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ANATOMICAL VARIANTS OF RETROTYMPANUM - AN ENDOSCOPICAL STUDY

Otorhinolaryngology

Dr. Archi Charpota* PG Resident Otorhinolaryngology Dept. Kota (Raj.). *Corresponding Author
Dr. Shiv Kumar Senior Prof. Otorhinolaryngology Dept. Kota (Raj.).
Dr. Resusci Annie M.B.B.S. Student Govt. Medical College Kota (Raj.).
Dr. Nandlal Charpota P.M.O. Mahatma Gandhi Hospital Banswara (Raj.).

ABSTRACT

Aim: To describe and classify the anatomical variants of retrotympanic structures by using transcanal endoscopy approach. **Methodology:** A cross-sectional study was conducted in The Department of Otorhinolaryngology, Government Medical college, Kota, (Raj.) from Jan. 2022 to June 2022. We reviewed 45 endoscopic ear surgery to explore anatomical variations in retrotympanum. The anatomy was documented photographically. The final classification was tabularized and summarized. **Results:** 7 cases of extended cholesteatoma with bony erosion were excluded. Study was performed in remaining 38. Ponticulus showed high variability among the bony crests. Ridge shape being the most frequent presentation. The subcochlear canaliculus was 50% detectable indicating a connection to the petrous apex. Sinus tympani was mostly of normal shaped (type A). Rarely a type C or D was observed. **Conclusion:** The retrotympanum bears a high anatomical variability. If it is affected by disease, the endoscopic approach offers prompt recognition of the disease extension due to the wide-angle view of the whole region and the possibility to use angled scopes which helps the surgeon to completely clean the region from disease. Using the endoscope in the middle ear recesses in cholesteatoma surgery, we may also reduce the residual cholesteatoma.

KEYWORDS

Retrotympanum, middle ear anatomy, cholesteatoma, ponticulus, subiculum, sinus tympani, subcochlear canaliculus.

INTRODUCTION

The middle ear can be divided into subspaces, based on their relationship with the mesotympanum. Superior to it lies the epitympanum; anterior the protympanum; and inferior is the hypotympanum. [1] The retrotympanum is located at the posterior portion and holds several complex anatomic and surgical structures.

Its anatomy represents a challenge both in understanding and visualization, because conventional microscopic approaches can neither visualize nor preserve some of those important structures even when performing a retrofacial access or an open canal wall down technique.[1,2,5,6]

The retro-tympanum is a critical area of the middle ear and gets regularly affected by disease especially cholesteatoma [3]. Due to its limited direct access and hidden position in between anatomical structures such as the facial nerve (FN), the stapes, the oval and the round window, the jugular vein bulb (JVB), the internal carotid artery (ICA) etc., it is one of the most challenging regions for surgical treatment. By these reasons, this part of the middle ear holds a high risk of residual cholesteatoma after middle ear surgery.[4]

The recently introduced minimal invasive endoscopic techniques to access the middle ear may increase the visibility of the retro-tympanum as angled scopes can be used [7–10]. However, exact knowledge on the variability of the retro-tympanic anatomy is still lacking.

The aim of this study is to describe and classify the anatomical variants of retrotympanic structures by the means of transcanal endoscopy approach.

We think that the retro-tympanum holds more anatomical variability than actually thought. This may have direct impact on further middle ear surgical management.

MATERIALS AND METHODS

We conducted a cross-sectional study in The Department of Otorhinolaryngology, Government Medical college, Kota, Rajasthan from Jan. 2022 to June 2022. We reviewed 45 endoscopic ear surgery using two 3mm diameter, 15cm length, endoscopes with angles of 0° and 45°, a 4K camera system and a high-resolution monitor to explore anatomical variations in retrotympanum.

The exploration was performed holding the endoscope with attached camera in one hand (usually the left) and the instrument in the other. The exploration of the sinus required prior cleaning and removal of present mucosal folds using angled instruments.

We included exclusive cases with unchanged anatomy of the retro- and hypotympanum. The indications to surgery were tympanic membrane perforations, retraction pockets of the attic, minor attic cholesteatoma or otosclerosis. Seven cases of extended cholesteatoma with erosion of the bony structures of the retrotympanum were excluded from this study.

The anatomy was documented photographically and underwent further review by the authors. The final classification was tabularized and summarized.

ANATOMY OF RETROTYMPANUM (NOMENCLATURE AND CLASSIFICATION)

The retrotympanum is divided by the subiculum in the superior and inferior divisions. (Fig. 1) The superior part contains the posterior sinus (PS) and sinus tympani (ST), which are divided by the ponticulus. The inferior retrotympanum is represented by the sinus subtympanicus (SST), which contains the round window niche. The finiculus separates the inferior retrotympanum to the hypotympanum (HT) and marks the anterior boundary of the subcochlear canaliculus (SC). [2,3,10–12]

Figure 1 gives an endoscopic view and a schematic drawing of the investigated region.

A. Bony crests (Fig. 2&4):
Ponticulus: A bony connection between the promontory and the pyramidal eminence.

Subiculum: A bony structure arising from the posterior pillar of the round window niche towards the styloid eminence.

Finiculus: A bony structure extending from the anterior pillar of the round window niche to the jugular bulb.

All the three are classified as bridge, ridge or incomplete.

B. Retro-tympanic sinus (Fig. 2&3):
Posterior sinus: A triangular space medial to the stapedial tendon, inferiorly bounded by the ponticulus and anteriorly by the stapes footplate and oval window.

Sinus tympani (ST): A round shaped space between the ponticulus and the subiculum, medial to the pyramidal eminence and the facial nerve and lateral to the posterior semicircular canal.

The shape of ST is classified according to Marchioni et al. [3] in –Type A: normal, Type B confluent (incomplete ponticulus), Type C: partitioned, Type D: restricted. (Fig. 3)

Sinus subtympanicus: A space medial to the facial nerve and styloid prominence, limited by the subiculum superiorly and the finiculus inferiorly and connected with the round window niche anteriorly.

Subcochlear canaliculus (SC): A space of variable pneumatization connecting the round window chamber with the petrous apex lying below the cochlea. Classified by Marchioni et al. [10] as Type A: Deep tunnel extending inferiorly to the petrous apex, Type B: Small tunnel easily accessible endoscopically and type C: No tunnel. The assessment of the depth of the tunnel is based on an endoscopic and radiologic evaluation. In this study, we limited the assessment of SC to the pure endoscopic perceptibility as type A (detectable) or type B (not detectable).

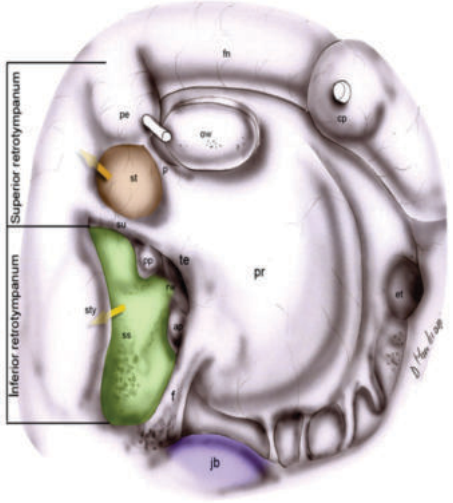


Fig. 1. Anatomy of retrotympanum. Yellow arrow indicates the depth of SS e ST. ap, anterior pillar; cp, cochleariform process; et, Eustachian tube; f, finiculus; fn, facial nerve; jb, jugular bulb; p, ponticulum; pe, pyramidal eminence; pp, posterior pillar; pr, promontory; ss, sinus subtimpanicum; st, sinus tympani; su, subiculum; rw, round window.

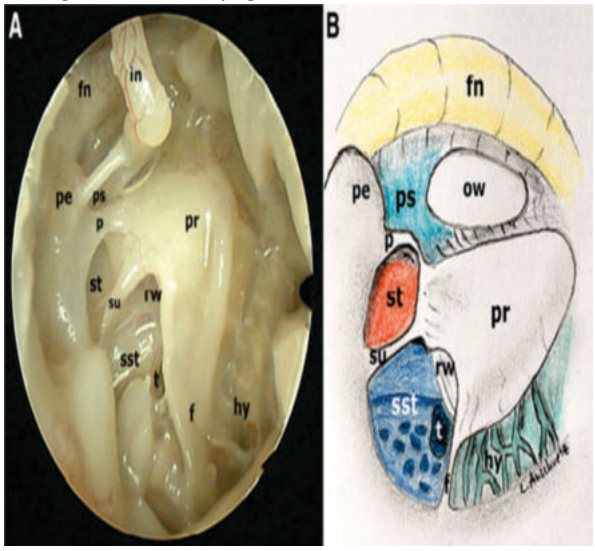


Fig. 2 Right ear. Endoscopic view (a) and schematic drawing (b) showing the bony crests and sinuses of the retro- and hypotympanum. Note the bridge ponticulus in the drawing. fn facial nerve, in incus, pr promontory, pe pyramidal eminence, ps posterior sinus, p ponticulus, st sinus tympani, su subiculum, sst sinus subtympanicus, f finiculus, t subcochlear tunnel, hy hypotympanum, ow oval window, rw round window region.

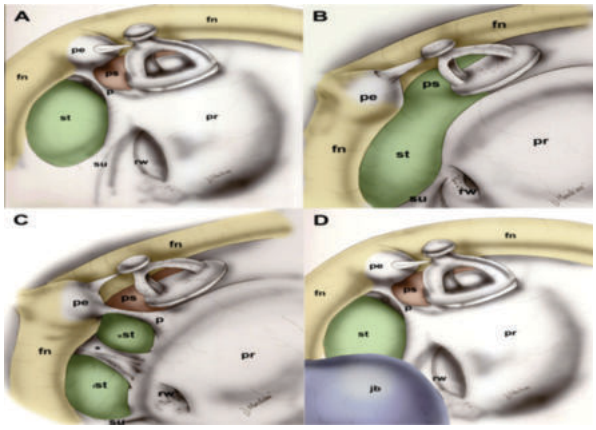


Fig. 3. (A–D) Drawing of the anatomy describing the sinus tympani shape variations. fn, facial nerve; jb, jugular bulb; p, ponticulum; pe, pyramidal eminence; pr, promontory; ps, posterior sinus; rw, round window; su, subiculum; st, sinus tympani.

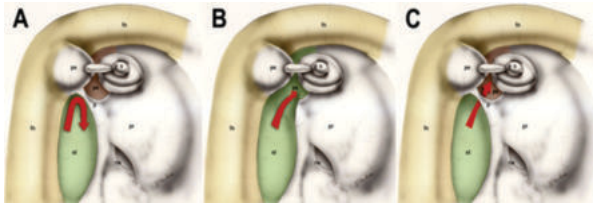


Fig. 4. (A–C) Drawing showing different types of ponticulus. Red arrow indicates represents the sinus tympani shape. fn, facial nerve; p, ponticulum; pe, pyramidal eminence; pr, promontory; ps, posterior sinus; rw, round window; st, sinus tympani

RESULTS

We explored a total of 38 middle ears cases undergoing surgery. The retrotympanic structures were well identifiable using the transcanal endoscopic approach.

DESCRIPTION OF ANATOMICAL VARIANTS

A. Bony crests (Fig. 5):

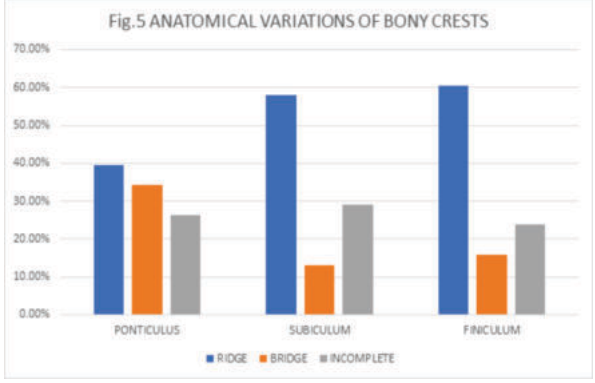
Ponticulus: Has high variability with almost equally represented variants. In most cases, we observed a ridge (n=15, 39.47%) or bridge (n=13, 34.21%) shape and incomplete in only 10 cases (26.31%).

Subiculum: Mainly represented in ridge shape (n=22, 57.89%). In 11 of cases (28.94%), the subiculum was missing creating a unique large retrotympanic sinus and only in five cases (13.15%) the subiculum was observed as bridge.

Finiculus: Has the less variability with almost 23 ridge (60.52%), 9 incomplete (23.68%) and 6 bridge (15.78%) representations.

B. Retro-tympanic sinus:

- Sinus tympani: normal shaped (type A) in 27 cases (71.05%) followed by 7 (18.42%) of confluent shape (type B) forming a common sinus with PS. Rarely a type C shape with a bony crest inside the ST was observed (n=3, 7.89%) and only in one case the access to the ST was restricted (type D, 2.63%) by a very high jugular bulb.



- Subcochlear canaliculus: the tunnel was well perceptible in half of the cases (n=19, 50%) and absent in 13 cases (34.21%). In 6 cases (15.7%), the tunnel could not be assessed, because of obliteration of SST (e.g., high jugular bulb). Figure 6 shows the two described anatomical situations.

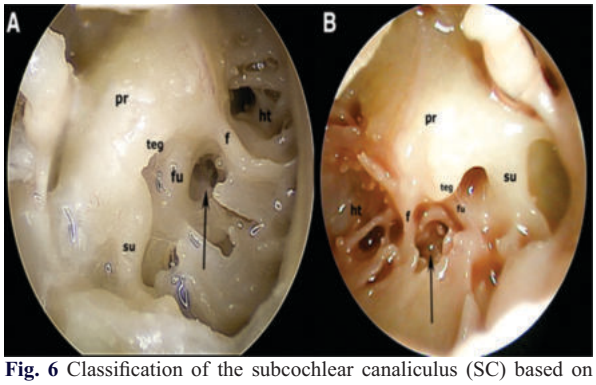


Fig. 6 Classification of the subcochlear canaliculus (SC) based on endoscopic perceptibility. a Right ear. Type A SC, well perceptible. Black arrow indicates the SC. b Left ear. Type B SC, absent. Black arrow indicates the SC. Finiculus is only hinted and has an unusual direction. pr promontory, teg round window tegmen, fu fustis, su subiculum, f finiculus, ht hypotympanum

DISCUSSION

The endoscopic surgical anatomy of the retrotympanum has been progressively studied and described. These studies focus on one particular region or structure: e.g., the ST [2,3,12], the inferior retrotympanum [11] with the round window region [10], the ponticulus [13] or the subpyramidal space [14]. Due to the presence of bony crests, which may be of bridge configuration, these areas are truly interconnected with each other.

The clinical importance of the described anatomical variability is the possible spread of cholesteatoma matrix underneath the bridges from one region to the other. Moreover, a fragment of matrix may easily hide behind a bony crest or under a bridge and therefore escape to the surgeon's eyes. As previously assessed, ST remains the main site of residual disease after middle ear surgery for cholesteatoma [7,15].

When the cholesteatoma involves the ST, there might be 2 clinically important risks-
1. The potential for residual disease because of incomplete removal of the disease.
2. The increased risk for ossicular discontinuity and hearing loss because of cholesteatoma within the ST, which the surgeon cannot control. [4,16]

To avoid these risks, maximum exposure of the ST along with the other hidden areas of retrotympanum and complete removal of the disease are essential.

If the retrotympanum is affected by disease, the endoscopic approach offers prompt recognition of the disease extension due to the wide-angle view of the whole region and the possibility to use angled scopes. Therefore, the use of an endoscope improves the outcome of cholesteatoma surgery by preventing residual disease [8,9].

The literature [3,11] presents clear description of the endoscopic approaches to retrotympanum (with 0, 45, and 70 optics); these approaches ensure the complete visualization of the retrotympanum surgical spaces, and allow the surgeon to completely study the anatomic variations and pathologic tissues hidden behind.

Holt [13] observed the presence of ponticulus in 33 of 50 examined temporal bones in 2004. He described it as a bony bridge extending between the pyramidal eminence and the promontory. He denies the observation of a ridge formation, but rather describes a “sheet of bone.” These assumptions can be disproved due to the observation of 39.47% ridge ponticulus in our study.

Comparing the results of Marchioni et al. (2009) with 5.3% bridge ponticulus in their case series of 40 surgical patients [3], we observed a much higher rate of 34.21% bridge ponticulus in this study.

Another study by Marco Bonali et al. (2017) observed a ridge (n=47, 38%), bridge (n=44, 35%) shape and the ponticulus was incomplete in 34 cases (27%).[22]

This finding is very similar to our study as we observed incomplete in only 10 cases (26.31%).

This may be due to technical advances in endoscopy and the awareness of the observers to the possible variants.

Regarding the subiculum Marchioni et al. [11] described in a cohort of 25 surgically treated subjects a distribution of 19 ridges, two bridges and a lack of subiculum in four patients. In the same study, describing the finiculus, they observed 12 ridges, two bridge and a lack of finiculus in 11 patients.

Another study by Marco Bonali et al. (2017) observed Subiculum mainly represented as ridge shape (n=73, 58%). Only in (8%) the subiculum was observed as bridge and (n=42, 34%) it was missing creating a large retrotympanic sinus. Finiculus showed two thirds ridge (n=79, 63%), 25 incomplete (20%) and 21 bridge (17%) representations. [22]

We can consider these results as in concurrence to our observations with a ridge shape being the most frequent presentation of these bony crests.

On a larger scale, we found very rarely a bridge-shaped subiculum only five cases (13.15%), while the finiculus was present in 15.78% of the cases as a bridge.

Sinus tympani was mostly normal shaped (type A) in 27 cases (71.05%) followed by 7 (18.42%) of confluent shape (type B) forming a common sinus with PS. Rarely a type C shape with a bony crest inside the ST was observed (n=3, 7.89%) and only in one case the access to the ST was restricted (type D, 2.63%) by a very high jugular bulb.

The subcochlear canaliculus was in half of the cases detectable (50%) indicating a connection to the petrous apex. We observed difficulties assessing the actual depth of this tunnel by means of an exclusive endoscopic approach. Clinically, we must consider that the presence of an extensive cholesteatoma in this region may extend in the petrous apex inferior to the cochlea. At times, the subcochlear canaliculus may not be visible in some situations. In cases of cholesteatomatous invasion of the petrous apex, an infracochlear approach may be necessary to completely eradicate the disease [17]. Moreover, during cochlear implant surgery a large subcochlear canaliculus may be mistaken for the round window niche, this applies especially in cases of a narrow facial recess. This situation bears the risk of unnecessary additional bone removal around the Facial nerve, and therefore time loss, or in extremis the positioning of the electrode array into the petrous apex.

The hidden areas of the retrotympanum are difficult to access, and therefore represent a region of risk for residual cholesteatomatous disease after surgical treatment. The extension of the disease into a deep sinus, extending below the facial nerve (ST Type C) demands thorough exploration. Therefore, exact anatomical knowledge and an efficient technique to visualize the middle ear structures are required.

In our experience, the transcanal endoscopic approach is a very useful technique offering the necessary vision to the surgeon to clean these hidden areas from disease. The superiority of the endoscope to visualize the middle ear compared to the microsope is illustrated in Fig.7.

Recently, Benett et al. published a comparative work between endoscopic and microscopic technique for the visualization of the middle ear anatomy supporting our study results [18]. We emphasize that the use of angled scopes allows not only the visualization of hidden areas but also proper precise dissection under view.

A recently published cross-sectional study among ENT surgeons in Canada reports growing experience in endoscopic ear surgery [19]. The main instrument among the surgeons still remained the microscope but collectively they acknowledged the advantage of the endoscopic access in the reduction of residual disease. The feasibility of the endoscopic approach was even described in children [20] and James et al. recently observed reduced residual disease in endoscopic management of cholesteatoma [21].

Our dissection and surgery experience are favorable to the endoscopic exploration due to the excellent views of the anatomical structures without need of bone removal for access purposes.

Using the endoscope in the middle ear recesses in cholesteatoma surgery, we may reduce the residual cholesteatoma rate by using a transcanal minimally invasive approach that allows the preservation of bone and mucosa of the mastoid cell system, which have an important functional role at the middle ear homeostasis. This atraumatic approach is a suitable method for exploring the mesotympanic structures also.

Our results describe the anatomical variability of the retrotympanic region which will surely help the surgeons to completely clean the region from disease.

Advantages of Endoscopic Approach

Endoscopic approach to ST and retrotympanum offers a direct mini-invasive surgical approach to the middle ear avoiding mastoid bone and mucosa removal. Also, it allows a direct visualization of the retrotympanum and surrounding structures such as ossicular chain, chorda tympani, facial nerve, and round and oval window niches, offering a wide exposition of the retrotympanic region.

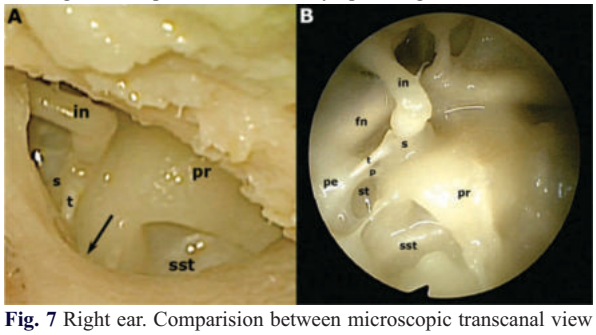


Fig. 7 Right ear. Comparision between microscopic transcanal view (a) and transcanal endoscopic view (b). The microscopic view does not allow the visualization of the retro and hypotympanum (indicated by black arrow). in incus, s stapes, t stapedial tendon, pr promontory, sst sinus subtympanicus, fn facial nerve, pe pyramidal eminence, p ponticulus, st sinus tympani

CONCLUSION

The retrotympanum bears a high anatomical variability. If the retrotympanum is affected by disease, the endoscopic approach offers prompt recognition of the disease extension due to the wide-angle view of the whole region and the possibility to use angled scopes. Using the endoscope in the middle ear recesses in cholesteatoma surgery, we may reduce the residual cholesteatoma rate by using a transcanal minimally invasive approach that allows the preservation of bone and mucosa of the mastoid cell system, which have an important functional role at the middle ear homeostasis. Also, it allows a direct visualization of the retrotympanum and surrounding structures such as ossicular chain, chorda tympani, facial nerve, and round and oval window niches, offering a wide exposition of the retrotympanic region. This atraumatic approach is a suitable method for exploring the mesotympanic structures also.

Our results describe the anatomical variability of the retrotympanic region which may help the surgeon to completely clean the region from disease.

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