Original Article

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Study of Anatomical Variations of Temporal Bone Using High Resolution Computed Tomography of Temporal Bone

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Abstract

Background and objective: High Resolution Computed Tomography (HRCT), a modification of routine Computed Tomography, provides a direct visual window into the temporal bone providing minute structural details. Purpose of the present study is to evaluate the normal anatomical variations involving the temporal bone. *Materials and Methods*: A cross-sectional study of 80 randomly selected HRCT temporal bone films were studied in the department of ENT at Navodaya Medical College, Raichur during the month of February 2017. The HRCT films were studied in both the coronal and axial planes with thin 2mm sections using ultra high algorithm obtaining both contrast and non-enhanced images. Results were tabulated using percentages. *Results*: In our entire series of 80 films, we found that the facial canal was dehiscent in 2 cases. In both the cases, the dehiscence was at the region of the oval window niche. *Conclusion:* HRCT is a revolutionary imaging modality that helps in evaluating the anatomical variations affecting the temporal bone. HRCT of temporal bone predicts certain normal anatomical variants of surgical significance preoperatively.

Keywords: Human; Anatomy; Variations; Computed Tomography; Temporal Bone.

Introduction

Many imaging modalities are available for the evaluation of the temporal bone pathologies including plain radiographs, angiography, air and non-ionic contrast cisternography, computed tomography (CT), and magnetic resonance imaging (MRI). CT and MRI are currently the most widely used techniques and have largely replaced the other modalities [1]. CT scanning excels in the evaluation of bone and air space anatomy and disorders [2].

Because CT scans are more accurate in identifying many soft tissue abnormalities and are much less prone to artifacts, they have largely replaced polytomography; there is also less radiation to the lens of the globe with CT scans than with polytomography. CT has the advantage of producing images with higher contrast and a better spatial resolution [3].

High Resolution Computed Tomography (HRCT), a modification of routine CT provides a direct visual window into the temporal bone providing hitherto unavailable minute structural details [3]. The purpose of the study is primarily to study the different anatomical variations of the temporal bone using a randomly selected pool of HRCT films of temporal bones.

Materials and Methods

Our study is a cross-sectional study where in 80 randomly selected HRCT temporal bone films were studied in the department of ENT at Navodaya Medical College, Raichur of Karnataka state during the month of February 2017. The HRCT films were studied in both the coronal and axial planes with thin 2mm sections using ultra high algorithm obtaining both contrast and non-enhanced images. Pathological or fractured temporal bone HRCT films were excluded from the study.

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The CT scans were taken previously in the ENT department for evaluation of patients coming with ear symptoms. Patients were scanned in the axial and coronal (supine or prone) axes. Scout films were taken routinely in all patients before starting the scan. Scanning commenced from the lower margin of the external auditory meatus and extended upward to the arcuate eminence of the superior semicircular canal as seen on lateral topogram. HRCT comprises the use of a thin collimation, a high spatial frequency algorithm, smallest practical FOV (15 to 20cm) and a large reconstruction matrix (512 x 512). With a 1cm collimation the volume averaging within the plane of scan reduces the ability of CT to resolve small structures significantly. CT images are usually acquired or displayed in axial and coronal planes. For axial imaging, sections are made in a plane rotated 300 superior to the anthropologic base line. Scan produced in this plane display the temporal bone structures to good advantage. This plane allows separation of individual component of the temporal bone so that they are better visualized in their entirely, with less of overlap and fewer partial volume imaging artifacts. Direct coronal images are usually obtained at an angle of approximately 1200 from arthropologic baseline, while reconstruction coronal images are usually oriented 900 from arthropologic baseline.

All the 80 scans were studied for presence of anatomical variations of the temporal bones. We searched for anatomical variants like dehiscent facial nerve, aberrant internal carotid artery, Jugular bulb variants, persistent stapedial artery, anterior and wider sigmoid sinus, size of mastoid antrum, presence of Korner's septum, deep posterior wall recesses and low lying middle cranial fossa. Anatomical variations, if present, were noted down.

Results and Observations

In our study we noted that of the total 80 films, 52 (65%) were of male subjects and 28 (35%) were of female subjects. In our entire series of 80 films, we found that the facial canal was dehiscent in 2 cases. In both the cases, the dehiscence was at the region of the oval window niche (Figure 1). In both the cases, the bony canal defect was present over the oval window. In one case, the length of dehiscence was 1.4 mm and in another case, the length of dehiscence was 2.1 mm. We did not find any other anatomical variation mentioned above in the temporal bones' scan study.

Fig. 1: High-resolution ct scan of left ear, demonstrating dehiscence of facial nerve canal

Discussion

The two temporal bones are situated laterally at the base of the skull. Each one consists of five parts, namely squamous, mastoid, petrous, tympanic and styloid process. The squamous portion is easily seen on routine skull films. The styloid process can be studied in a prone Townes projection [2].

Squamous

The squamous portion forms the anterolateral, thin shell like part of the bone from which arises the zygomatic process. The external surface gives attachment to the temporalis muscle; it forms part of the wall of temporal fossa. The inner surface is concave and irregular. Meningeal vessels groove the inner surface. The superior border articulates with parietal bone, and the anteroinferior border with the greater wing of sphenoid [2].

Styloid Process

The styloid process is 2.5cm long and projects downward and forward, anterior to the stylomastoid foramen [2].

Mastoid

The mastoid portion is hollowed to form a number of mastoid air cells [1]. The largest air cell which is situated in the upper and anterior part is the antrum. It communicates with the remaining air cells and attic by a narrow channel called aditus ad antrum. In the upper and anterior part of the bone these cells are large and irregular, towards the middle they diminish in size and in the apexes are small [2].

Petrous Portion

The petrous portion is a three sided pyramid resting

on its side, wedged between the sphenoid and occipital bones with its long axis 450 to sagittal plane. its base is lateral and apex is directed medially. The apex has a shallow depression medially where the semilunar ganglion lies (Meckel s cave). The petrous portion has an anterior surface which, separates it from the middle cranial fossa. In the midportion is the arcuate eminence formed by the underlying superior semicircular canal. The cranial cavity is separated from the tympanic cavity by the tegmen tympani. The posterior surface is the bony demarcation between the posterior fossa and the tympanic cavity. It is more vertical. Near its centre is the internal auditory meatus which transmits the VIIth and the VIIIth nerves. The opening is Porous Acousticus. The lateral end of the internal auditory canal is closed by a bony plate known as lamina spirales, which separates the fundus of the canal from the vestibule. The fundus is divided by a bony crest crista falciformis into the smaller upper and the larger lower compartment. Postero-inferior to the internal aqueduct., superiorly and inferiorly are the respective petrosal sinuses [4].

The Tympanic Portion

It is a "C" shaped curved plate which forms the anterior wall, floor and posterior-inferior aspect of the external auditory canal [2]. At the medial end is the tympanic sulcus which lodges the tympanic membrane. The lateral border forms a large part of the margins of the opening of external auditory canal [4].

The External Auditory Canal

It comprises of a lateral fibro-cartilagenous part and a medial bony part. The osseous part is a bony canal 16mm long and is directed downwards, forwards and inward. On sagittal scan the canal is oval or elliptical with its long axis directed downward and slightly backward. The tympanic membrane is oriented obliquely so that the inferior and anterior walls of the external auditory canal are longer. It forms the medial boundary of the external auditory canal, separating the canal from the middle ear [2].

The Middle Ear

It is a irregular, laterally compressed space within temporal bone. It is filled with air conveyed from the nasopharynx via the Eustachian tube. It is transversed by an ossicular chain, connecting the lateral and medial walls. It consists of three parts. a) Mesotympanum b) Attic c) Hypotympanum [4].

Roof or Tegmen Wall

The tegmen tympani is a plate of bone that arises from the petrous portion of temporal bone. It separates the middle cranial fossa from the tympanic cavity. In children the lateral margin of tegmen tympani may be unossified and may allow direct passage of infection from the middle ear to epidural space [2].

Floor or Jugular Wall

It is a thin plate of bone that separates the hypotympanum from the internal jugular vein. The jugular foramen is a complex canal coursing anteriorly, laterally and inferiorly to exit from the skull base. It has a smaller anterior compartment (pars nervosa) and larger posterior compartment (parsvascularis). The terminal portion of the sigmoid sinus flows anteriorly to enter the jugular foramen (pars vascularis), turns laterally to expand and form the jugular bulb and then drains inferiorly into the internal jugular vein [5]. The Carotico-Jugular spine is a vertically oriented plate which separates the jugular foramen from the carotid canal [5].

Posterior or the Mastoid Wall

It has the aditus ad antrum superiorly which connects the epitympanic recess to the mastoid antrum. The pyramidal eminence is a "W" shaped elevation situated behind the oval window and gives origin to the stapedius muscle. It divides the posterior wall into two recesses [1]. The facial recess between pyramidal eminence medially and bony tympanic annulus laterally. The sinus tympani between the labyrinthine wall medially and pyramidal eminence laterally. The incudal fossa is a shallow depression in the epitympanum for the attachment of the posterior ligament of the short process of incus [2].

Anterior or Carotid Wall

It is wider above than below and corresponds to carotid canal, from which it is separated by a thin plate of cortical bone that is perforated by tympanic branch of internal carotid artery and by tympanic nerve. The internal carotid artery is intimately related to the horizontal vertical segments of the anterior wall. Superiorly are the orifices for origin of semicanals of tensor tympani and Eustachian tube [2].

Eustachian Tube

The tympanic cavity communicates with the nasopharynx through this tube. It is 3.5cm and is directed downward, forward and medially. It has both osseous and cartilaginous parts. The pharyngeal opening of the cartilaginous portion is "C" shaped and can open its lumen maximally during swallowing. This helps ensure that the middle ear and pharyngeal air pressures are equilibrated during swallowing [6].

Lateral or Membranous Wall

It is formed by the tympanic membrane. It is lodged in the tympanic ring. It is directed downwards and medially with an angle of 500 to the floor of external auditory canal. It is divided into two parts by the manubrium of the malleus. The superior pars flaccida and the inferior pars tensa [2].

The Medial or Labyrinthine Wall

This wall separates the inner ear from the middle ear. Posterior-superiorly is prominence produced by the anterior limb of the lateral semicircular canal. Below this and more anteriorly is the prominence of the intratympanic portion of the facial nerve canal. Anterior to this prominence is the curving terminus of septum canalismusculotuborii, which serves as a landmark for the position of geniculum of facial nerve. Immediately inferior to the facial nerve canal is the laterally directed oval window niche, which contains the oval window at its medial terminus. The promontory is a convex bulge formed by the otic capsule over the basal turn of the cochlea. Below and behind the promontory is the round window niche leading to round window. Posterior to promontory is subiculum-promontorii which forms inferior border of tympanic sinus [6].

The Tympanic Cavity

It consists of three parts: Mesotympanum-Medial to the tympanic membrane, Epitympanum or attic-Above the level of the membrane and Hypotympanum- Inferior and medial extension of the mesotympanum. The contents of the tympanic cavity are: 1) Auditory ossicles 2) Ligaments and muscles and 3) Facial nerve [2].

Auditory Ossicles

The ossicular chain extends from the medial to the lateral wall of the middle ear cleft and is a sound conducting medium. Malleus consists of head, neck, anterior process and lateral process. The head lies in the epitympanum. The neck (manubrium) is attached to the tympanic membrane. The lateral process abuts the tympanic membrane below the pars flaccida. The anterior process is a very small spicule of bone. The incus is shaped like a premolar. It has a body and two processes. The body has an anterior concavo-convex facet, which articulates with the head of malleus. The short process is placed horizontally and directed backwards. It is attached to the incudal fossa. The long process descends parallel to the manubrium and bends medially to end in a rounded projection called lenticular process. The stapes has a head, two crura and a foot plate. The head articulates with the lenticular process of incus. The neck is constricted. Stapedius muscle is inserted on its posterior aspect.

The anterior and posterior crura diverge from the neck and meet the foot plate. The foot plate covers the oval window. The ossicles are connected to the walls by ligaments and muscles [4].

Ligaments and Muscles

The anterior malleolar ligament commences from the neck of malleus and is inserted over the carotid wall. The superior malleolar ligament is attached from the roof of epitympanum to the head of malleus. The lateral ligament goes from the posterior part of notch of Rivinus to the head of malleus. The posterior incudal ligament connects the short crus of incus to the posterior wall of incudal fossa. The annular ligament of the base of stapes encircles the base of the stapes along the margin of oval window. Tensor tympani muscle is in an osseous compartment above the Eustachian tube. It takes a sharp bend around the processuscochleaformis and is inserted over the neck of malleus. Stapedius muscle arises from the hollow cavity of the interior of pyramidal eminence and is inserted on the posterior surface of the neck of stapes [4].

The Facial Nerve

It emerges from the brainstem by a sensory and a motor root; leaving the brainstem at the inferior border of pons medial to the VIIIth nerve. The intracranial segment is 23-25mm long. The internal auditory canal segment is 7-8mm and lies above the cochlear nerve. The labyrinthine segment is 3-4mm and passes forward and laterally in its bony canal (fallopian canal). At a point laterals to the cochlea. It angles forward perpendicular to the petrous to reach the geniculate ganglion. At the ganglion the direction of the nerve reverses. This is the first knee or genu. The

tympanic segment is 12mm long and passes posteriorly and laterally on the medial wall of the middle ear. It lies below the bulge of the lateral semicircular canal and above the oval window. At the level of sinus tympani the nerve assumes a vertical position. This is the second genu of the facial nerve. It runs along the posterior wall of the tympanic cavity to exit at the base of the skull from the stylomastoid foramen. This mastoid segment is 15-20mm in length. The three important branches of the facial nerve arising in the temporal bone are – 1) Greater superficial petrosal nerve arises at the geniculate ganglion and carries the secretomotorfibres to the lacrymal gland. 2) The nerve to the stapedius is given off in the mastoid course of the facial nerve behind the pyramid eminence. 3) The chorda tympani which is the special gustatory nerve to the anterior 2/3rd of tongue originates 5mm above the stylomastoid foramen [7,8].

The Inner Ear

The bony labyrinth consists of the vestibule, semicircular canals and the cochlea. Vestibule is an ovoid perilymphatic space, 4mm in diameter, opening anteriorly into the cochlea and posteriorly into the semicircular canals. The vestibule has two openings. Oval window – for communication with the foot plate of stapes.Vestibular aqueduct – this is a bony canal which extends from the posterior-medial wall of the vestibule to the posterior surface of the petrous pyramid. It is inverted "J" shaped. The proximal "isthmus" arches medial to the crus and measures 03mm in diameter. The duct widens inferiorly and forms a triangular slit parallel to the posterior surface of the pyramid. Outer aperture is 2-6mm in diameter. The aqueduct contains the endolymphatic duct which enlarges to end blindly in the endolymphatic sac on the posterior surface of the petrous pyramid [9].

Semicircular Canals

There are three canals communicating with the vestibule. Each canal makes 2/3rd of a circle and is 1mm in diameter. Each is enlarged anteriorly to form the ampulla. The non-ampullary ends of the superior and posterior canals join to form the common crus. A portion of the superior semicircular canal forms a ridge on the anterior surface of the petrous bone called arcuate eminence. The lateral semicircular canal projects as a ridge on the medial wall of the attic [9]. The superior and posterior semicircular canal are aligned in a vertical orientation perpendicular to each other. The superior semicircular canal is placed at an angle of 450 to the mid-sagittal plane antero laterally and is directed postero-laterally at a corresponding angle. The posterior semicircular canal is similarly placed with the angle directed postero-laterally. The lateral semicircular canal does not occupy a horizontal plane and for this reason the older terminology has been discarded. The anterior limb of the lateral semicircular canal lies in the plane higher than that of posterior limb, making at angle of 300 with the horizontal. In the erect position therefore the neck would have to be fixed about 300 for the lateral semicircular canal to be "horizontal" [9].

Cochlea

It consists of a central conical axis – modiolus and a bony canal wound spirally around it for 2 ½ turns [10]. The 1st turn bulges along the medial wall to form the promontory. The cochlear aqueduct is a well corticated notch medial to the pars nervous and inferior to porusacousticus. It serves as a potential communication between the sub arachnoid space and inner ear perilymph [9].

Anatomical Variants

The common anatomical variants of the temporal bone are dehiscent facial nerve canal, aberrant internal carotid artery, jugular bulb variants, persistent stapedial artery, anterior and wider sigmoid sinus, size of mastoid antrum, presence of Korner's septum, deep posterior wall recesses and low lying middle cranial fossa.

HRCT Appearance

1. *Dehiscent Facial Nerve:* The mid tympanic segment is the most common site of involvement. The nerve is seen in cross section below the lateral semi circular canal on coronal images. This nerve is prone to infection and surgical trauma [7].
2. *Aberrant Internal Carotid Artery:* It occurs when an enlarged inferior tympanic artery anastomoses with enlarged carotico-tympanic artery as a result of regression of cervical internal carotid artery. Aberrant internal carotid artery is seen entering the tympanic cavity through the enlarged tympanic canaliculus posterior to the normal internal carotid artery. It courses anteriorly across the promontory to join the horizontal internal carotid artery. It is seen as a soft tissue density and may mimic a vascular middle ear mass [11].
3. *Jugular Bulb Variants:*

   1. Asymmetric jugular bulbs- A high riding jugular bulb which extends above the tympanic spine 2) A dehiscent jugular bulb presents as a vascular

mass in the retrotympanum. It is best seen on coronal CT as being directly continuous with the middle ear. 3) Jugular diverticulum 47 is a finger like projection from the jugular bulb which projects cephalad [5,12,15].

4. *Persistent Stapedial Artery:* The foramen spinosum is absent and the proximaltympanic segment of the facial nerve canal is enlarged. This important anomaly is to be identified to prevent excess intraoperative bleeding [2].
5. *A wide Sigmoid Sinus and Mastoid Antral Size:* It is present more anteriorlyand the mastoid antral size is consequently compromised. The post auricular approach has to be guarded in these cases to prevent entry into the sigmoid sinus [2].
7. *Koerner's septum:* It is a bony demarcation between mastoid and temporalsquamae. It presents as a thick bony plate during mastoid surgery and may mimic sigmoid wall [2].
8. *Deep Posterior Wall Recesses:* These are the facial canal recess and sinus tympani.On occasion these may be abnormally deep and house occult infection [2].
9. *Low Lying Middle Cranial Fossa:* It occurs due to absence of tegmentalpneumatization. The tegmen plate is thin and prone to infection and surgical trauma [2].

In our entire series of 80 films, we found that the facial canal was dehiscent in 2 cases (2.5%). In both the cases, the dehiscence was at the region of the oval window niche. In both the cases, the bony canal defect was present over the oval window. In one case, the length of dehiscence was 1.4 mm and in another case, the length of dehiscence was 2.1 mm. Moreano et. al have mentioned in their study about prevalence of facial canal dehiscence to be 56%. Like in our study, their study also had the oval window area as the most site for facial canal dehiscence, followed by the facial nerve genu area and the area of tensor tympani [14]. Baxter has reported the prevalence of facial canal dehiscence as 0.75% in his study [15].

We did not find any other anatomical variation mentioned above in the temporal bones' scan study.

Conclusion

HRCT is a revolutionary imaging modality that helps in evaluating the anatomical variations affecting the temporal bone. HRCT of temporal bone predicts certain normal anatomical variants of surgical significance preoperatively.

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