the JB from the middle ear cavity. Jugular bulb variations are relatively common and include asymmetrically large JB, high-riding JB with or without dehiscence and jugular diverticulum. These variations may be difficult to clinically differentiate from paragangliomas in patients with pulsatile tinnitus or vascular retrotypanic mass.

An **asymmetrically large JB** (fig. 1) is a very common finding, which only becomes an imaging problem when the radiologist discovers it in the search for a cause of tinnitus, but rarely this vascular variant causes symptoms. The JB is asymmetrically larger on the right side twice as often as it is on the left side. CT demonstrates asymmetry in the size of the jugular foramen; preservation of the jugular spine and all cortical margins
helps the radiologist to make correct diagnosis, excluding pathological conditions as paragangliomas. The transverse and sigmoid sinuses as well as the internal jugular vein are enlarged on the side of the enlarged JB.

A "high-riding jugular bulb" is defined as an extension of the most cephalad portion of the jugular bulb superior to the floor of the internal auditory canal, up to the level of the basal cochlear turn. In axial planes the jugular bulb is high if extends above the basal turn of the cochlea (fig 2). A high-riding bulb complicates the drilling process and exposure, especially with a translabyrinthine approach and influences surgical approach for cerebello-pontine angle lesions.

**Dehiscent jugular bulb** (fig 3) extends into the middle ear cavity, herniating to the hypotympanum, through a dehiscent sigmoid plate. The other margins of the adjacent jugular foramen are smooth and intact. Dehiscence most often is associated with high-riding JB. Otoscopically, this is seen as a blue mass in the lower part of the middle ear behind an intact tympanic membrane. Usually it is asymptomatic, but may cause pulsatile tinnitus or conductive hearing loss. and requires differential diagnosis with aberrant internal carotid artery or glomus tympanicum tumor. Radiologic diagnosis is important to prevent injury during procedures as myringotomy.

**A jugular bulb diverticulum** is defined as a focal polypoid extension of the jugular bulb superiorly (or, less commonly medially, anteriorly or posteriorly) into the deep temporal bone just behind the internal auditory canal, with an intact sigmoid plate.

Jugular bulb abnormalities may cause dehiscence of inner ear structures, most commonly eroding into the vestibular aqueduct, followed by facial nerve and posterior semicircular canal. The potential overestimation error on HRCT resulting from volume averaging may be minimized by interpreting dehiscence only when an absence of intervening bone is seen in at least 2 consecutive images and in multiple planes.

The sigmoid sinus is the most distal dural venous sinus and serves to connect the transverse sinus to the internal jugular vein at the level of the jugular bulb; it passes along the medial border of the mastoid air cells, defining usually a shallow indentation on the posterior aspect of the mastoid. An **anteriortly located sigmoid sinus** (fig 4) produces a deep groove in the mastoid and reaches the posterior wall of the external auditory canal, separated from it only by a thin bony plate.

An unusual anterior position of the sigmoid sinus can determine surgical difficulties in performing mastoidectomy and poses a challenge to dissection with the translabyrinthine approach; therefore it should be reported by radiologist in order to avoid complications as profuse bleeding, cerebral hemorrhage, infarctions and dural arteriovenous malformations.
Posterior fossa emissary veins pass through cranial apertures and participate in extracranial venous drainage of the posterior fossa dural sinuses. These emissary veins are usually small and asymptomatic; during growth of the jugular sinuses, most of them disappear, but some persist and enlarge. The mastoid emissary veins (fig 5-6) run between the sigmoid sinus and posterior auricular or occipital vein by crossing the mastoid foramen. Assessing this vein preoperatively would allow one to modify the surgical procedure to reduce complications, as life-threatening bleeding, thrombosis of the sigmoid sinus and - since it may be the main outflow pathway of the posterior fossa dural sinuses - venous ischemic and hemorrhagic consequences.

In the presence of a dehiscent (lateralized) internal carotid artery (ICA) (fig 7), petrous ICA canal has dehiscent lateral wall with protrusion of artery into middle ear. ICA is laterally displaced at level of cochlear promontory. The dehiscence is usually near the basal turn of the cochlea, may be an incidental finding or presents with pulsatile tinnitus. When prominent, a vascular retrotympanic mass may be seen otoscopically.

Concerning to the petrous portion of ICA, in order to avoid penetration during cochlear implant surgery, the preoperative CT evaluation of the minimal distance between the cochlea and carotid canal has been proposed as risk parameter in order to avoid inadvertent penetration of the electrode array into the petrous carotid canal during cochlear implant surgery. The thickness of the bone between the otic capsule and carotid canal (Fig 8) has been described to vary from 0.5 to 10 mm, with mean distances of 1.3-1.5 mm. Small or absent cochlea-carotid interval represents a potential surgical hazard during cochlear implantation and a possible source of auditory and vestibular symptoms.

**Aberrant carotid artery** is an enlarged inferior tympanic artery that occurs as a result of agenesis or underdeveloping of the cervical segment of the ICA. It presents as an abnormal tubular structure that runs along medial aspect of middle ear, enters posterior middle ear cavity through enlarged inferior tympani canaliculus and courses anteriorly across cochlear promontory to join horizontal carotid canal through a dehiscence in carotid plate. Other associated typical sign is the absence of carotid foramen and vertical segment of petrous ICA. This variant is important to recognize and report to avoid massive hemorrhage during middle ear surgery.

**Persistent stapedial artery** is an uncommon vascular anomaly in which embryological stapedial artery persists, presenting as a curvilinear structure arising from normal or aberrant ica, passing through the stapes footplate and crossing medial wall of middle ear cavity. Findings associated are the enlargement of tympanic segment of facial nerve and the absence of foramen spinosum. This condition can complicate surgical procedures on middle ear, as stapedectomy.

Pneumatization of the temporal bone is important for the choice of surgical technique, so the radiologist should indicate hypopneumatization (fig 9) or hyperpneumatization of
the mastoid. The closed canal wall technique in tiny mastoid cavity is technically difficult because of poor access, so in poor pneumatized ears, canal wall-down mastoidectomy is considered. CT is also useful to indicate a **low lying dura** (fig 10) lateral to the attic or an anteposed sigmoid sinus, that often coexist in sclerotic mastoid.

Conversely an extensively developed mastoid will result in a large cavity if the canal wall is taken down, and it may be difficult to manage postoperatively. **Hyperpneumatization** (fig 11) of temporal bone also increases the risk of postoperative cerebrospinal fluid leak after translabyrinthine approach.

**Koerner’s septum** (fig 12) is a plate of bone lateral to the antrum and represents the posterior extension of the petrosquamous suture line within the mastoid. It passes through the antrum, where it can be mistaken for the hard bone of labyrinth at surgery. As a consequence, when it is thick, there can be incomplete removal of disease during mastoidectomy.

In case of **dehiscent or prolapsing facial nerve** (fig 13-14), facial nerve protrudes through a segmental dehiscence of fallopian canal. The tympanic part of the bony canal next to the oval window is the most common site for dehiscence. In case of a large defect, the tympanic part of the facial nerve may even herniate and prolapse into middle ear. CT coronal images at level of oval window demonstrate soft tissue mass along the undersurface of the lateral semicircular canal. This anomaly implies risk of accidental iatrogenic facial nerve during middle ear surgical procedures, such as stapedectomy.

**Images for this section:**
**Fig. 1:** Asymmetric jugular bulb (asterisk)
**Fig. 2:** High-riding jugular bulb (white arrow) extending over basal turn of the cochlea
**Fig. 3:** Axial (A) CT image shows jugular bulb protruding in the middle ear; coronal CT (B) image demonstrates bony dehiscence.
**Fig. 4:** Anteriorly located right sigmoid sinus. A protrudent right jugular bulb in the middle ear is also seen.
**Fig. 5:** Mastoid emissary vein (white arrow)
Fig. 6: Mastoid emissary vein (white arrow)
Fig. 7: Axial CT scan shows an anomalous lateral position of the ICA genu which is located lateral to the vertical aspect of the bony cochlear labyrinth, characteristic of a lateralized petrous ICA
Fig. 8: In this coronal CT view distance between the cochlea and carotid canal is appreciable (white arrow)
Fig. 9: Sclerotic mastoids with anteriorly located sigmoid sinus
Fig. 10: Coronal CT section shows a low dura lying over the roof of the external auditory canal.
Fig. 11: The mastoids and the petrous pyramidalis are extensively pneumatized
Fig. 12: Koerner septum (white arrow)
Fig. 13: Coronal plane at the level of the oval window. Normal aspect of the tympanic portion of the facial nerve (white arrow)
**Fig. 14:** Dehiscent facial nerve (white arrow)
Conclusion

Anatomical variations of the temporal bone are not rare. Preoperative radiological evaluation with MDCT may prevent neurovascular injuries and contribute to surgical success by recognition of possible variants that, if undetected, may pose a hazard in the course of otosurgery.

Personal information

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