"ASSESSMENT OF DEPTH OF JUGULAR BULB FROM VARIOUS MIDDLE EAR STRUCTURES AND ITS SIGNIFICANCE IN MIDDLE EAR SURGERIES- A CADAVERIC MORPHOMETRIC STUDY "

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LIST OF ABBREVIATIONS

GLOSSARY	ABBREVIATIONS
RW	Round Window
JB	Jugular bulb
IAC	Internal Auditory Canal
SS	Sigmoid Sinus
HJB	High Jugular bulb
IJV	Internal Jugular Vein
TM	Tympanic Membrane
ACC	Anterior Condylar Confluent
JBD	Jugular Bulb Diverticulum
PSC	Posterior Semicircular Canal
TT	Trautmann’s Triangle
CT	Computerised Tomography
MR	Magnetic resonance

ABSTRACT

Title: ASSESSMENT OF DEPTH OF JUGULAR BULB FROM VARIOUS MIDDLE EAR STRUCTURES AND ITS SIGNIFICANCE IN MIDDLE EAR SURGERIES- A CADAVERIC MORPHOMETRIC STUDY

Objectives:

1. Assessing the depth and distance of the vertical segment of the facial nerve from the jugular bulb.
2. Assessing the depth and distance between the jugular bulb and posterior end of round window niche.

Methods:

- A one-year study was undertaken and cadaveric dissection was performed on 30 wet mount, formalin-fixed temporal bones.
- Evaluation of distance of the jugular bulb apex was recorded from posterior end of the round window niche and vertical segment of the facial nerve.
- The results are gathered and assessed based on difficulty of approach and depth of the jugular bulb from these structures.

Results:

- The study found that 60% of the bones were right-sided, and 66.7% had a visible pinna.
- The external auditory canal was patent in 96.7% of cases, and the tympanic membrane was intact in 96.7% of specimens.

- Prominent mastoid tips were observed in 76.7% of cases, with 70% showing pneumatization.
- The ossicular chain was intact in all cases.
- The subiculum showed ridges in 66.7% and bridges in 33.3%, while the funiculus exhibited ridges in 83.3%, bridges in 13.3%, and was absent in 3.3%.
- Descriptive measurements of the vertical segment from the jugular bulb apex and the round window niche were also recorded; at the lowest level, where the facial nerve exits the middle ear cavity through the stylomastoid foramen being only 3.47±1.04 mm was the most significant finding as here chances of injury to the jugular bulb and facial nerve is highest due to their close proximity to each other.
- Similarly, from the middle segment of facial nerve 5.59±1.07 mm, and uppermost segments, at the level of second genu measure 8.46±1.28 mm.
- The findings also indicate that the distance between the JB apex and the posterior end of the RW niche can vary significantly among individuals, with mean measurements ranging from approximately 2.77 mm to over 10 mm.

Conclusion:

In our study, we dissected and analysed 30 wet-mount, formalin-fixed temporal bone specimens to assess various anatomical features. The findings emphasize the importance of understanding temporal bone anatomy for surgical planning, especially in otologic skull-base procedures. The variations observed, particularly in the jugular bulb position, facial nerve canal, and round window niche,

may pose significant challenges during middle ear surgeries. The study highlights the critical role of anatomical knowledge in avoiding iatrogenic complications and improving surgical outcomes. Additionally, the findings reinforce the need for incorporating advanced imaging modalities, such as high-resolution computed tomography and magnetic resonance imaging, in routine preoperative assessments to better visualize anatomical anomalies. In view of the paucity of data regarding the relationships of these anatomical structures, further studies with larger sample sizes, diverse demographic representation, and technological advancements will contribute to refining surgical techniques and optimizing patient safety and outcomes.

Keywords: Jugular Bulb, Facial nerve, Round window

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INTRODUCTION

Middle ear surgeries consist of some of the most complex procedures known due to the microscopic anatomy and close relations of multiple critical structures which are not only related to the hearing mechanism but also surrounding it . The procedures may be indicated due to a multitude of condition but requires extensive training and methodical planning beforehand. Each procedure is unique, pertaining to a particular individual, presenting with its own set of challenges, possible complications and expected outcomes.

Recent developments in neuro-otologic diagnosis and surgery have indicated the necessity for a thorough revaluation of the jugular bulb's relationship and relevance to other middle ear structures.

During the era of septic temporal bone disease and surgery, the specialty of otology was established, and a great deal of knowledge was acquired about these important temporal bone venous structures. But popularity of these structures declined with the end of this era and advent of newer generations of antibiotics. It wasn't until lately that it became clear that a re-evaluation was urgently required due to extensive progress in lateral skull-base and neurosurgical procedures.

Internal jugular vein (IJV) is an anatomical extension of sigmoid sinus (SS), which is responsible for draining the majority of venous blood through intracranial cavity. Jugular bulb (JB) is its initial slightly enlarged segment, oriented towards hypotympanum base. The bony jugular fossa surrounds the bulb, which is located inferior and posterior to internal auditory canal (IAC) near base of petrous bone pyramid. Pneumatization is infrequent, and compact bone separates it from IAC. Apex is highest portion of bulb.[1]

JB is a crucial component of cranial venous system, connecting SS to IJV within jugular fossa and positioned posterolaterally in pars vascularis area of jugular foramen.[1] Delicate interaction between venous channels and neurological pathways near base of skull is highlighted by JB's proximity to cranial nerves IX, X, and XI as well as its connection to cavernous sinus via inferior petrosal sinus. [2] JB's upper boundary is usually located beneath the hypotympanum, placing it at a crucial point close to several significant temporal bone anatomical characteristics, encompassing carotid artery, round window, and vertical portion of the facial nerve. [4]

Jugular foramen is significant for lateral skull base surgery, especially concerning extracranial or intracranial diseases.[5] Surgery that does not directly involve the JB, like neurotologic[6] or cardiac[7] surgery, depends on its accessibility. Accurately identifying and controlling normal venous drainage channels from lateral skull or infratemporal fossa requires this. It establishes limit for exposure in a variety of surgical techniques aimed at the posterior fossa, including retrolabyrinthine, translabyrinthine, and transcochlear.[8] The JB's exposure methods and manipulation, which are usually restricted to skeletonization and cauterization, highlight the need for careful surgical planning and exact anatomical understanding of need to maintain the integrity of this intricate area. [9]

“High jugular bulb (HJB) is congenital variation that is demonstrated to impact middle as well as inner ear structures. In addition to causing associated clinical symptoms encompassing vertigo, conductive hearing loss, or pulsatile tinnitus, an aberrant JB can even erode into facial nerve, vestibular aqueduct, and posterior semicircular canal”. [11-13]

It has been demonstrated that a hypopneumatized mastoid system increases the chance of developing several middle ear conditions.[10] **"**Variabilities and variations of these vessels have been thought to be impacted by several elements, encompassing mastoid's pneumatization, as previously documented. [14] According to Graham[15] and Aladeyelu et al.[16], pneumatization of temporal bone was associated with height and shape of JB.

"High jugular bulb" (HJB) is the most clinically significant and prevalent anatomic variation of the temporal bone (TB). A JB may not arise, in which case IJV is produced directly from SS.

Although most HJBs are asymptomatic, some people may exhibit the clinical symptoms that are linked to the condition, such as vestibular dysfunction, pulsing venous tinnitus, or hearing impairments. [31-35]

Recent developments in neuro-otologic diagnosis and surgery have shown that the relationship and importance of JB concerning other temporal bone structures need to be thoroughly reevaluated.

The relevance of the JB and sigmoid sinus has changed in the modern era with stapes, tympanoplasty, sigmoid sinus, glomus tumour, acoustic neuroma, and cochlear surgery.

The goal of our study is to compile our understanding of the JB and facial nerve in a current, thorough, and pertinent manner. Historical material will only be discussed in detail when it is pertinent to the demands of modern otology, and clinical entities that are rarely seen in modern times will only be mentioned briefly to ensure the research is thorough.

AIMS AND OBJECTIVES

1. Assessing the depth and distance of the vertical segment of the facial nerve from the jugular bulb.
2. Assessing the depth and distance between the jugular bulb and posterior end of round window niche.

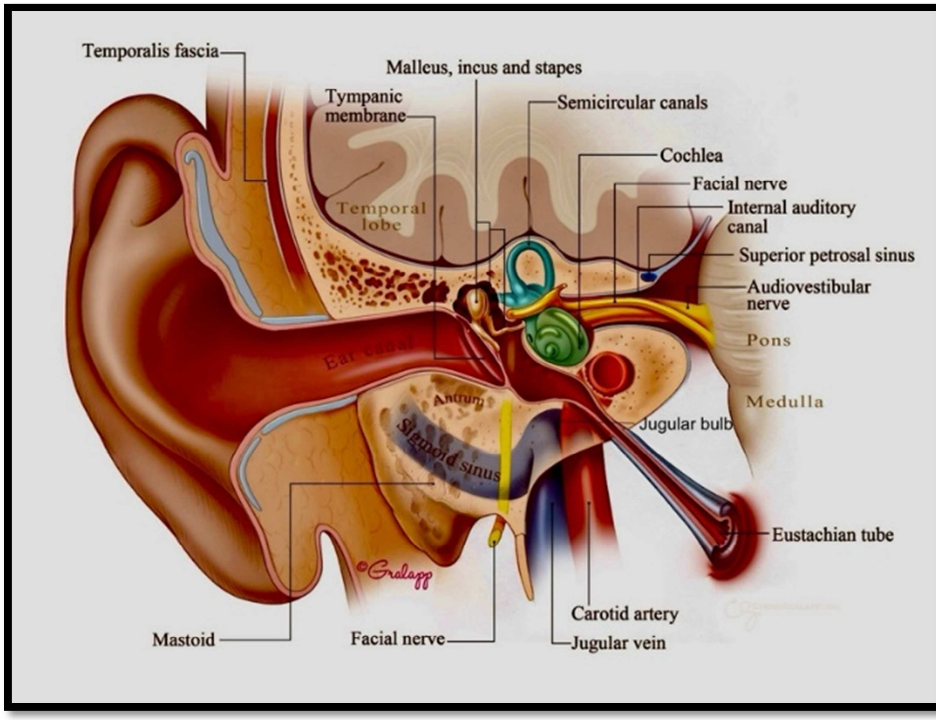
REVIEW OF LITERATURE

Surgical anatomy and pathology of the middle ear[37]

The ear is a strong, precise, and reliable sense organ. The ear's primary function in social communication is combined with its significance as the body's primary warning sensor from an evolutionary perspective. It is the foundation of two human sensory systems since it contains both the acoustic organ and the equilibrium organ. Our most significant biological information source, after sight, is hearing. Immanuel Kant eloquently characterized the significance of hearing sense of hearing for human social life: ‘Blindness separates people from things. Deafness separates people from people’.

Compared to ‘functional anatomy’, which addresses question ‘What function does an anatomical structure have and how does its design contribute to this?’, ‘Surgical anatomy’ focuses on question: ‘What can go wrong in the human middle ear? Do pathologies and their complications have an anatomical or developmental basis? What are the consequences of the middle ear anatomy for surgery and vice versa?’.

Figure 1: Middle ear cleft



The majority of middle ear space is represented by tympanic cavity. However, the tympanic cavity isn't a distinct air-filled chamber housed inside temporal bone; rather, it connects backward with mastoid cavity by a recess termed tympanic antrum and communicates anteriorly with epipharynx through auditory (Eustachian) tube. Middle ear cleft is formed by adjacent pneumatic spaces of mastoid, Eustachian tube, and tympanic cavity. These areas have a significant influence on middle ear surgeries.

Understanding 2-D anatomy (i.e., studying anatomical atlases) is not enough. The surgeon must learn the intricate, three-dimensional interactions between the structures in the ear by dissecting human temporal bones before performing ear surgery. Additionally, the instruments utilized in ear surgery differ greatly from those employed for other surgeries, and the surgeon must be proficient in them before conducting surgery on a live patient. Binocular microscope is used for all middle ear surgeries because of the low size. Finger movements must be correlated with this expanded vision through extensive training with temporal bone preparations.[37]

Tympanic membrane

Tympanic membrane, also known as eardrum or membrana tympani, forms lateral boundary of tympanic cavity and is situated at medial end of external ear canal. In human body, it is the only membrane with air surrounding it on both sides. TM is made up of 3 layers, with fibrous stratum (lamina propria) being major component in middle and providing stability to membrane. Its thickness is around 0.1mm, and its diameter is approximately 10mm.

Two epithelial layers cover the fibrous stratum on either side. Stratified, keratinizing epithelium, a thin extension of skin lining external ear canal, forms this layer on the lateral side. This condition becomes crucial when cholesteatoma develops (see below), as the disease is caused by a TM retraction pocket or TM perforation.

Cuboidal, mucosal epithelium from medial side forms epithelial layer. A sulcus of bony ear canal anchors thicker annulus fibrosus of the membrane, which is made of fibrocartilage.[37]

The TM is anatomically separated into two parts: the considerably "smaller flaccid portion (pars flaccida or Shrapnell's membrane) and tense portion (pars tensa). Wide section of membrane beneath malleus' neck, inferior to plicae mallearis anterior and posterior, which is surrounded by the annulus, is referred to as the tense portion. Tense portion is transparent when healthy, but scarring, inflammation, or effusion can cause a distinctive color shift. An annulus is absent from the flaccid region that covers incisura Rivini of lateral epitympanic wall between processus brevis mallei and bony ear canal roof (tympanic notch). Here, TM fits directly into bony ear canal. In contrast to pars tensa, pars flaccida does not have a fibrous layer" in middle.

At "superior end of manubrium (malleus handle) is short process of malleus (processus brevis, sometimes referred to as lateral process). Manubrium ends distally in the TM's umbo and stays loosely attached to the pars tensa. There is a small outward convex curvature between the annulus and the manubrium, giving membrane a conical appearance, with umbo of TM being most depressed point".

TM can be viewed as the middle ear apparatus's vibrational driver from a functional perspective. Sound pressure waves enter ear canal and travel to TM to initiate hearing process. The TM vibrates in response to vibrations of air molecules. The last vibration of hair cells in cochlea originates from impedance change that middle ear produces, which converts vibrations in air into vibrations in cochlea fluid.

A healthy middle ear depends on the TM's acoustic characteristics. Its micro- and macro-anatomy are directly related to the TM's ability to respond to the lowest sound pressures while also enduring very significant (atmospheric) pressure differences. Therefore, it is necessary to take into account the unique physical properties of the TM when performing surgery on it.[37]

Tympanic cavity

Tympanic cavity, which is vital primary component of middle ear cavity, is space between inner ear and external ear canal. A mucosal epithelium that is cuboidal to columnar and contains scattered goblet cell lines. A microscope is required for manipulations since almost all of the significant anatomical structures are less than 10 mm apart. The tympanic cavity has a mean height of 12.8+7.2mm, width of

7+1.2mm, and depth of 10+1.2mm, and it is "bounded by six not too clearly demarcated walls" in each direction, much like a cube.

Tympanic cavity and middle cranial fossa are divided by superior paries tegmentalis (tegmen tympani), which forms floor of one compartment and roof of the other. A middle ear infection could spread to intracranial space or cause dura damage while manipulating the tegmen tympani because it frequently has a very thin bony layer. Meninges (meningocele) or brain (meningoencephalocele) may herniate into middle ear cavity due to a disturbed tegmen and a potential dura defect, which can cause cerebrospinal fluid to flow.

The hypotympanum, or floor of the tympanic chamber, is represented by the inferior paries jugularis. Although bone normally makes up this floor, some air-filled cells may also excavate it irregularly. The JB, which is the dome of IJV, is located just beneath floor. Otosurgeon may unintentionally open it, which could result in significant and problematic venous bleeding.

Labyrinth capsule, which is lateral cochlear wall with its basal turn forming promontory, constitutes majority of the medial paries labyrinthica. Dorso-superior to promontory is oval window (vestibular window; fenestra vestibuli), while caudal to it is round window (fenestra cochleae). Stapes footplate closes oval window, but a membrane alone seals the round window. Opening the labyrinth could cause perilymph to leak, which could cause varying degrees of vertigo and deafness.

The sinus tympani indistinctly encloses the posterior border (paries mastoidea). Through the antrum region, its superior portion opens into mastoid.

Anterior border, known as paries caroticus, is a location that should only be handled carefully because opening an exposed carotid artery could be fatal. However, since the carotid artery is typically entirely covered in bone and severe pathologies are uncommon there, it is typically not visible during middle ear surgery. The eustachian tube opens into tympanic cavity superiorly and laterally to carotid artery. Its bony canal contains tensor tympani muscle, which runs supero-medial and parallel to tube.

TM and its bony frame effectively compose lateral paries membranaceus. Three levels of the tympanic cavity can be distinguished clinically: hypo-, meso-, and epitympanum. There are no functional components in the hypotympanum, which is the level below TM. Its clinical and surgical importance stems from possibility of opening JB here as well as middle ear diseases that start at mesotympanum level and might spread to this region, making treatment challenging. A portion of middle ear muscles or their tendons, stapes, oval and round windows, facial nerve, and long processes of malleus and incus are all located in mesotympanum (level of TM). Epitympanum, which is situated above the TM, contains the malleus and incus's major upper sections. [37]

Jugular bulb and its anatomical and clinical considerations[38]

Location and Structure

- **Position**: The JB is situated inside the jugular foramen, at base of skull. IJV, which drains blood from brain, begins at this structure.
- **Shape and Size**: Each person has a different size and shape. It is frequently referred to as a high-riding JB because it extends into the middle ear cavity.

Surrounding Anatomy

- **Cranial Nerves**: Several cranial nerves pass close to the JB, involving the accessory, vagus, and glossopharyngeal nerves.

- **Carotid Artery**: The JB is closely connected with the carotid artery, requiring attention during surgical interventions to prevent injury to these critical structures.

- **Sigmoid Sinus**: The sigmoid sinus, another large vein that removes blood from the brain, continues into the JB.

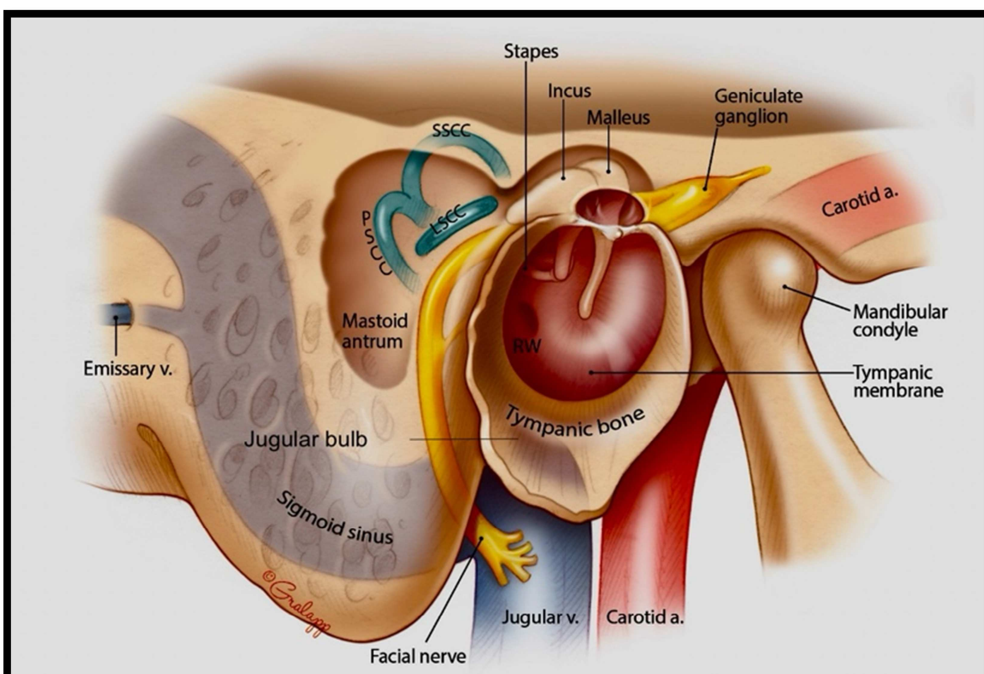
Relations

- **Superiorly:** Vestibule, middle ear, external auditory canal, posterior semicircular canal, internal auditory canal

- **Anteriorly:** Lower cranial nerves, meningeal branch of ascending pharyngeal artery, inferior petrosal sinus, internal carotid artery, posterior meningeal artery, cochlear aqueduct

- **Posteriorly:** sigmoid sinus, facial nerve, occipital bone

Figure 2: Relations of Jugular bulb



One important venous structure is the JB, which is a “dome-shaped dilatation that reaches into the tympanum's floor. It inhabits jugular fossa on extracranial side of jugular foramen and” connects SS and IJV. Since these anatomical entities represent various anatomical properties, it is crucial to accurately identify and differentiate between them.

According to anatomical terminology, “dilatation of IJV at its origin in jugular foramen is known as superior bulb of IJV (bulbus superior venae jugularis). Various venous affluents flow into JB through petrosal confluence or Trolard's anterior condylar confluent (ACC). ACC is situated in anterior condylar fossa, where hypoglossal canal” exits the cranium. Thus, it is positioned antero-inferiorly to JB. The ACC is directly related to IJV, anterior condylar vein, “inferior petrosal sinus, lateral condylar vein, Trolard's inferior petrooccipital vein, prevertebral vein” or plexus, and clival diploic veins (figure 6 and 7). Due to their lack of valves, these veins let venous flow in multiple directions. Additionally, “in cases of dural arteriovenous fistulas”, retrograde venous flow into SS is made possible by the ACC's integration with IJV or IJV bulb through vein bridging.

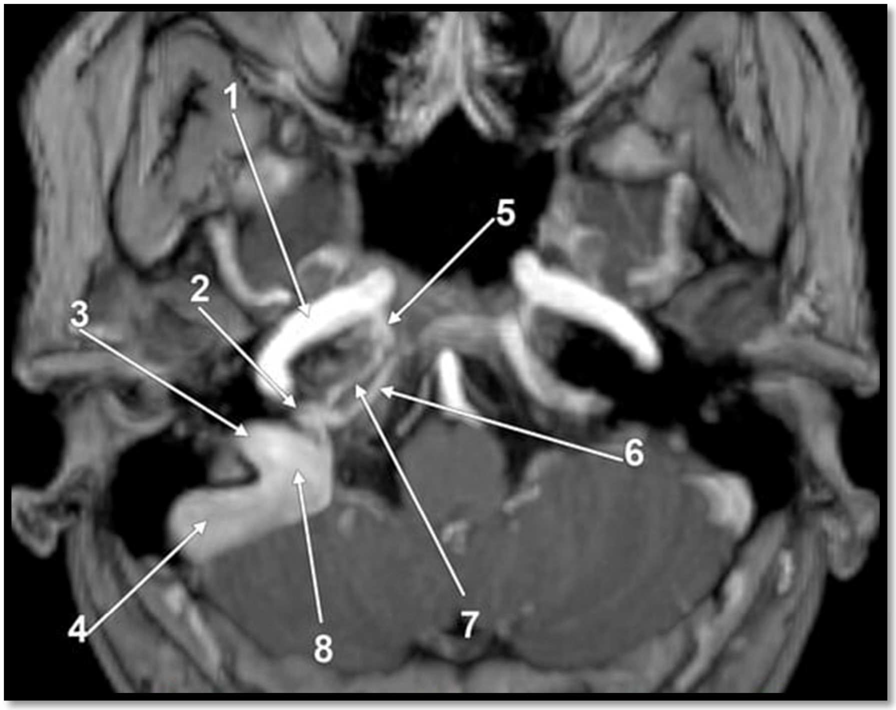


Figure 3. "**The venous anatomy antero-medial to the initial segment of the internal jugular vein. MR angiogram.** Curved-planar axial slice viewed inferiorly. Right side. 1. internal carotid artery; 2. anterior condylar confluence; 3. internal jugular vein; 4. sigmoid sinus; 5. venous plexus of Rektorzik; 6. inferior petrosal sinus; 7. inferior petrooccipital vein of Trolard; 8. jugular bulb". [38]

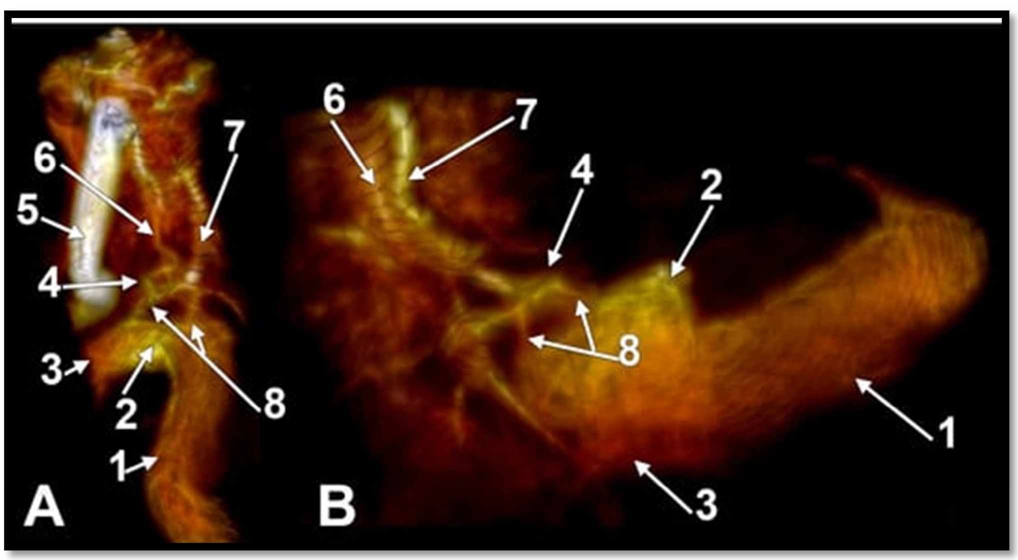


Figure 4. "**The anterior condylar confluent of Trolard. MR angiogram.** Three-dimensional volume renderings on the right side, viewed supero-laterally (**A**) and laterally (**B**). The internal carotid artery was cropped out in (**B**). 1. sigmoid sinus; 2. jugular bulb; 3. internal jugular vein; 4. anterior condylar confluent; 5. internal carotid artery; 6. inferior petrooccipital vein of Trolard; 7. inferior petrosal sinus; 8. bridging veins". [38]

“High JB (HJB), JB dehiscence, hypoplasia and hyperplasia, and JB diverticulum (JBD) are among JB variations. The HJB is most prevalent and significant anatomical variation of JB”, and it often results in difficulties in diagnosis, treatment planning, and surgery.

Facial nerve and chorda tympani

Middle ear's vascular supply and innervation are provided by a variety of nerves and smaller blood vessels. However, most surgically relevant neural structures—chorda tympani and facial nerve—primarily cross middle ear and have little to no functional contribution to ear.

Facial nerve is always near any surgical incision made in middle ear and passes through entire temporal bone. Nerve “runs along back wall of tympanic cavity cranial to oval window within its bony canal (Fallopian canal) immediately after forming its second (outer) "knee-bend" (geniculum nervi facialis) close to cochleariform process in anterior part of middle ear. After there, it travels dorsally, inferior to lateral semicircular canal (prominentia canalis semicircularis lateralis), until it reaches stylomastoid foramen, where it leaves skull. Therefore, the surgeon must be aware of nerve and know its precise location while doing middle ear surgery, whether it is in mastoid cavity or” tympanic. When doing a posterior tympanotomy, which involves drilling in mastoid beneath semicircular canal, and operating in the vicinity of the stapes footplate, particular attention must be given to facial nerve. Normally, nerve passes in bony canals with bone covering them. The most prevalent anatomical defect of the nerve, however, is dehiscence of bone canal with an exposed nerve. Facial nerve's anatomical path via temporal bone is comparatively stable.

The chorda tympani's path is presented to the surgeon during any middle ear procedure. Chorda tympani may need to be sacrificed (cut through) in situations of chronic otitis media and, more specifically, cholesteatoma to increase safety and achieve complete eradication of condition (i.e. if chorda tympani is lodged in cholesteatoma). It's necessary to stretch and reposition chorda tympani to enhance access to middle ear and, in particular, ossicular chain during endaural approach to stapes during otosclerosis surgery. Chorda can be temporarily moved aside due to its flexibility, however, it could cause taste problems. These usually disappear rapidly since 6 nerves on either side of mouth (nervi VII, IX, and X) that express taste eventually restore the entire sense once again. However, the chorda may sustain an unintentional injury, especially when a portion of the dorsal aspect of bony ear canal is removed. Similarly, drying up nerve fibers due to the constant intense light from surgical microscope or merely touching exposed nerves with a thick suction tube might damage nerve's ability to function. [37]

Eustachian tube

Three key roles of the middle ear tube are described in otolaryngology textbooks: ventilation, clearance, and protection (against autophonia and bacterial dissemination from nasopharynx). It is debatable, though, if auditory tube completely serves a purpose in middle ear ventilation. Although there are many tubal tests (Valsalva, Politzer maneuver, etc.) and an extensive body of literature regarding the significance of tubal function in emergence of middle ear disorders, "tubal dysfunction" with regard to middle ear aeration and pressure control has never been established or defined with certainty.

The bidirectional gas exchange between tympanic cavity and middle ear mucosa's blood vessels may also account for the morning overpressure in the middle ear following a prolonged period of non-opening of the tube. Therefore, it is possible to balance middle ear pressure without a tube. Other investigations did not demonstrate that there is any gas shift from nasopharynx to tympanic cavity during tube opening phases or even demonstrated that swallowing caused the middle ear to de-aerate instead than aerate. Therefore, all research examining function of middle ear tube yields intricate results that are challenging to understand. [37]

Variations in Jugular Bulb Anatomy

1. Hypoplasia and Hyperplasia of the Jugular Bulb

Literature review identifies a weakness in quantitative analysis and objective definition of JB hyperplasia and hypoplasia. For example, there is no empirical support for the two investigations conducted by Graham[39] that propose the typical dimensions of JB to be 15mm broad and 20mm high, including measurements, standard deviations, reference numbers, and range data. Since there is no hard evidence to back up these arguments, this omission diminishes their applicability. The normal JB's dimensions (anteroposterior: 0.68 cm; mediolateral: 0.76 cm) are also provided by Friedmann's study[13] on “prevalence of JB anomalies and the resulting inner ear dehiscence, but it excludes the maximum diameter. We have a gap in our knowledge of JB variations beyond these parameters” since, although their results indicate that the normal JB diameter falls between 0.5 and 1.5 cm, which is what we propose, it does not account for hyperplastic or hypoplastic circumstances.

Furthermore, ambiguity in current academic discourse surrounding JB dilatation is further illustrated by use of terms like phlebectasia rather than hyperplasia without any measurements or numerical data. [40] Such explanations are inadequate for properly detecting and categorizing JB problems because of this imprecision. Employing no numerical measurements to establish sinusojugular hypoplasia, Moretti (1976) reported a case of the condition. [41]

This sort of qualitative discussion is also present in “Kennedy et al.'s [42] considerations on JB enlargement”, which do not provide precise measurements or objective standards for defining JB enlargement. Without setting quantitative criteria for what qualifies as enlargement, the emphasis is still on the clinical consequences, size and location variations, along with their effects on otologic surgery and patient symptoms. Although this qualitative method draws attention to the variation in JB anatomy, it is inadequate in offering a framework for methodical evaluation.

People with achondroplasia have been found to have a greater incidence of larger JBs. In individuals “suffering from Paget's disease, particularly those with substantial skull involvement, enlargement” of the JB has also been observed. Although increased venous flow may also contribute to this expansion, bone remodeling is the main cause. “Arteries, arterioles, and associated venous blood vessels were observed to increase greatly in size and number in cases of widespread pagetoid bone transformation. This resulted in a large expansion of JB in all temporal bones exhibiting active bone transformation.”

Additionally, it has been shown that sclerosteosis causes the jugular venous system to significantly narrow, which causes intracranial pressure as a result of bone remodeling and severe JB constriction. Lumina of JB and the lower part of SS were discovered to be severely restricted. Surgery was shown to be potentially life-saving, involving decompression of transverse SS and JB, as well as “posterior and, if necessary, anterior craniectomy for decompression.

Although these studies offer pertinent information regarding the presence of enlarged JBs in diseases such as achondroplasia and Paget's disease, as well as apparent narrowing observed in sclerosteosis, it is" important to note that these analyses do not precisely identify or classify what an altered dimension of JB is, even though they describe the effects of these diseases on the JB's dimensions.

A systematic classification method is required in light of these findings to evaluate JB variations properly. "A JB diameter of 5mm or less must be classified as hypoplasia, as suggested in the previous study, and a JB diameter of at least 15 mm should be classified as hyperplasia". In order to improve diagnosis, communication, and research in field, this proposal seeks to close the existing gap in the literature by offering simple yet efficient way to classify JB aspects. Implementing classification could standardize evaluation of JB variations, improving "clinical and surgical planning precision and fostering a more thorough academic understanding of these conditions".

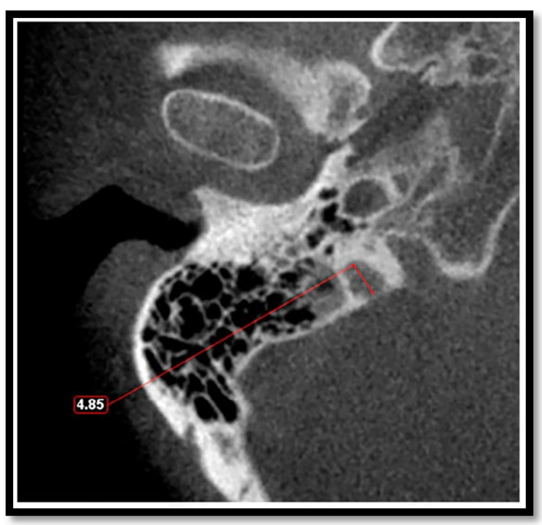


Figure 5. "Axial slice through the right hypoplastic jugular bulb reveals an underdeveloped structure with a maximum diameter of less than 5 mm".[38]

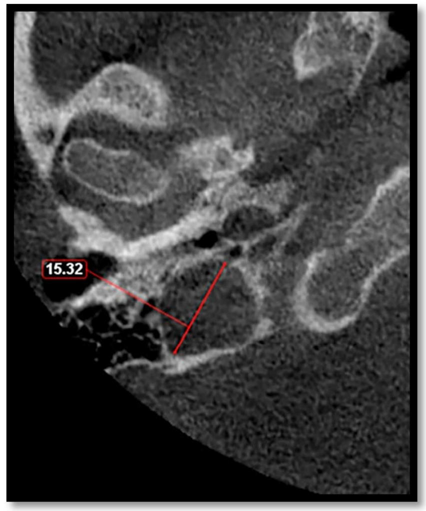


Figure 6. "Axial slice through the right hyperplastic jugular bulb illustrates an enlarged structure with a maximum diameter exceeding 15 mm". [38]

The left IJV's caliber was 7.28 mm, whereas the right IJV's was 11.4 mm in the case described above. The left JB's transverse diameter was 8.16 mm, while the right JB's was 13.8 mm. Significantly, right JB and right IJV are dominant, even if both JB values are within typical range of 5-15mm.

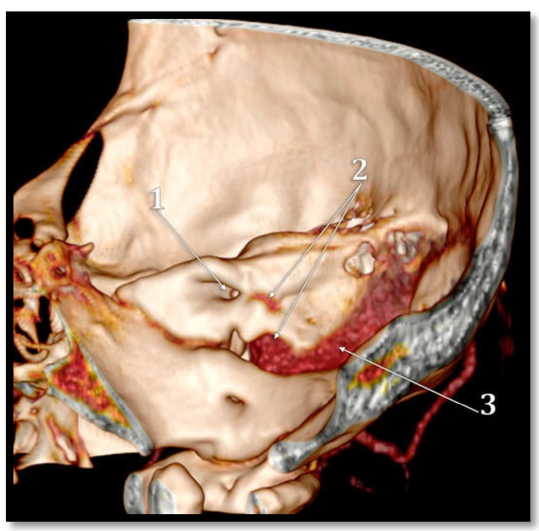


Figure 7. "Three-dimensional volume rendering of the right temporal pyramid. Medial view. 1. internal acoustic canal; 2. high jugular bulb; 3. sigmoid sinus". [38]

2. Diverticula

JBD's occurrence, anatomical characterization, and possible health risks have all been examined in a number of research that investigated into its prevalence and clinical implications.

In a thorough investigation employing "dry skulls having plastic casts and CT scans, Wadin et al.43,44,45 found JBD in 32 of 84 cases analyzed by CT and 17 out of 245 in dry skulls. As evidenced by 28 cases, their results showed that JBD usually extends in a medio-vertical orientation. A JBD is defined as a protrusion from dome of high fossa, indicated by a waist-like edge in contour of fossa, and a high fossa, which extends up to and above level of round window."

Lower prevalence was observed by Bilgen et al.[46], who found "17 cases with JBD out of 1474 CT scans. In order to distinguish between posterior and anterior JBD with respect to an axial reference line, they described JBD as a real venous anomaly, an outpouching of JB that extends superiorly, medially, and posteriorly within petrous bone."

3. High jugular bulb

It's critical to first distinguish between a JBD and an HJB. Venography made this disparity more evident, highlighting the need for imaging methods in correctly diagnosing these conditions. According to Wadin et al.[43], a HJB is a JB structure that resembles a waist. But according to "Vachata et al.[33], the JBD is more accurately described as a protrusion that resembles a finger. As a result, we draw attention to the differences between superior diverticula and a true HJB", particularly with regard to their size in relation to the primary vessel.

In contrast to temporal bone histology specimens, Friedmann et al.[40] further explain that temporal bone CT can be used to distinguish HJBs from JBD. This approach emphasizes how crucial advanced imaging is to the exact anatomical classification of JB variants, enabling precise diagnosis and guiding surgical strategy. In contrast to temporal bone histology specimens, Friedmann et al.[40] further explain that temporal bone CT can be used to distinguish HJBs from JBD. This approach emphasizes how crucial advanced imaging is to the exact anatomical classification of JB variants, enabling precise diagnosis and guiding surgical strategy.

Despite not offering prevalence information, Manjila et al.[47] established a unique classification system for JBs that emphasizes continuous attempt to more accurately classify these anatomical abnormalities. They suggested a 5-type classification of JB's anatomical location based on CT. However, the lack of precise measurements or particular prevalence data in their classification scheme suggests that additional numerical evidence is required to support any new categorization approach.

. “Types and subtypes of the jugular bulb (JB)—the classification of Manjila et al[47]. PSC—posterior semicircular canal; IAC—internal acoustic canal”.

Type	Subtype	Description
1		no JB
2		JB below the PSC
	2A	the JB is not dehiscent into the middle ear
	2B	the JB is dehiscent into the middle ear
3		JB between the PSC and IAC
	3A	the JB is not dehiscent into the middle ear
	3B	the JB is dehiscent into the middle ear
4		JB above the IAC
	4A	the JB is not dehiscent into the IAC
	4B	the JB is dehiscent into the IAC
5		combination of dehiscences

Figure 5 illustrates the "high and dehiscent JB that was recorded in the case that was described. The internal wall of the facial nerve canal was dehiscent toward the right JB, and a 0.6 mm thin wall separated it from mastoid air cells posteriorly and posterolaterally. Near the sinus tympani, round foramen, and fustis, the right JB was dehiscent anterolaterally toward the retro- and hypotympanum (**figure 8).** A superior diverticulum length of 3.11 mm posterior to the IAC, reaching 1.33 mm posterior to the IAC's roof, was projected by the superior side of the JB inferiorly to the cochlea. In the posterior cranial fossa, it extended across the posterior face of the temporal pyramid and had a thin posteromedial wall. A 1.17 cm long and 1.58 mm thin right styloid process was also observed on the lateral side of the JB and IJV". Preoperative imaging is crucial because this anatomical variation has the potential to be misdiagnosed as a glomus tumor, which makes it clinically relevant.

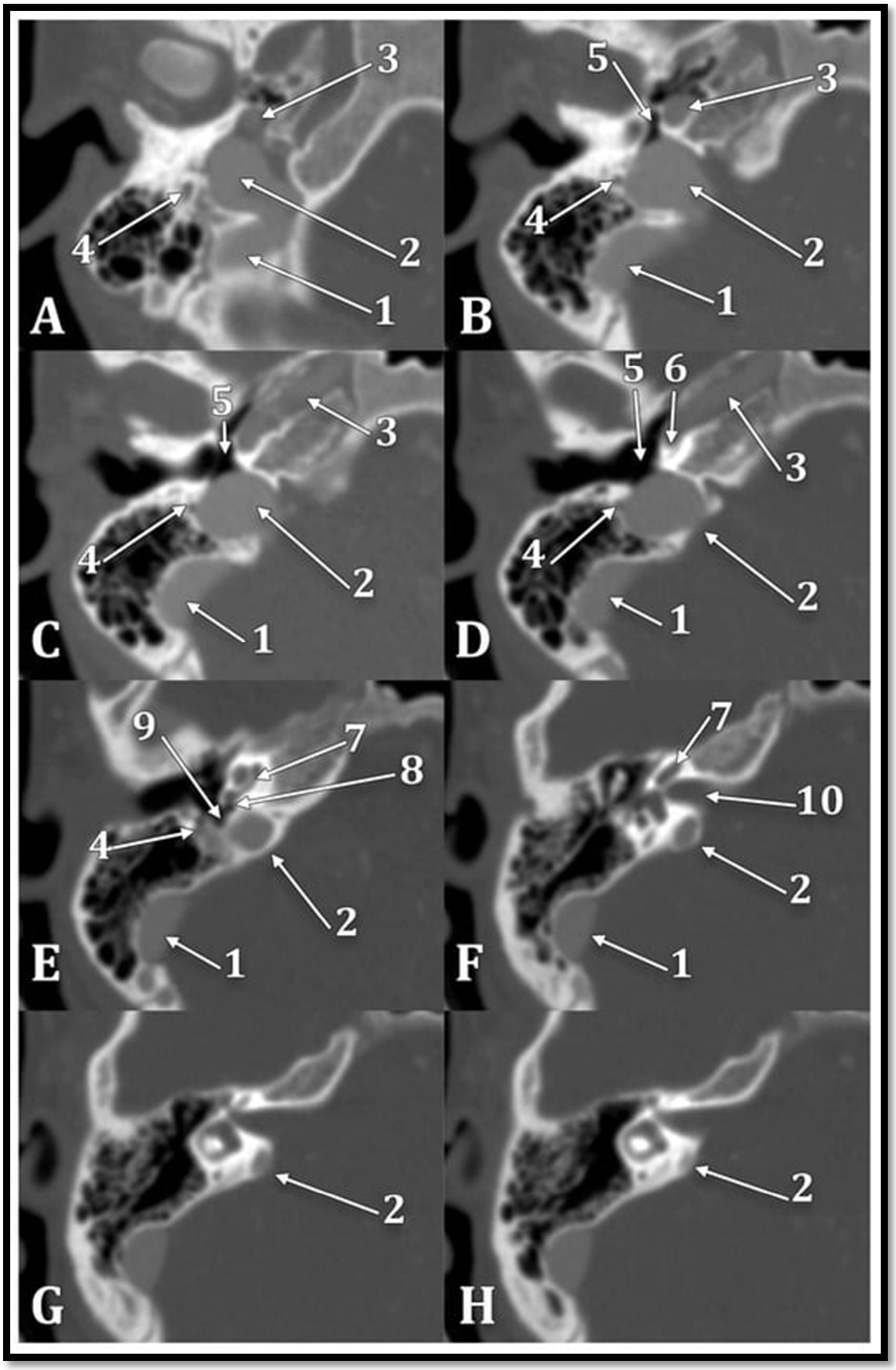


Figure 8. "Inferior-to-superior sequence (**A**–**H**) of axial slices through the right jugular bulb (JB), inferiorly viewed. 1. sigmoid sinus; 2. JB; 3. internal carotid artery; 4. facial nerve; 5. hypotympanum; 6. fustis; 7. basal turn of cochlea; 8. round window; 9. sinus tympani; 10. internal acoustic canal".[38]

At a distance of 1.17mm below PSC, the left JB reached superiorly. Additionally, it extended internally to round window and the sinus tympani posterior. Left JB's upper end extended 7.82mm posterior to IAC floor. Left JB's dehiscent walls were absent.

Dura mater on posterior aspect of temporal bone, which interfaces with cerebellopontine angle, is opened by surgeons during posterior transpetrosal procedures designed to target posterior fossa. This area of operation, called Trautmann's triangle (TT), is crucial for surgical procedures like posterior petrosectomy. It is defined by “JB at its inferior vertex, sino-dural angle that forms its superior base, and posterior semicircular canal that marks its anterior boundary.”

With distances ranging from 6-11mm, on average 8.5mm, the JB is close to the posterior semicircular canal, highlighting the anatomical relevance of TT. An HJB that reaches or exceeds IAC level **(figure 9)** poses a significant surgical variability. Due to dimensional reduction, it may limit the surgical field within TT, increasing the chance of JB injury during surgery. This anatomical heterogeneity has a substantial impact on surgical planning and execution, making a thorough preoperative evaluation necessary to reduce problems and improve patient outcomes.

Figure 9. “Axial slice through the right internal acoustic canal (IAC) (arrow). A high jugular bulb can be identified postero-laterally to the IAC (arrowhead)”.

Tinnitus is the most prevalent symptom of a HJB, “followed by vertigo, pre-syncope, and hearing problems. It can be difficult to manage an HJB during middle ear surgery. A postauricular technique has been suggested previously because of its wider surgical area, which lowers chance of harming the JB by enabling surgeon to pass from facial recess through round window niche to hypotympanum. If a hemorrhage happens, packing with different hemostatic agents right away can help control the bleeding. HJB isn’t a contraindication for middle ear surgery, hence, it is crucial to be aware of this anatomical variation by preoperative imaging”.

4. Dehiscent Jugular Bulb

A dehiscent JB **(figure 8)** has a thin mucosal layer covering it and lacks a complete bony covering as it extends into middle ear cavity through a dehiscent sigmoid plate. This anatomical variation is particularly susceptible to damage after surgery.

According to Atilla et al.[48], 27 out of 142 HJBs were also dehiscent; 74% of these cases “occurred on right side, 26% on left, and 7% were bilateral. Wang et al.[43] found a strong relationship between HJBs and carotid canal dehiscence, pointing out that latter is frequently related to a thinner carotid canal wall.” An HJB may consequently have a general bone deficit, which is a reasonable expectation. Preoperative imaging is essential since over 55% of the JBs (12 out of 22) in patients with Crouzon's disease “were either protruding or dehiscent, posing a high risk of puncture during myringotomy.”

5. Jugular Bulb Variations across Age and Demographic Groups

The physical position of the HJB varied clearly by ethnicity, according to one study by Low et al.[50] According to their findings, the HJB was often more medially placed in Chinese participants and more laterally located in Caucasian subjects. A significant finding of this study was that ethnicity had a significant impact “on whether a HJB was likely to be medial or lateral to cochlea, but it did not appear to have an impact on JB height or placement in sagittal plane. This has clinical significance since positional variation of JB may be” important for risk assessment and surgical planning, particularly when it comes to procedures involving the temporal bone and its associated structures. Furthermore, 62% of the JBs were found to reside medially to the cochlea in an analysis of Japanese temporal bones by Yagi et al.[50]. Considering the genetic similarity between Chinese and Japanese populations, this finding is in line with that of Low et al[5].

JB's height and size are age-related, according to earlier research[38].

A study by Wang et al.[51] revealed age-related variations in incidence and characteristics of HJB. They discovered that age group of people aged 35-45 had the highest prevalence rate of HJBs (17.6%). Even though there was a propensity toward its decline with age, it was still relatively common among people over 65, at 12.8% ($p = 0.039$). A significant lateral difference in JB size was also observed in the investigation as the patient's age increased. The left JB's size declined significantly from $47.4mm^2$ to $42.5mm^2$, while “right JB, which had greater prevalence of HJBs and was larger” than the left, did not exhibit the same size decline. These data demonstrate that lateral disparities should be taken into account in addition to age when doing a clinical examination of the JB.

Additionally, Rauch et al.[52] observed that the JB varied with age. In particular, HJBs were detected in 6% of cases (2 of 32) in patients under 6 years old, which is substantially lower than much greater “prevalence rate of 63% (47 of 75) in older age groups ($p < 0.01$). This significant difference suggests that during early childhood, prevalence rates for HJBs rise quickly and steadily with age".

JB anomalies affect 10-15% of patients, according to Friedmann et al[53]. During the first decade of life, these abnormalities are uncommon (less than 2%), but they gradually become more common during the next 40 years, settling at about 10% beyond the age of 50. Significantly, HJB cases have been observed in children as young as 5yrs old, indicating that while most JB defects develop over the first 50 years of life, some are either congenital or acquired early in life. Although reason is unknown, the incidence of these abnormalities significantly increases between the ages of 31 and 50. It also significantly "doubles during adolescence (ages 11-20), perhaps due to pubertal development. Few JBAs are acquired later in life, as evidenced by the incidence stabilizing after age 50. This pattern indicates that JB anomalies are predominantly acquired during growth phase of JB, as" evidenced by another developmental investigation that shows JB first arises at age 2, expands throughout first 40yrs, and then stabilizes in size.

Congenital anomalies of the middle ear

Middle ear congenital defects affect one in 3000-20,000 newborns. The fact that they are distinguished by their deviation from both regular function and normal anatomical development makes them relevant for clinical and surgical settings. Unilateral or bilateral, middle ear abnormalities can be generically categorized into 3 degrees (mild, moderate, severe) or minor (only involving middle ear) and major (also including tympanic membrane and external ear). Medical management is difficult, particularly for abnormalities linked to syndromes [such as Franceschetti (Treacher–Collins), Goldenhar, and Klippel–Feil]. The otologist must work closely with various specialists, including pediatrics, radiology, neurology, genetics, and orthopedics.

Minor middle ear abnormalities involve reduction in the distance between the middle ear's anatomical structures and fixed ossicles, or a change in size or shape of tympanic cavity. Rarely normal and rarely absent, the ossicles are frequently involved with significant malformations. Middle ear abnormalities, such as a movable stapes footplate or dysplasia/aplasia of round or oval window, can involve inner ear windows. Additional abnormalities includes an apneumatized mastoid, a missing antrum, abnormal artery and vein courses, and dehiscence or displacement of facial nerve.

Cholesteatoma

Cholesteatoma is a frequent and renowned ear condition that may have its origins in the TM. An abnormal development of skin into middle ear area behind plane of eardrum is identified as a cholesteatoma. Histologically, cholesteatoma is only a squamous keratinizing cell development, like the TM or lining of external ear canal. This "skin" has spread to a mucosal area, such as the lining of tympanic or mastoid cavities, and its granulating undersurface, perimatrix, can break down bone. These are two characteristics that set this skin apart from normal skin.

Since the absence of fibrous layer and annulus is a critical weakness of TM, many cholesteatoma cases begin with a TM retraction in flaccid section (prospective cholesteatoma). Normally, any keratin generated by the keratinizing cells in the outer ear canal and on the TM is transferred outward (epithelial migration). However, this self-cleaning mechanism might fail in retraction pockets. Keratin debris builds up (pre-cholesteatoma) if it is no longer carried beyond the retraction's rim. All nearby structures are destroyed as a result of the foreign body reaction caused by these inflammatory aggregates in the perimatrix (manifest cholesteatoma). A "cholesteatoma sac" is created when the retraction pockets enlarge and move deeper into the tympanic cavity. Due to the continuous pressure and the perimatrix tissue's destructive activity, “cholesteatoma sac may destroy structures it comes into contact with.

Retraction may occur in tense portion of TM, with the majority of cholesteatoma growth occurring into mastoid and/or tympanic cleft, in addition to development in area of Shrapnell's membrane (epitympanic cholesteatoma)”.

The majority of cholesteatoma cases (99%) are secondary cholesteatomas, which are derived from TM (after a “TM retraction or a defect). The embryonic epidermal crest is the source of primary cholesteatoma, a congenital dermoid cyst that forms behind an intact TM. Due to its extension into middle ear cleft and ossicular chain's destruction”, primary cholesteatoma usually appears as hearing impairment within the first few years of development.

The fact that cholesteatomas never heal on their own but instead progressively spread and destroy adjacent structures is one of their undesirable features. Cholesteatoma can, therefore, go beyond the temporal bone and into the middle or inner ears in addition to the TM. Despite its name, cholesteatoma is a "benign" disease—it isn’t a tumor and doesn’t spread—but because of its destructive nature, it can cause serious morbidity and even death if treatment is not received. [37]

Mastoid surgery

Since surgery is heavily impacted by intricate spatial interactions between the many components, understanding the relationships between the anatomical structures is equally important for middle ear surgery as understanding their morphology. Otosurgeons must be able to freely rotate a 3D imaginary image of temporal bone to perform ear surgery. Situation is exacerbated by fact that patient is lying flat on his back during surgery (the x-axis of the imaginary picture is rotated by 90°), and his head is turned to the side that is not being operated on (the z-axis is rotated by roughly 45°). Furthermore, the perspective is always shifting since the surgeon frequently shifts his point of view and "moves around" ear with microscope while performing ear surgery. The projection of anatomical structures varies in accordance with variations in the angle of view. For example, when working and observing via ear canal, anterior boundary of vestibular organ and round window niche are obscured by the malleus and incus. However, the ossicles block the view of the geniculate ganglia and cochlea during a transmastoid approach. Particularly in patients with deformed ears or those who have had middle ear surgery, anatomy and therefore, topographic relations of middle ear structures can significantly deviate from what is regarded as a "normal" middle ear.

A cholesteatoma's mass may occasionally extend into the mastoid cavity. Retraction pocket may extend from antrum to supralabyrinthine region, then laterally up to cortical bone level and posteriorly to sinus dura angle, depending on where it originated. The entire mastoid, down to the tip, can be filled with and destroyed by cholesteatomas. The cholesteatoma extension may, therefore, need to be removed backward with a mastoidectomy. To do this, transmeatal and transmastoidal techniques are typically used in combination, with the external meatus's posterior wall acting as a barrier between them. This "intact canal wall" or "canal wall up" approach works best when mastoid cavity is relatively large and exhibits good pneumatization with healthy mucosa. However, a "canal wall down" method is frequently used if mastoid is extremely narrow, has scant pneumatization or almost no cells, and mastoid cavity cannot be adequately ventilated (due to chronically irritated or completely damaged mucosa). Here, the external meatus's posterior wall is completely removed, creating a "radical cavity" that includes the mastoid and external auditory canal. Optimal overview of pathologies (inflammatory processes or cholesteatoma) that may now be generally and consistently eliminated, even in obscure areas like the sinus tympani, is a primary benefit of posterior wall removal. Shadow of posterior wall is where residual cholesteatomas that form from remaining epithelial cells are most commonly observed in canal wall up technique. Additionally, there is no one-size-fits-all approach to middle ear surgery, and cholesteatoma treatment must always be customized. Thus, in cholesteatoma surgery, both the canal wall up and canal wall down techniques have a role. [37]

MATERIALS AND METHODS

Source of Data: cadaveric temporal bones

Study Design: analytical study

Study Period: 1 YEAR

Sample Size: 30

Sampling technique: N/A

Inclusion Criteria:

1) Formalin fixed, wet mount specimens of temporal bones

Exclusion Criteria:

2) Temporal bones with fractures
3) Damaged and diseased temporal bones
4) Temporal bones of paediatric age group

6. Study protocol: Consort flow chart for RCTs: N/A

Data processing and analysis/statistical analysis: Based on the prevalence rate, the minimal sample size formula is

$$n = \frac{z_{\alpha}^{2} P(1-P)}{d^{2}}$$

Here, P denotes prevalence rate and d represents percentage likely difference in prevalence.

z α is denotes level of significance.

For 5% level of significance z α=1.96.

Reference: Cömert E, Kiliç C, Cömert A. Jugular bulb anatomy for lateral skull base approaches. Journal of Craniofacial Surgery. 2018 Oct 1;29(7):1969-72.[56]

The parameter considered in the calculation is the rate of JB located in mastoid cavity and under FN is more than 80% With P = 80% and d = 20% of P = 16%, sample size is 24.

The sample size will be increased to 30 to improve consistency in the research.

7. Data collection procedure: The left and right temporal bones of humans were harvested for this investigation. The temporal bone was mounted on a temporal holder to the surgical position. Under microscopic guidance, superior and inferior tympano-meatal incision was taken, and tympano-meatal flap was raised exposing the middle ear cavity. Mastoid cavity was drilled using drill and burr. Cavity was entered through McEwen's triangle. Intact wall mastoidectomy was done on the sample. Photographic data collection with digital software assessment of depth of the JB from the aforementioned structures was done.

Statistical analysis: Data had been collected utilizing a structured proforma. Data was entered into an MS Excel spreadsheet and subsequently analyzed. Qualitative data was articulated as proportions. Quantitative data was represented using the Mean and Standard Deviation. The relationship between 2 qualitative variables was assessed employing Chi-square test or Fisher's exact test.

RESULTS

Table 1: Distribution according to laterality of bone

		Frequency	Percent
Laterality	Left	12	40.0
	Right	18	60.0
	Total	30	100.0”

We included total 30 formalin fixed, wet mount specimens of temporal bones. Majority of the bones were of right side i.e. 60% and remaining 40% were left-sided.

Graph 1: Distribution according to laterality of bone

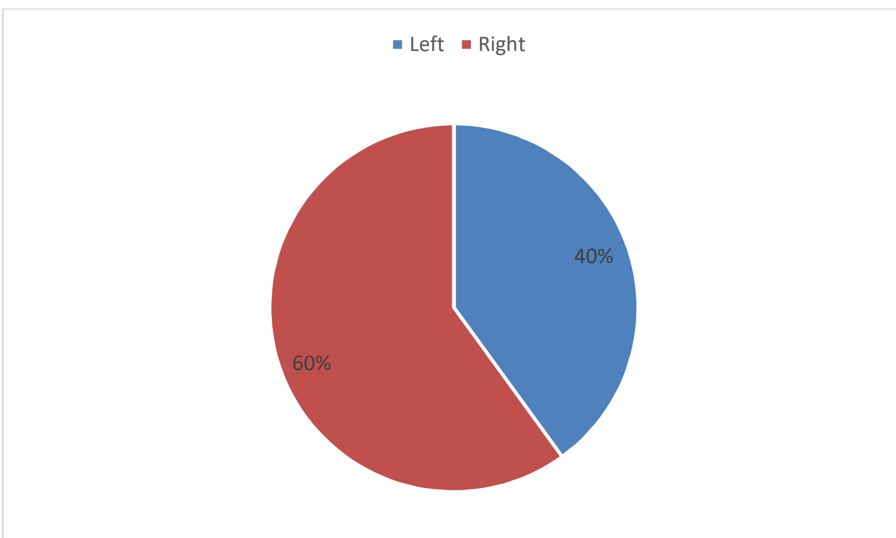


Table 2: Distribution according to presence of pinna

		Frequency	Percent
PINNA	Absent	10	33.3
	Present	20	66.7
	Total	30	100.0

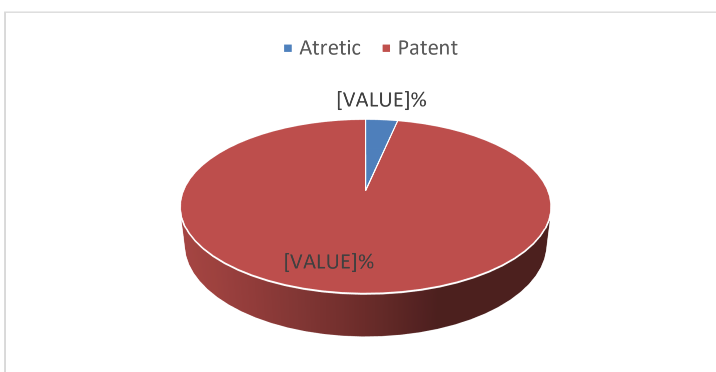
Presence of pinna was observed in 20 bones, i.e. 66.7%.

“**Table 3: Distribution according to status of EAC**

		Frequency	Percent
EAC	Atretic	1	3.3
	Patent	29	96.7
	Total	30	100.0”

Distribution based on status of EAC was patent in 29 bones (96.7%) and atretic in one bone (3.3%).

Graph 2: Distribution according to status of EAC



“Table 4: Distribution according to status of tympanic membrane

		Frequency	Percent
Tympanic membrane status	Intact	29	96.7
	Not intact	1	3.3
	Total	30	100.0”

Distribution according to status of tympanic membrane showed that it is intact in 29 cases i.e. 96.7% and non-intact in one case i.e. 3.3%.

Table 5: Distribution according to mastoid tip appearance

		Frequency	Percent
Mastoid tip	Not prominent	7	23.3
	Prominent	23	76.7
	Total	30	100.0

Distribution according to mastoid tip appearance revealed it as prominent in 23 cases i.e. 76.7%. It was not prominent in 7 cases i.e. 23.3%.

Graph 3: Distribution according to mastoid tip appearance

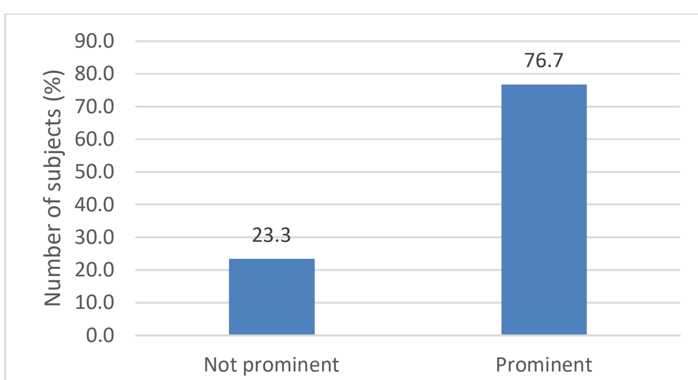


Table 6: Distribution according to pneumatisation

		Frequency	Percent
Pneumatization	Diploic	8	26.7
	Pneumatized	21	70.0
	Sclerotic	1	3.3
	Total	30	100.0

Distribution according to pneumatisation showed that it was pneumatised in 21 cases i.e. 70%, diploic in 8 cases i.e. 26.7% and sclerotic in one case i.e. 3.3%.

Graph 4: Distribution according to pneumatisation

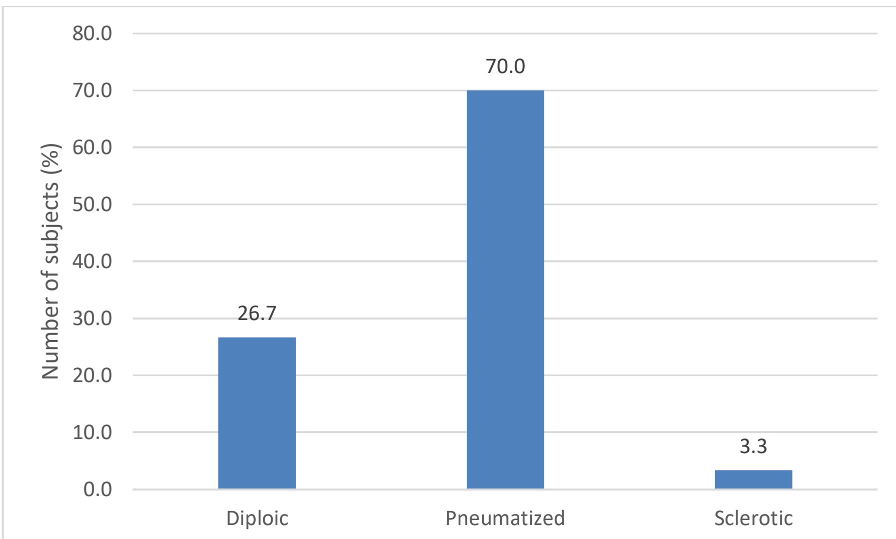


Table 7: Distribution according to ossicular chain

		Frequency	Percent
OSSICULAR CHAIN	INTACT	30	100.0

Distribution according to ossicular chain revealed intact in all 30 cases.

Table 8: Distribution according to subiculum

		Frequency	Percent
Subiculum	Bridge	10	33.3
	Ridge	20	66.7
	Total	30	100.0

Distribution according to subiculum showed ridges in 20 cases i.e. 66.7% and bridges in 10 cases i.e. 33.3%.

Graph 5: Distribution according to subiculum

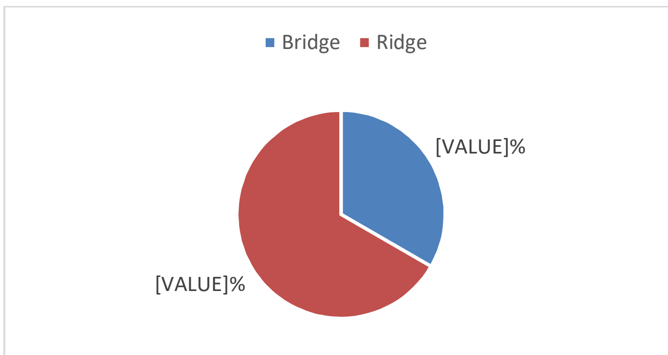


Table 9: Distribution according to status of funiculus

		Frequency	Percent
Funiculus	Absent	1	3.3
	Bridge	4	13.3
	Ridge	25	83.3
	Total	30	100.0

Distribution according to status of funiculus showed ridges in 25 cases i.e. 83.3% and bridges in 4 cases i.e. 13.3%.

Graph 6: Distribution according to status of funiculus

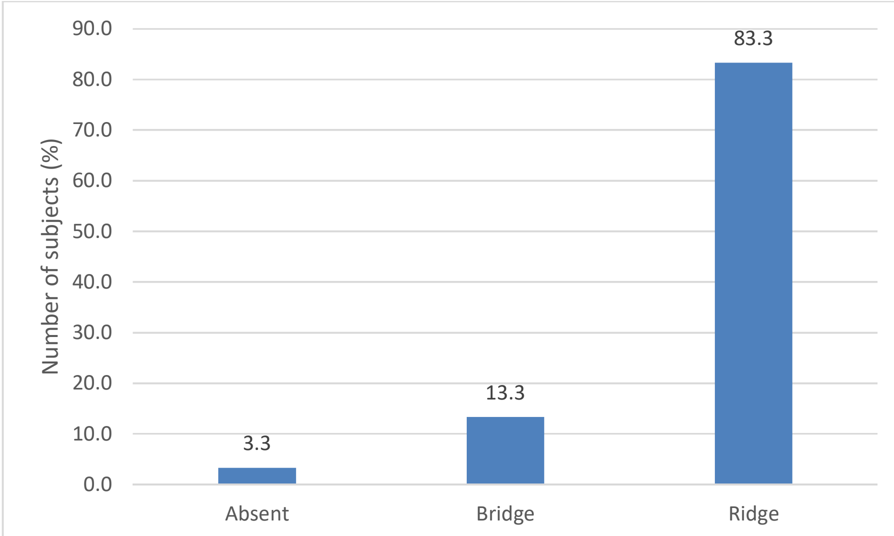


Table 10: Descriptive statistics of the variables

	N	Mean	Std. Deviation	Std. Error	Range	Minimum	Maximum”
Distance of vertical segment from jugular bulb apex (lowest)	30	3.47	1.04	0.19	5.9	1.8	7.7
Distance of vertical segment from jugular bulb apex (Middle)	30	5.59	1.07	0.20	5.7	3.5	9.2
Distance of vertical segment from jugular bulb apex (Uppermost)	30	8.46	1.28	0.23	5.9	5.2	11.1
Distance from posterior end of round window niche	30	7.59	1.32	0.24	6.0	5.4	11.4

- Distance from apex of JB to lowest vertical segment of facial nerve, located at exit from stylomastoid foramen, was measured as 3.47±1.04 mm.
- Distance from mid-point of vertical segment of facial nerve to apex of JB was 5.59±1.07 mm.
- Distance from apex of JB to uppermost vertical segment of facial nerve at level of second genu was 8.46±1.28 mm.
- Distance of posterior end of round window niche from JB apex was 7.59±1.32 mm.

Graph 7: Descriptive statistics of the variables

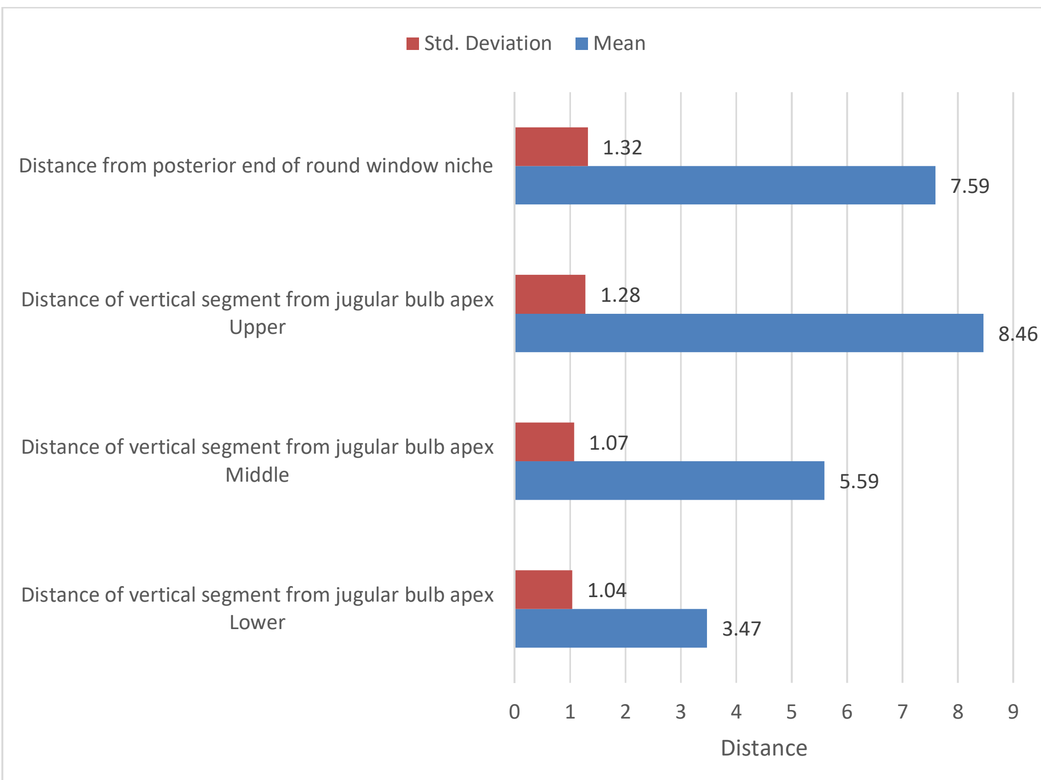


Table 11: Comparative analysis of variables with similar studies

Distance of vertical segment from jugular bulb apex	**Site of measurement (mm)**	**Mean**	**Std. Deviation**
Our study	Lowest	3.47	1.04
	Mid-point	5.59	1.07
	Uppermost	8.46	1.28
Arístegui M. et al (2019)	Lowest	5.19	2.01
	Mid-point	N/A	N/A
	Uppermost	N/A	N/A

Jugular bulb distance from round window niche		**Mean Distance (mm)**	**Standard Deviation (mm)**
Our study	lowest	5.4	± 1.32 mm
	highest	11.4	± 1.32 mm
Eirik Juelke *et al.* (2023)	lowest	3.22	± 0.97 mm
	highest	10.34	± 1.41 mm

DISCUSSION

Through this dissertation, we analysed 30 wet-mount, formalin-fixed temporal bone specimens to assess various anatomical features. The distribution of bones by laterality indicated a greater prevalence of right-sided bones (60%) relative to left-sided bones (40%). The reason for this predominance can be attributed to random sampling depending upon the availability of temporal bone samples.

The presence of pinna was observed in 66.7% of the specimens, which is a significant finding as the external pinna plays a crucial role in sound localization. External auditory canal (EAC) was patent in 96.7% of cases, with only one case showing atresia (3.3%). The prevalence of congenital EAC atresia is reported to be 1 in 10,000-20,000 live births, equating to 0.005% to 0.01% of the population(Lambert PR *et al*,1996)[58] . This indicates that a patent EAC is present in over 99.99% of individuals, making cases of atresia relatively rare. Therefore, observing a patent EAC in 96.7% of specimens, with 3.3% exhibiting atresia, is higher than the general population prevalence. This discrepancy may be due to factors such as sample selection or regional variations. For instance, studies focusing on specific populations or clinical settings might report different prevalence rates.

Similarly, the tympanic membrane was found intact in 96.7% of cases, reflecting the normal anatomical status of the temporal bones included in this study. Previous studies examining temporal bones often report a high prevalence of intact tympanic membranes. For instance, "a histopathological analysis of 144 human temporal bones with chronic otitis media found that 116 bones (81%) had intact tympanic membranes, while 28 bones (19%) had perforated membranes"(da Costa SS *et al*,1992.)[59] . These findings align with the previous observation, reflecting the normal anatomical status of the temporal bones included in the study.

The mastoid tip appearance was prominent in 76.7% of cases, while 23.3% showed non-prominent mastoid tips. Given the limited data on mastoid tip prominence specifically, further research is needed to establish prevalence rates and clinical implications.

The degree of mastoid pneumatization is known to vary among individuals and may be influenced by genetic and environmental factors. The present study found that 70% of the bones exhibited pneumatization, while 26.7% were diploic and 3.3% were sclerotic. These findings are consistent with prior anatomical research indicating that well-pneumatized mastoids are more common(Hindi K *et al*.,2014)[60] . A study by Iqbal IZ *et al.* done in Iqbal IZ *et al* in 2018 also showed pneumatisation of the mastoid was cellular in 60.3 per cent of all cases(n=393) which corroborates with the finding of our study.

The ossicular chain was intact in all specimens, highlighting the rarity of ossicular chain anomalies in the general populace. The subiculum exhibited a ridge in 66.7% of cases and a bridge in 33.3% of cases, a similar study using "endoscopic evaluation of middle ear anatomical variations in 204 autopsy cases found that the subiculum presented as a ridge in 64.7% of ears, as a bridge in 2% of ears, and was absent in 33.3% of ears" (Şahin B. *et al* ,2018)[61] this difference in findings may be attributed to different demographics and therefore, morphology of the temporal bones with non-quantified effect of environmental and genetic factors.

Similarly, the funiculus showed a ridge in 83.3% of cases, a bridge in 13.3%, and was absent in only one case (3.3%). Sahin B. *et al*[61] study found "the ponticulus as a ridge in 76.4% of cases, as a bridge in 12.3%, and absent in 11.3%", thereby correlating with the observed values in our study. These variations are significant as they can have implications in middle ear surgeries, with varied approaches necessitated and present difficulty in comprehending the anatomy of each temporal bone.

The descriptive statistics revealed that the mean distance of the vertical segment from the JB apex varied along different levels, with lower, middle, and upper segments measuring 3.47±1.04 mm, 5.59±1.07 mm, and 8.46±1.28 mm, respectively. One study examining 100 temporal bones by Arístegui M. *et al* Anatomical Variations of the Intrapetrous Portion of the Facial Nerve,2019 showed similar results as our study.

The mean distance of JB apex from posterior end of round window niche was 7.59±1.32 mm. Another study "utilizing 3D surface models of temporal bones reported that the mean distance from the RW to the JB ranged between 3.22 ± 0.97 mm and 10.34 ± 1.41 mm, depending on the JB's position"(Eirik Juelke *et al*,2023)[63]. These measurements provide valuable anatomical data that can aid in surgical planning and improve understanding of temporal bone anatomy. Also, findings indicate that the distance between the JB apex and the posterior end of the RW niche can vary significantly among individuals, with mean measurements ranging from approximately 2.77 mm to over 10 mm.

Correlation with Surgical Approaches

Understanding the anatomical variations of the JB, facial nerve, and round window is crucial for optimizing surgical approaches to the middle ear and minimizing potential complications.

Jugular Bulb

The descriptive statistics from this study show that mean distance of vertical segment from JB apex varied significantly along different levels, with the upper segment of vertical segment of facial nerve, at level of second genu, measuring highest (8.46±1.28 mm). This measurement is particularly relevant in surgical approaches involving the mesotympanum and hypotympanum, where a high-riding jugular bulb (HRJB) can increase the risk of haemorrhage and limit surgical access. Proximity of JB to round window niche (7.59±1.32 mm) further emphasizes the importance of preoperative imaging to identify HRJB and avoid complications, particularly during cochlear implantation, posterior tympanoplasty approach and facial recess approaches, modified radial mastoidectomy and stapedectomy procedures.

Facial Nerve

The anatomical integrity of the ossicular chain in all specimens, coupled with the observed variations in the subiculum and funiculus, highlights the potential risk of facial nerve injury while performing middle ear surgeries. Dehiscence of facial nerve canal is a common anatomical variation that can complicate surgical interventions. Employment of high-resolution imaging and intraoperative nerve monitoring to prevent postoperative facial nerve dysfunction, particularly in cases where JB is displaced is extremely necessary to prevent injury to nerve during dissection at any point, when carried out in close proximity of the nerve. (Friedmann et al., 2012; Yamasoba et al., 2014; Park et al., 2020).

Round Window

Round window niche's mean distance of 7.59±1.32 mm from the JB apex is consistent with previous anatomical studies. This relationship is critical for cochlear implantation as improper electrode placement can compromise hearing outcomes. The presence of adjacent vascular and neural structures necessitates meticulous surgical planning and technique to minimize complications. With wide variations seen in the position of round window niche and positioning of window. A preoperative analysis of radiological studies is of utmost importance for planning of approaches to the middle ear and predicting possible complications which may have a profound impact on the day-to-day life of an individual. (Friedmann et al., 2012; Yamasoba et al., 2014; Park et al., 2020).

Clinical Implications

Present study findings underscore the importance of understanding anatomical variations in the temporal bone for surgical planning. Preoperative high-resolution imaging, like CT or MRI, combined with intraoperative nerve monitoring and careful dissection techniques, can significantly reduce the risk of complications.

The JB starts to develop around 2 years of age with its anatomy and course changing well into adulthood. One of the critical surgical approaches in middle ear surgery is posterior tympanotomy or facial recess approach, which provides access to middle ear cavity through mastoid process, This method is particularly useful in cochlear implantation and cholesteatoma surgeries, offering a pathway to round window and oval window niches while avoiding facial nerve. Variations observed in this study, such as ridges and bridges in the subiculum and funiculus, emphasize the need for meticulous dissection. Identification of facial recess and round window niche, along with awareness of any HRJB, is crucial for minimizing surgical complications and improving outcomes.

CONCLUSION

In our study, we dissected and analysed 30 wet-mount, formalin-fixed temporal bone specimens to assess various anatomical features. The findings emphasize the importance of understanding temporal bone anatomy for surgical planning, especially in otologic skull-base procedures. The variations observed, particularly in the jugular bulb position, facial nerve canal, and round window niche, may pose significant challenges during middle ear surgeries. In our study we have dissected 30 temporal bones, in which we found that, mean distance of the vertical segment from the apex of the jugular bulb, the main focus of our study, which is a highly variable vascular structure, varied along different levels; with lowest, middle, and uppermost segments measuring **3.47±1.04 mm**, 5.59±1.07 mm, and 8.46±1.28 mm, respectively. **The values attained at the lowest segment are surgically the most important and one should be vary of the proximal relationship of the jugular bulb and facial nerve at this point**. As for the round window niche, mean distance from the jugular bulb apex was observed to be 7.59±1.32 mm. Recognizing these anatomical differences can help surgeons adopt tailored surgical approaches, such as posterior tympanotomy, and improve patient outcomes.

The study highlights the critical role of anatomical knowledge in avoiding iatrogenic complications and improving surgical outcomes. Additionally, the findings reinforce the need for incorporating advanced imaging modalities, such as high-resolution computed tomography and magnetic resonance imaging, in routine preoperative assessments to better visualize anatomical anomalies. In view of the paucity of data regarding the relationships of these anatomical structures, further studies with larger sample sizes, diverse demographic representation, and technological advancements will contribute to refining surgical techniques and optimizing patient safety and outcomes.

This study underscores that dissection of temporal bone is integral and plays a very important role in the development of surgical skills, techniques and confidence of a budding otologic and skull-base surgeon.

SUMMARY

- In this study we aim to provide comprehensive anatomical data on temporal bones through dissection of 30 wet-mount specimens, highlighting the variations in mastoid pneumatization, ossicular chain status, subiculum, and funiculus, jugular bulb and facial nerve. As the middle ear is an irregular cavity with no clear demarcation between its walls and boundaries. It is important to note that the middle ear is an extremely small cavity with critical structure in sub-centimetre distance of each other.
- The study found that 60% of the bones were right-sided, and 66.7% had a visible pinna.
- The external auditory canal was patent in 96.7% of cases, and the tympanic membrane was intact in 96.7% of specimens.
- Prominent mastoid tips were observed in 76.7% of cases, with 70% showing pneumatization.
- The ossicular chain was intact in all cases.
- The subiculum showed ridges in 66.7% and bridges in 33.3%, while the funiculus exhibited ridges in 83.3%, bridges in 13.3%, and was absent in 3.3%.
- Descriptive measurements of the vertical segment from the jugular bulb apex and the round window niche were also recorded; at the lowest level, where the facial nerve exits the middle ear cavity through the stylomastoid foramen being only 3.47±1.04 mm was the most significant finding as here chances of injury to the jugular bulb and facial nerve is highest due to their close proximity to each other. Therefore, the surgeon should be extremely careful while dissecting in this area.

- Similarly, from the middle segment of facial nerve 5.59±1.07 mm, and uppermost segments, at the level of second genu measure 8.46±1.28 mm.
- The findings also indicate that the distance between the JB apex and the posterior end of the RW niche can vary significantly among individuals, with mean measurements ranging from approximately 2.77 mm to over 10 mm.
- These findings provide important anatomical data for otologic and skull-base surgeons and enhance our understanding of temporal bone morphology, anatomical relations of various structures and sheds light upon the variations within the temporal bone of the various structures and landmarks contained within it .
- Normally, the floor of the middle ear cavity consists of bone tissue, but it may also be irregularly excavated by some pneumatised cells. Right under the floor, the JB (fossa of IJV) lingers and can be inadvertently opened by the otologic and skull-base surgeons, possibly leading to the heavy and troublesome venous bleeding.
- The facial nerve runs through the whole of the temporal bone and is always close to any surgical approach to the middle ear. Therefore, during middle ear surgery, whether in tympanic or mastoid cavities, surgeon must be cognizant of the nerve along with its exact location and its relation to the jugular bulb.
- Anatomical variations, such as an obscured round window niche or close proximity to the jugular bulb, may complicate surgical access, particularly during surgeries like modified radical mastoidectomy, posterior tympanotomy, facial and extended facial recess approaches and lateral skull-base procedures, either to remove pathology or during cochlear implantation.

BIBLIOGRAPHY

1. Gray H, Standring S, Anand N, Birch R, Collins P, Crossman A, Gleeson M, Jawaheer G, Smith AL, Spratt JD, Stringer MD, Tubbs SR, Tunstall R, Wein AJ, Wigley CB. Gray's anatomy: the anatomical basis of clinical practice, 2016; 41 edn. Elsevier
2. Bernard F, Zemmoura I, Cottier JP, Fournier HD, Terrier LM, Velut S. The interperiosteodural concept applied to the jugular foramen and its compartmentalization. J Neurosurg 2018; 129:770–778. https://doi.org/10.3171/2017.1.JNS161890
3. Liu J, Xie W, Ding Y, Hu Y, Lai R, Hu P, Zhu G. Wave I(n) in auditory brainstem response suggests a high possibility of a high jugular bulb. Front Pediatr 2023; 11:1183388. https://doi. org/10.3389/fped.2023.1183388
4. Mansour S, Magnan J, Ahmad HH, Nicolas K, Louryan S. Comprehensive and clinical anatomy of the middle ear. Springer, Berlin, Heidelberg 2013; 1:1-8
5. Kveton JF. Anatomy of the jugular foramen: the neurotologic perspective. Oper Tech Otolayngol Head Neck Surg 1996; 7:95– 98. https://doi.org/10.1016/S1043-1810(96)80020-0
6. Moffat DA, Quaranta N, Chang P. Management of the high jugular bulb in translabyrinthine surgery. Laryngoscope 2003; 113:580– 582. https://doi.org/10.1097/00005537-200303000-00034
7. Shaaban Ali M, Harmer M, Latto I. Jugular bulb oximetry during cardiac surgery. Anaesthesia 2001; 56:24–37. https://doi. org/10.1046/j.1365-2044.2001.01707.x
8. Hoz SS, Palmisciano P, Albairmani SS, Kaye J, Muthana A, Johnson MD et al. A proposed classification system for presigmoid approaches: a scoping review. J Neurosurg 2023; 139:965–971. https://doi.org/10.3171/2023.2.JNS222227

9. Liu JK, Sameshima T, Gottfried ON, Couldwell WT, Fukushima T. The combined transmastoid retro- and infra labyrinthine transjugular transcondylar transtubercular high cervical approach for resection of glomus jugulare tumors. Neurosurgery 2006; 59. https:// doi.org/10.1227/01.NEU.0000220025.81500.8D. ONS115-125; discussion ONS115-125
10. Mey KH, Sørensen MS, Homøe P. Histomorphometric estimation of air cell development in experimental otitis media. Laryngoscope. 2006; 116:1820–3. doi: 10.1097/01.mlg.0000233540.26519.ba
11. Friedmann DR, Eubig J, Winata LS, Pramanik BK, Merchant SN, Lalwani AK. Prevalence of jugular bulb abnormalities and resultant inner ear dehiscence: a histopathologic and radiologic study. Otolaryngol Head Neck Surg. (2012) 147:750–6. doi: 10.1177/0194599812448615
12. Friedmann DR, Le BT, Pramanik BK, Lalwani AK. Clinical spectrum of patients with erosion of the inner ear by jugular bulb abnormalities. Laryngoscope. 2010; 120:365–72. doi: 10.1002/lary.20699
13. Friedmann DR, Eubig J, Winata LS, Pramanik BK, Merchant SN, Lalwani AK. A clinical and histopathologic study of jugular bulb abnormalities. Arch Otolaryngol Head Neck Surg. 2012; 138:66–71. doi: 10.1001/archoto.2011.231
14. Aladeyelu OS, Olojede SO, Lawal SK, Mbatha WE, Sibiya AL, Rennie CO. Influence of pneumatization on morphology of temporal bone-related vasculatures and their morphometric relationship with ear regions: a computed tomography study. Sci Rep. 2023; 13:1996. doi: 10.1038/s41598-023-29295-4
15. Graham MD. The jugular bulb: its anatomic and clinical considerations in contemporary otology. Laryngoscope. 1977; 87:105–25. doi: 10.1288/00005537-197701000-00013 Orr JB,

16. Todd NW. Jugular bulb position and shape are unrelated to temporal bone pneumatization. Laryngoscope. (1988) 98:136–8. doi: 10.1288/00005537-198802000-00003 Dai PD, Zhang HQ, Wang ZM, Sha Y, Wang KQ, Zhang TY. Morphological and positional relationships between the sigmoid sinus and the jugular bulb. Surg Radiol Anat. 2007; 29:643–51. doi: 10.1007/s00276-007-0266-5
17. Hourani R, Carey J, Yousem DM. Dehiscence of the jugular bulb and vestibular aqueduct. Findings on 200 consecutive temporal bone computed tomography scans. J Comput Assist Tomogr 2005;29:657–62.
18. Koesling S, Kunkel P, Schul T. Vascular anomalies, sutures and small canals of the temporal bone on axial CT. Eur J Radiol 2005;54:335–43.
19. Overton SB, Ritter FN. A high placed jugular bulb in the middle ear: a clinical and temporal bone study. Laryngoscope 1986;83:1986–91.
20. Roche PH, Moriyama T, Thomassin JM, et al. High jugular bulb in the translabyrinthine approach to the cerebellopontine angle: anatomical considerations and surgical management. Acta Neurochir (Wien) 2006;148:415–20.
21. Savic D, Djeric D. Surgical anatomy of the hypotympanum. J Laryngol Otol 1987;101:419–25.
22. Subotic R. The high position of the jugular bulb. Acta Otolaryngol 1979; 87:340–4. 8.
23. Wadin K, Wilbrand H. The topographic relations of the high jugular fossa to the inner ear. Acta Radiol Diagn (Stockh) 1986;27:315–24.
24. Saleh EA, Aristegui M, Taibah AK, et al. Management of the jugular bulb in the translabyrinthine approach. Otolaryngol Head Neck Surg 1994;110:397–9.

25. Shao KN, Tatagiba M, Samii M. Surgical management of high jugular bulb in acoustic neurinoma via retrosigmoid approach. Neurosurgery 1993;32:32–7.

26. Page JR. A case of probable injury to the jugular bulb following myringotomy in an infant 10 months old. Ann Otol Rhinol Laryngol 1914;23:161.

27. Graham MD. The jugular bulb: its anatomic and clinical considerations in contemporary otology. Laryngoscope 1977;87:105–25.

28. Chandler JR. Diagnosis and cure of venous hum tinnitis. Laryngoscope 1983;106:303–7.

29. Kennedy DW, El-Sirsy HH, Nager GT. The jugular bulb in otological surgery: anatomic, clinical, and surgical consideration. Otolaryngol Head Neck Surg 1986;94:6–15

30. Morretti JA. Highly placed jugular bulb and conductive deafness. Arch Otolaryngol 1976;102:430–1.

31. Stenglein C, Cidlinsky K. Magnetic resonance angiography: diagnosis of pulsatile tinnitus. HNO 1993;41:274–7.

32. Schwartz JD, Bazarnic ML, Naidich TP, et al. Aberrant internal carotid artery lying within the middle ear. Neuroradiology 1985;27:322–6.

33. Vachata P, Sames M. Topographic relationships of the internal meatus in Czech. Otorinolaryng a Foniatr(Prague) 2002;51:231–5.

34. Aslan A, Falcioni M, Russo A, et al. Anatomical considerations of high jugular bulb in lateral skull base surgery. J Laryngol Otol 1997;111:333–6.

35. Rauch SD, Wen-Zhuang X, Nadol JB. High jugular bulb: implications for posterior fossa neurotological and cranial base surgery. Ann Otol Rhinol Laryngol 1993;102:100–7.

36. Orr JB, Todd NW. Jugular bulb position and shape are unrelated to temporal bone pneumatization. Laryngoscope 1988;98:136–8.

37. Luers JC, Hüttenbrink KB. Surgical anatomy and pathology of the middle ear. J Anat. 2016 Feb;228(2):338-53. doi: 10.1111/joa.12389. Epub 2015 Oct 19. PMID: 26482007; PMCID: PMC4718166.
38. Tudose RC, Rusu MC, Triantafyllou G, Piagkou M, Toader C, Rădoi PM. Anatomical Variations of the Jugular Bulb: A Critical and Comprehensive Review. Medicina (Kaunas). 2024 Aug 28;60(9):1408. doi: 10.3390/medicina60091408. PMID: 39336448; PMCID: PMC11434453.
39. Graham, M.D. The jugular bulb: Its anatomic and clinical considerations in contemporary otology. Laryngoscope 1977, 87, 105–125. [Google Scholar] [CrossRef]
40. Walsh, R.M.; Lannigan, F.J.; McGlashan, J.A.; Bowdler, D.A. Jugular bulb phlebectasia. *Int. J. Pediatr. Otorhinolaryngol.* **1993**, *25*, 249–254. [**Google Scholar**] [**CrossRef**] [**PubMed**]
41. Moretti, J.A. Highly placed jugular bulb and conductive deafness secondary to sinusojugular hypoplasia. *Arch. Otolaryngol.* **1976**, *102*, 430–431. [**Google Scholar**] [**CrossRef**]
42. Kennedy, D.W.; el-Sirsy, H.H.; Nager, G.T. The jugular bulb in otologic surgery: Anatomic, clinical, and surgical considerations. *Otolaryngol. Head Neck Surg.* **1986**, *94*, 6–15. [**Google Scholar**] [**CrossRef**] [**PubMed**]
43. Wadin, K.; Wilbrand, H. The jugular bulb diverticulum. A radioanatomic investigation. *Acta Radiol. Diagn.* **1986**, *27*, 395–401. [**Google Scholar**] [**CrossRef**] [**PubMed**]

44. Wadin, K.; Wilbrand, H. The topographic relations of the high jugular fossa to the inner ear. A radioanatomic investigation. *Acta Radiol. Diagn.* **1986**, *27*, 315–324. [**Google Scholar**] [**CrossRef**]

45. Wadin, K.; Thomander, L.; Wilbrand, H. Effects of a high jugular fossa and jugular bulb diverticulum on the inner ear. A clinical and radiologic investigation. *Acta Radiol. Diagn.* **1986**, *27*, 629–636. [**Google Scholar**] [**CrossRef**] [**PubMed**]

46. Bilgen, C.; Kirazli, T.; Ogut, F.; Totan, S. Jugular bulb diverticula: Clinical and radiologic aspects. *Otolaryngol. Head Neck Surg.* **2003**, *128*, 382–386. [**Google Scholar**] [**CrossRef**]

47. Manjila, S.; Bazil, T.; Kay, M.; Udayasankar, U.K.; Semaan, M. Jugular bulb and skull base pathologies: Proposal for a novel classification system for jugular bulb positions and microsurgical implications. *Neurosurg. Focus* **2018**, *45*, E5. [**Google Scholar**] [**CrossRef**]

48. Atilla, S.; Akpek, S.; Uslu, S.; Ilgit, E.T.; Isik, S. Computed tomographic evaluation of surgically significant vascular variations related with the temporal bone. *Eur. J. Radiol.* **1995**, *20*, 52–56. [**Google Scholar**] [**CrossRef**]

49. Low, W.K.; Fenton, J.E.; Fagan, P.A.; Gibson, W.P. The influence of race on the position of the jugular bulb. *J. Laryngol. Otol.* **1995**, *109*, 610–613. [**Google Scholar**] [**CrossRef**]

50. Yagi, M. [A temporal bone study of the jugular fossa]. *Nihon Jibiinkoka Gakkai Kaiho* **1992**, *95*, 878–890. [**Google Scholar**] [**CrossRef**]

51. Wang, Y.; Lu, D.; Chung, Y.J.; Xu, S. Genetic structure, divergence and admixture of Han Chinese, Japanese and Korean populations. *Hereditas* **2018**, *155*, 19. [**Google Scholar**] [**CrossRef**] [**PubMed**]

52. Rauch, S.D.; Xu, W.Z.; Nadol, J.B., Jr. High jugular bulb: Implications for posterior fossa neurotologic and cranial base surgery. *Ann. Otol. Rhinol. Laryngol.* **1993**, *102*, 100–107. [**Google Scholar**] [**CrossRef**]

53. Friedmann, D.R.; Eubig, J.; McGill, M.; Babb, J.S.; Pramanik, B.K.; Lalwani, A.K. Development of the jugular bulb: A radiologic study. *Otol. Neurotol.* **2011**, *32*, 1389–1395. [**Google Scholar**] [**CrossRef**]

54. Boemo RL, Navarrete ML, Pumarola F, Quesada J, Doménech JM, Perelló E. Morphometric study of the mastoid segment of the facial nerve. Acta Otorrinolaringologica (English Edition). 2007 Jan 1;58(5):178-81.

55. Singla A, Gupta T, Sahni D, Aggarwal A, Gupta A. High jugular bulb: different osseous landmarks and their clinical implications. Surgical and Radiologic Anatomy. 2016 Oct;38:903-9.

56. Cömert E, Kiliç C, Cömert A. Jugular bulb anatomy for lateral skull base approaches. Journal of Craniofacial Surgery. 2018 Oct 1;29(7):1969-72.

57. Chen C, Weng S, Chen Z, Chen Y, Yao G, Huang X, Gu X, Lin C. The association between high jugular bulb and mastoid pneumatization in adults. Frontiers in Neurology. 2024 Jan 8;14:1331604.

58. Lambert, Paul R., and Edward E. Dodson. "Congenital malformations of the external auditory canal." *Otolaryngologic Clinics of North America* 29.5 (1996): 741-760.

59. Da Costa, Sady S., et al. "Temporal bone histopathology in chronically infected ears with intact and perforated tympanic membranes." The Laryngoscope 102.11 (1992): 1229-1236.

60. Hindi, Khalid, et al. "Pneumatization of mastoid air cells, temporal bone, ethmoid and sphenoid sinuses. Any correlation?." Indian Journal of Otolaryngology and Head & Neck Surgery 66 (2014): 429-436.

61. Şahin, Bayram, et al. "Endoscopic evaluation of middle ear anatomic variations in autopsy series: analyses of 204 ears." Brazilian Journal of Otorhinolaryngology 86.1 (2020): 74-82.

62. Arístegui, Miguel, et al. "Anatomical variations of the intrapetrous portion of the facial nerve." The Anatomical Record 302.4 (2019): 588-598.

63. Juelke, Eirik, et al. "Assessment of jugular bulb variability based on 3D surface models: quantitative measurements and surgical implications." Surgical and Radiologic Anatomy 45.3 (2023): 315-319.

ANNEXURE – I - CONSENT WAIVER FORM

"ASSESSMENT OF DEPTH OF JUGULAR BULB FROM VARIOUS MIDDLE EAR STRUCTURES AND ITS SIGNIFICANCE IN MIDDLE EAR SURGERIES- A CADAVERIC MORPHOMETRIC STUDY"

Name of Student/Principal Investigator: Dr

Name of Guide/Co Investigators: Dr

Objective:

- Assessing the depth and distance of the vertical segment of the facial nerve from the jugular bulb.
- Assessing the depth and distance between the jugular bulb and posterior end of round window niche.

Introduction and Need for the Study: Advances in neuro-otologic diagnosis and surgery has pointed to the need for a complete reassessment of the relationship and significance of the jugular bulb and facial nerve in the temporal bone.

The purpose of this dissertation is to bring together in a comprehensive, up-to-date, and relevant manner knowledge of the jugular bulb in relation to various middle ear structures and their clinical relevance in surgeries.

The anatomy of the bulb and relevant structures is discussed and selected temporal bone sections presented to illustrate the varying locations of the jugular bulb. 'Considerations in differential diagnosis are presented and examples of surgical procedures are discussed wherein an anatomic variation of jugular bulb was encountered and the methods of management are detailed in these instances.

Advances in neuro-otologic diagnosis and surgery has pointed to the need for a complete reassessment of the relationship and significance of the jugular bulb in relation to various structures in the temporal bone.

The specialty of otology was borne in the age of septic temporal bone disease and surgery, and during this period much knowledge was gained concerning these major venous structures of the temporal bone. However, with the demise of this era, interest waned in these structures, and not until very recently has it become evident that a reassessment is urgently required.

In this day of stapes, tympanoplasty, sigmoid sinus, glomus tumor, acoustic neuroma and cochlear surgery, the jugular bulb and sigmoid sinus have taken on a new and fresh significance.

It is the purpose of this dissertation to bring together in an up-to-date comprehensive and relevant manner our knowledge of the jugular bulb and facial nerve. Information from the past will be related in detail only where it has relevance to the needs of contemporary otology, and clinical entities rarely encountered today will only be touched upon for completeness of the study.

CONSENT WAIVER STATEMENT

Since it is a cadaveric study and does not pose any risk to subjects, consent waiver has been obtained from institutional ethics committee.

ANNEXURE – II - PROFORMA

"ASSESSMENT OF DEPTH OF JUGULAR BULB FROM VARIOUS MIDDLE EAR STRUCTURES AND ITS SIGNIFICANCE IN MIDDLE EAR SURGERIES- A CADAVERIC MORPHOMETRIC STUDY"

I.	DATE:			
II.	SPECIMEN NUMBER:			
III.	CHILD/ADULT: AGE(IF KNOWN):			
IV.	SIDE:	RIGHT (R) / LEFT (L)		
V.	EXTERNAL EAR:	PINNA PRESENT/ABSENT: PREAURICULAR ANOMALIES: (PRESENT/ABSENT) POSTAURICULAR ANOMALIES: (PRESENT/ABSENT) EXTERNAL AUDITORY (PATENT/ATRETIC) TYMPANIC MEMBRANE:	REGION REGION CANAL:	P / A P / A P / A P / A I / N

5.	MASTOID REGION:		MASTOID TIP: PNEUMATIZATION:	A. PROMINENT B. NOT- PROMINENT A. PNEUMATIC B. SCLEROTIC C. DIPLOIC D. MIXED
6.	MIDDLE CAVITY:	EAR	OSSICULAR CHAIN STATUS: SUBICULUM: FINNICULUS: DISTANCE OF VERICAL SEGMENT OF FACIAL NERVE FROM JUGULAR BULB APEX DISTANCE OF ROUND WINDOW NICHE FROM JUGULAR BULB APEX :	A. INTACT B. NOT INTACT A. RIDGE. B. BRIDGE. C. ABSENT. RIDGE. A. BRIDGE. C. ABSENT
7.	REMARKS:			

ANNEXURE – III - PHOTOGRAPHS

PHOTO 1: SAMPLE COLLECTION METHOD AND PICTURES TAKEN FROM MICROSCOPE

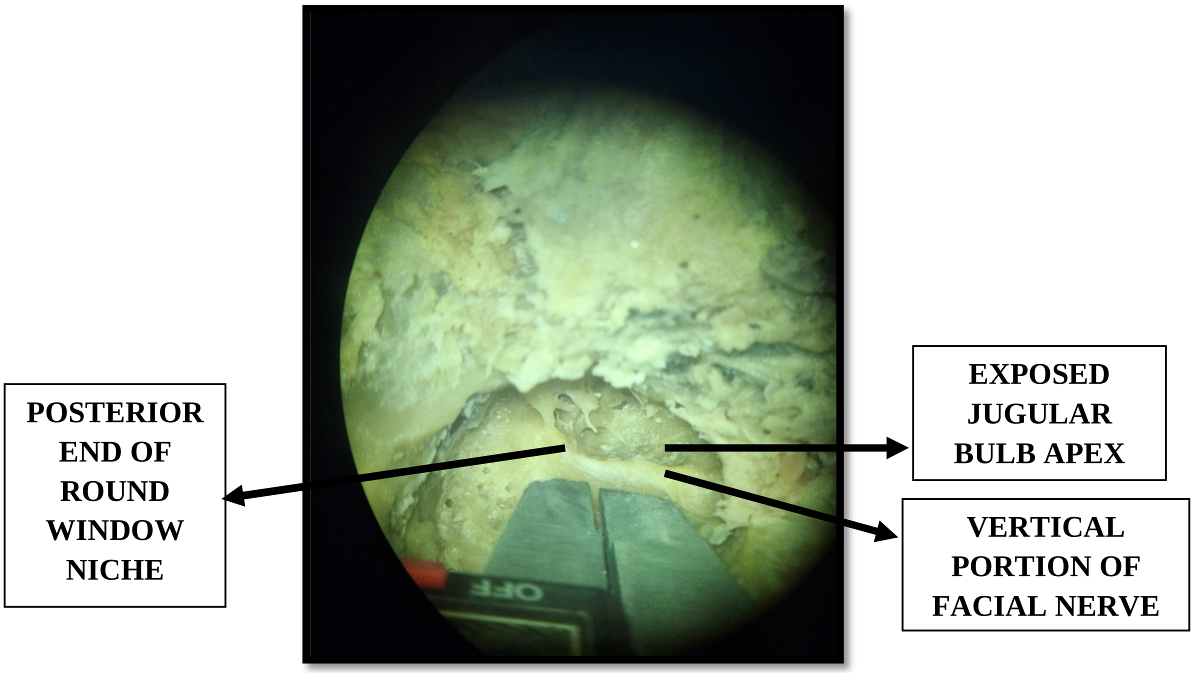


PHOTO 2: POSTERIOR TYMPANOTOMY/FACIAL RECESS

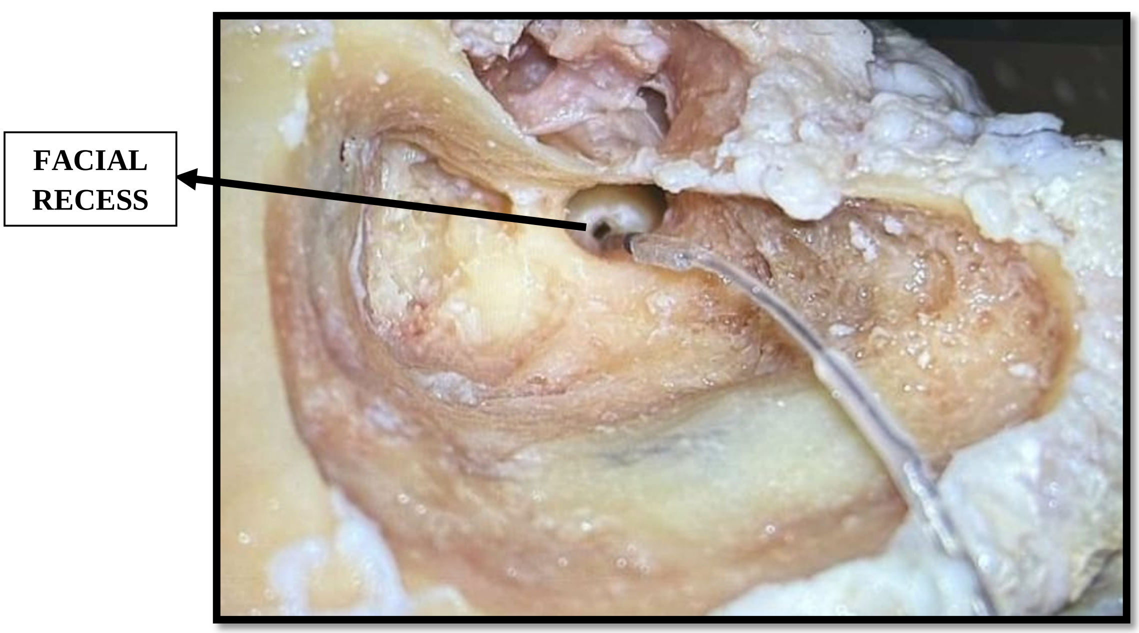


PHOTO 3: MEASUREMENT METHOD AFTER FINAL DISSECTION

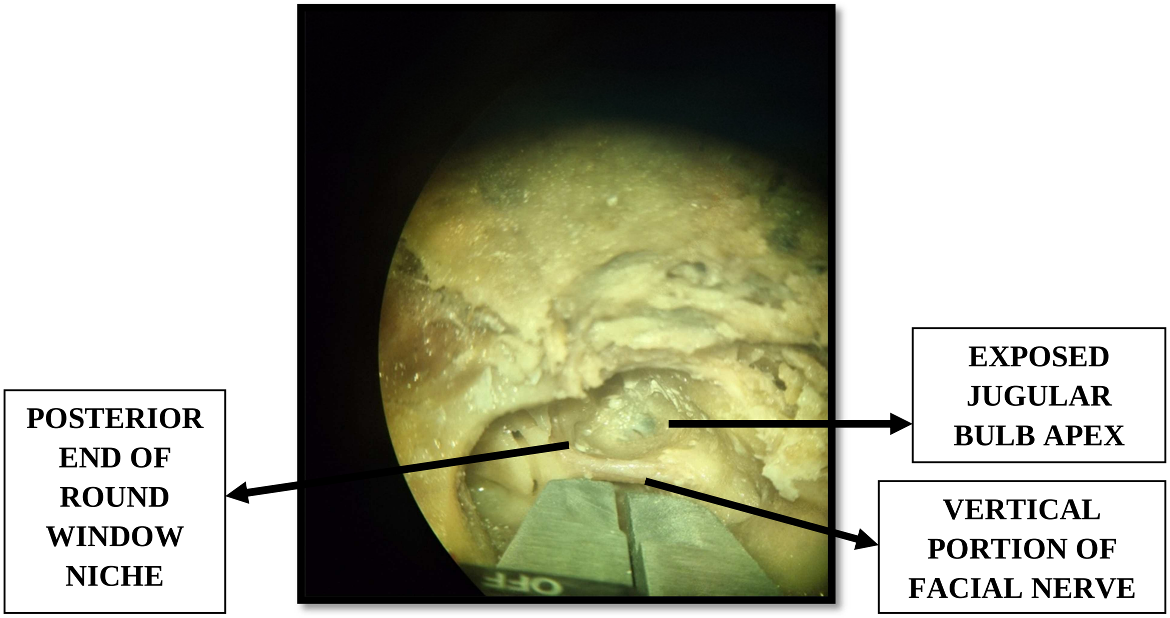


PHOTO 4: DISSECTION LAB SET-UP

PHOTO 5: DISSECTION INSTRUMENT SET-UP

ANNEXURE – IV - MASTER CHART

SPECIMEN	ADULT/CHILD	SIDE	EXTERNAL EAR					MASTOID REGION		MIDDLE EAR CAVITY						
			PINNA	PREAURICULAR REGION	POST AURICULAR REGION	EAC	TYMPANIC MEMBRANE	MASTOID TIP	PNEUMATIZATION	OSSICULAR CHAIN	SUBICULUM	FINNICULUS	DISTANCE OF VERICAL SEGMENT FROM JUGULAR BULB APEX			DISTANCE FROM POSTERIOR END OF ROUND WINDOW NICHE
													LOWER	MIDDLE	UPPER	
1	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	DIPLOIC	INTACT	RIDGE	RIDGE	3.7MM	6.1MM	8.3MM	5.4MM
2	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	7.7MM	9.2MM	11.1MM	11.4MM
3	ADULT	LEFT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	DIPLOIC	INTACT	RIDGE	RIDGE	2.8MM	4.4MM	7.1MM	7.4MM
4	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	3.0MM	4.6MM	10MM	9.2MM
5	ADULT	LEFT	ABSENT	NORMAL	NORMAL	PATENT	NOT INTACT	PROMINENT	DIPLOIC	INTACT	BRIDGE	RIDGE	4.2MM	6.3MM	8.0MM	6.7MM
6	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	ABSENT	3.8MM	5.8MM	10.0MM	7.3MM
7	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	DIPLOIC	INTACT	RIDGE	RIDGE	4.2MM	6.6MM	8.1MM	6.9MM
8	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	BRIDGE	3.1MM	4.8MM	7.4MM	6.3MM
9	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	1.8MM	3.9MM	7.9MM	7.4MM
10	ADULT	LEFT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	2.2MM	4.7MM	7.6MM	6.9MM
11	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	3.3MM	5.1MM	7.1MM	6.4MM
12	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	3.5MM	4.8MM	10.0MM	9.2MM
13	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	DIPLOIC	INTACT	BRIDGE	RIDGE	3.3MM	5.8MM	9.6MM	6.8MM
14	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	2.2MM	5.7MM	8.7MM	8.1MM
15	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	SCLEROTIC	INTACT	RIDGE	RIDGE	4.1MM	6.7MM	8.6MM	7.6MM
16	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	3.2MM	5.9MM	8.1MM	7.6MM
17	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	3.6MM	6.2MM	10.1MM	9.2MM
18	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	4.2MM	7.2MM	8.9MM	8.3MM
19	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	2.7MM	4.9MM	7.7MM	7.0MM
20	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	DIPLOIC	INTACT	BRIDGE	RIDGE	3.8MM	5.5MM	9.4MM	8.3MM
21	ADULT	LEFT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	2.3MM	5.7MM	8.1MM	7.2MM
22	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	4.0MM	6.3MM	8.8MM	8.2MM
23	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	BRIDGE	3.6MM	5.9MM	9.2MM	7.9MM
24	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	PNEUMATIZED	INTACT	BRIDGE	RIDGE	2.5MM	4.9MM	8.0MM	7.4MM
25	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	DIPLOIC	INTACT	RIDGE	RIDGE	3.1MM	5.5MM	9.8MM	9.5MM
26	ADULT	LEFT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	BRIDGE	3.8MM	5.9MM	9.8MM	9.4MM
27	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	NOT PROMINENT	DIPLOIC	INTACT	RIDGE	RIDGE	2.9MM	3.5MM	5.2MM	5.5MM
28	ADULT	LEFT	PRESENT	NORMAL	NORMAL	ATRETIC	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	BRIDGE	3.4MM	5.0MM	7.4MM	6.9MM
29	ADULT	RIGHT	PRESENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	3.9MM	5.0MM	6.6MM	6.0MM
30	ADULT	RIGHT	ABSENT	NORMAL	NORMAL	PATENT	INTACT	PROMINENT	PNEUMATIZED	INTACT	RIDGE	RIDGE	4.1MM	5.7MM	7.1MM	6.4MM