Endoscopic Anatomy of the Retrotympanum

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KEYWORDS

• Surgical anatomy • Cholesteatoma • Middle ear • Retrotympanum • Atraumatic

KEY POINTS

- The retrotympanum is located at the posterior portion and houses several important and complex anatomic and surgical structures.
- The greater the depth of the subpyramidal space (SS), the more is a surgical approach at high risk of leaving residual cholesteatoma.
- Use of the endoscope in the middle ear recesses in cholesteatoma surgery may reduce the residual cholesteatoma rate. Using a transcanal minimally invasive approach allows the preservation of bone and mucosa of the mastoid cell system. This atraumatic approach is a suitable method for exploring the mesotympanic structures.
- In type C sinus tympani (ST), especially associated with a well-developed mastoid cell system, it is not always possible to have a good control of the ST using endoscopes; in these cases, a combined (endoscopic-microscopic) posterior retrofacial approach is suggested.

ANATOMY OF RETROTYMPANUM

The middle ear can be divided into subspaces, based on their relationship with the mesotympanum. Superior to it lies the epitympanum; anterior to it, the protympanum; and inferior to it, the hypotympanum.[1]

The retrotympanum is located at the posterior portion and houses several important and complex anatomic and surgical structures. Its anatomy represents a challenge both in understanding and visualization, because conventional transcanal microscopic approaches can neither visualize nor preserve some of those important structures.[1,2] Recently, endoscopic techniques have allowed the complete visualization of these structures.

This article describes the endoscopic anatomy of the retrotympanum and its relationships to other important anatomic landmarks in the middle ear to understand its importance and relevance during surgical procedures.

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The retrotympanum is divided by the subiculum into superior and inferior retrotympanum. The superior retrotympanum can also be subdivided in 4 spaces: 2 medially and anteriorly and 2 laterally and posteriorly to the third tract of facial nerve.[1,2]

The ST is one of the most important spaces of the retrotympanum. It is represented by[1–4]

- Posterior outpouching cavity lying between the medial wall of the middle ear medially
- The pyramidal eminence (PE) laterally
- Posterolateral delineation by the second genu and third tract of the facial nerve, lateral semicircular canal (LSC), and vestibule
- Close relationship anteriorly with the superior portion of the promontory

The ST is bordered superiorly by the ponticulus that separates it from the posterior tympanic sinus (PTS), a bone niche of the superior portion of the retrotympanum.

PTS is not always present, depending on the presence of ponticulus and the extension of ST, by the oval window, and inferiorly by the subiculum, that separates it from the inferior retrotympanum and round window. This space could also be divided into 3 different types depending on its posterior extension with respect of the third portion of the facial nerve. Laterally and posteriorly to the second genu and vertical portion of the seventh cranial nerve are localized 2 anatomic bone niches: the facial sinus and the lateral tympanic sinus. These niches are separated by the chordal ridge, departing from the posterior portion of the PE. These anatomic regions are more accessible than ST and PTS because they are located laterally to a tangential plane passing on the seventh cranial nerve course, and their anatomies are more constant.[1–6]

The PE is a triangular bony structure, with its base oriented posteriorly and the tip anteriorly. The PE houses the stapes tendon and has a horizontal orientation, lying anteriorly and laterally to the second genu of the facial nerve.[3,4]

Under this bone structure, that is located at the middle of retrotympanum, is the SS, which is delimited laterally by the medial aspect of the PE, medially by the medial side of the bony wall of the retrotympanum, and posteriorly by the vertical tract of the seventh cranial nerve.

This space can present different morphologies, mostly in its depth, varying from a total absence, because of total ossification of the medial aspect of the PE with the medial wall of retrotympanum, to a particularly deep SS lying beneath the facial nerve.

The inferior retrotympanum is the posterior space that houses the sinus subtympanicus (SSt), delimited posteriorly by the styloid complex and the third portion of the seventh cranial nerve; anteriorly by the round window with its pillars, tegmen, and the inferior and posterior portions of the promontory; superiorly by the subiculum; and inferiorly by the jugular bulb.[1–6]

Endoscopic Anatomy of the Retrotympanum

Recent endoscopic anatomy study[7] clearly describes the following ST shape variations:

a. *Classical shape*: when the sinus is located between the ponticulus and subiculum, lying medial to the facial nerve and to the pyramidal process (**Fig. 1**A)
b. *Confluent shape*: when an incomplete ponticulus is present and the ST is confluent to the posterior sinus (see **Fig. 1**B)
c. *Partitioned shape*: when a ridge of bone extending from the third portion of the facial nerve to the promontory area is present, separating the ST into 2 portions (superior and inferior) (see **Fig. 1**C)

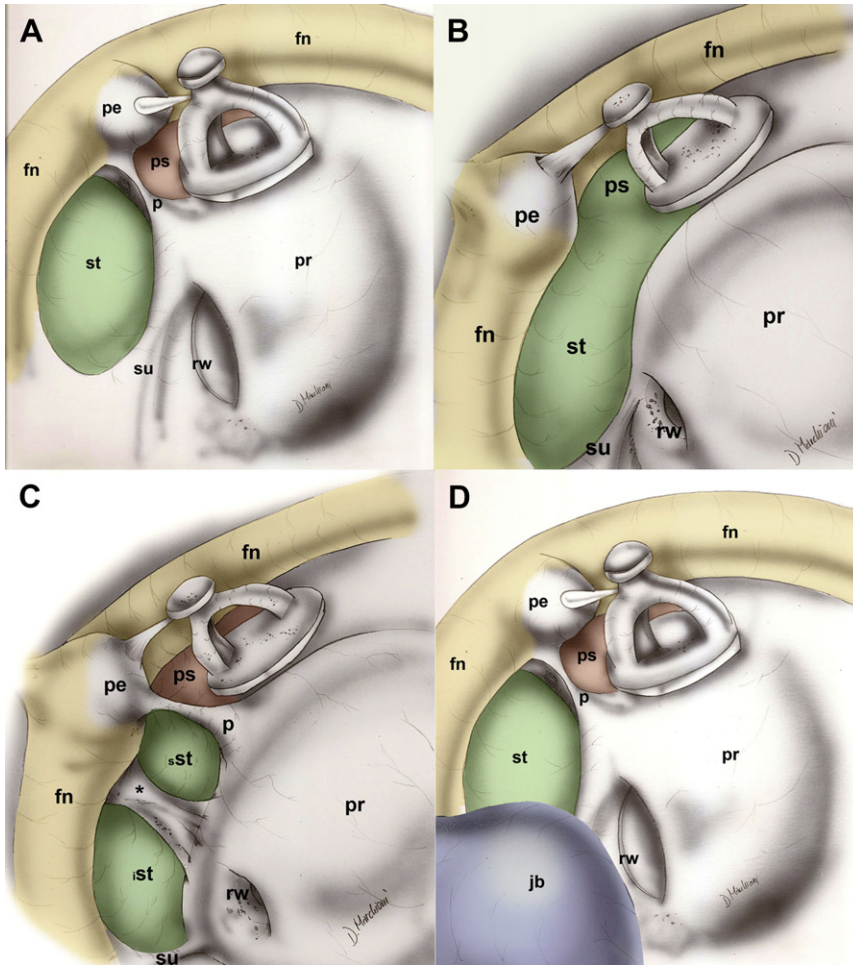

Fig. 1. (*A–D*)Drawing of the anatomy describing the sinus tympani shape variations. fn, facial nerve; jb, jugular bulb; p, ponticulum; pe, pyramidal eminence; pr, promontory; ps, posterior sinus; rw, round window; su, subiculum; st, sinus tympani.

d. *Restricted shape*: when a high jugular bulb is present, thus reducing the inferior extension of the ST (see **Fig. 1**D)

Several anatomic studies focused on the depth of ST. This detail is important because the greater the depth of the ST, the more is it difficult to achieve the complete removal of cholesteatoma, especially using traditional microscopic approaches. This is particularly true when the ST is deep. For this reason, it might be useful for the surgeon to study the extension of the ST before the surgery.

Another important endoscopic anatomic study[8] classified the depth of the ST into 3 types as follows:

- *Type A*: small ST. The medial limit of the third portion of the facial nerve corresponds to the depth of the sinus. In these cases, the ST is small and does not present a medial and posterior extension to the facial nerve (**Fig. 2**).

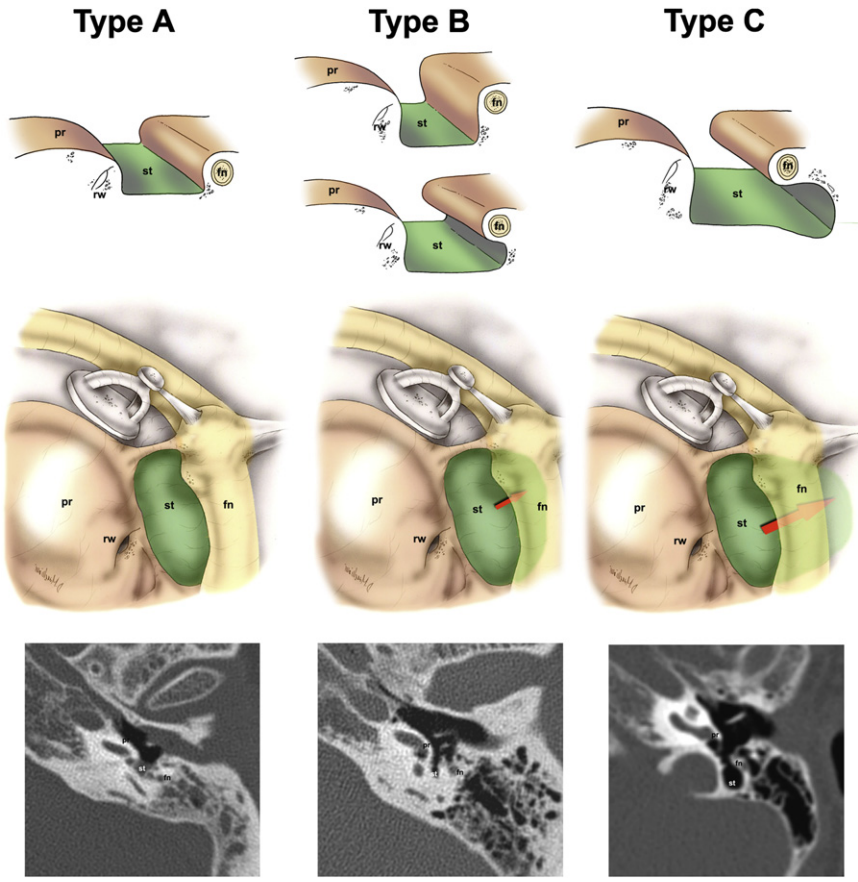

Fig. 2. Drawing of the classification of the sinus tympani depth. Red arrow indicates posterior extension of Sinus timpani respect the third portion of facial nerve. fn, facial nerve; Pr, promontory; rw, round window; st, sinus tympani.

- *Type B*: deep ST. The medial boundary of the ST lies medially with respect to the third portion of the facial nerve; however, it does not present a posterior extension to the facial nerve (see **Fig. 2**).
- *Type C*: deep ST with posterior extension. The medial boundary of the ST lies medial and posterior to the third portion of the facial nerve. In these cases, ST is very large and deep, and all these patients have a well-developed mastoid (see **Fig. 2**).

When a patient has a type C ST, it is not possible to explore the entire depth of the sinus, not even with the help of the endoscope, especially when it is associated with a well-developed mastoid cell system. In these cases, it is necessary to perform a posterior retrofacial approach.[7–9]

Endoscopic Anatomy of the Ponticulus

The endoscopic transcanal approach to the ST also permits a good view of the ponticulus. The ponticulus is a bony ridge extending from the pyramidal process to the promontory region, which separates the ST from the PTS.

Endoscopic anatomy study described the following 3 different variants of the ponticulus[7]:

a. *Classical morphology*: (**Fig. 3**A) in patients with such morphology, the ponticulus is completely formed and it is like a ridge of bone extending from the pyramidal process to the promontory area; this structure represents the superior limit of ST, dividing it from posterior sinus.
b. *Incomplete ponticulus*: (see **Fig. 3**B) in this morphology, the ST and posterior sinus are confluent.
c. *Communicating ponticulus*: in subjects with this morphology, the ponticulus is like a small bridge of bone and there is a communication between the ST and the posterior sinus under it (see **Fig. 3**C).

Especially when the ponticulus is like a small bridge, intraoperative endoscopic evaluation of the ponticulus area is very useful, because a residual cholesteatoma could be present under this bony bridge.[7–11]

Endoscopic Anatomy of Subiculum

The endoscopic approach to the ST also permits a good view of the subiculum.[7,8] Subiculum is a bony ridge extending outward from the posterior tip of the round window niche to the styloid eminence region, which separates the ST from the SSt.

When the subiculum is present, ST is separated by inferior retrotympanum (**Fig. 4**); when the subiculum is absent, the ST is confluent to the inferior retrotympanum.

The bridge subiculum is a rare conformation. When present, under this bridge of bone there is a communication between the inferior retrotympanum and the ST.

Endoscopic Anatomy of Subpyramidal Space

Endoscopic anatomy study[7,8] also describes close and variable relationships between ST, PTS, and the PE. Pneumatization of the retrotympanum may extend to a variable degree into a recess under the PE. This region is called the SS.

This space is limited laterally by the medial aspect of the pyramidal process, medially by the lateral wall of the tympanum, inferiorly by the ponticulus, and posteriorly and superiorly by the Fallopian canal, and it could be in direct anatomic continuity with the ST or with the PTS, depending on the position of the ponticulus. Features of this space (particularly its depth) vary significantly, and the authors have observed that it could range from total absence, due to the complete development of the medial aspect of the pyramidal process, to a clear representation of the SS with a significant depth. When the medial face of the PE is completely formed, the SS is large and

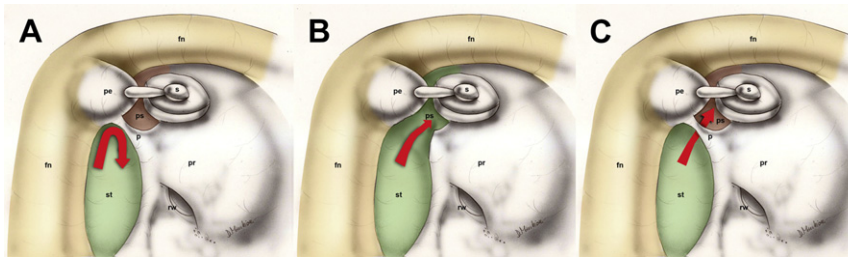

Fig. 3. (*A–C*) Drawing showing different types of ponticulus. Red arrow indicates represents the sinus tympani shape. fn, facial nerve; p, ponticulum; pe, pyramidal eminence; pr, promontory; ps, posterior sinus; rw, round window; st, sinus tympani.

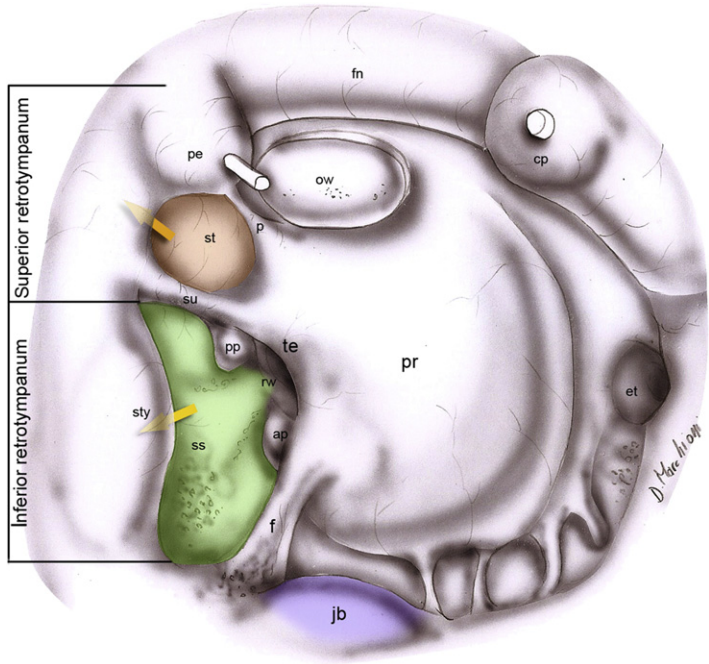

Fig. 4. Anatomy of subiculum. Yellow arrow indicates the depth of SS e ST. ap, anterior pillar; cp, cochleariform process; et, Eustachian tube; f, finiculus; fn, facial nerve; jb, jugular bulb; p, ponticulum; pe, pyramidal eminence; pp, posterior pillar; pr, promontory; ss, sinus subtimpanicum; st, sinus tympani; su, subiculum; rw, round window.

bounded by both the ST and PTS (*independent morphology of the PE*), and when the medial face of the PE is partially formed (*partial morphology of the PE)*, the SS is narrow and in some cases very deep, thus the posterior extension of this space is not explorable with an endoscope (**Fig. 5**).

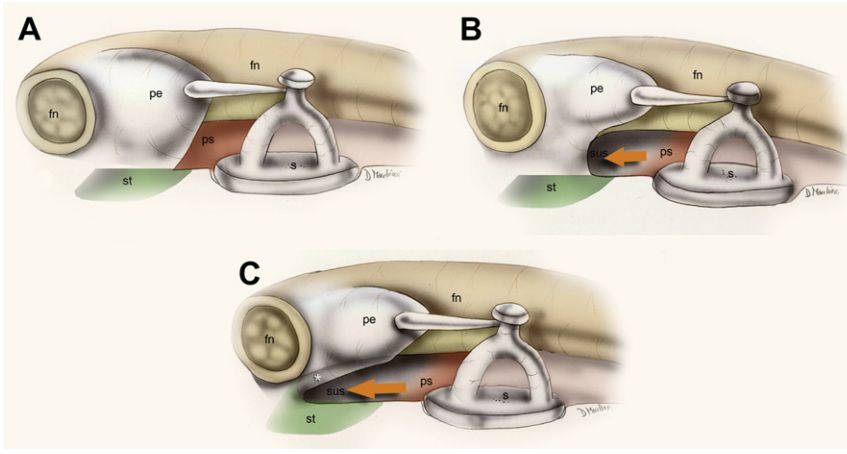

Fig. 5. (*A–C*) Anatomic variations of the subpyramidal space. Yellow arrow indicates the depth of PE. fn, facial nerve; pe, pyramidal eminence; ps, posterior sinus; st, sinus tympani; ps, pyramidal space.

In some cases that the authors observed, the medial bony wall of the PE was absent and the eminence was completely merged with the medial bone of the retrotympanum; in this case, the SS was not present *(merged morphology of the PE)* (see **Fig. 5**A).

The greater the depth of SS, the more is a surgical approach at high risk of leaving residual cholesteatoma. Thus, a good knowledge of these anatomic spaces may help in reducing the risk of residual cholesteatoma during middle ear surgery.[9–11]

Endoscopic Anatomy of Inferior Retrotympanum

Although surgeons have already studied the anatomy of the inferior retrotympanum,[1–5] this region has been quite neglected in the literature, most likely due to the low accessibility of this space during conventional microscopic procedures. In fact, in their studies, Proctor and colleagues have already identified almost all the structures in this region based on several temporal bone dissections.[12]

Proctor identified a quite constant structure, a ridge of bone connecting the basal helix of the cochlea to the jugular wall of the tympanum, in relation to the anterior pillar of the round window niche: the *sustentaculum promontorii*.

He called it the *sustentaculum* (from the Latin *sustentaculum*, *-i*: support) because he thought that it sustained the inferior tympanic artery, enveloping it during the development of the middle ear. Marchioni and colleagues[7,8] confirmed the presence of this structure in relation to the anterior pillar of the round niche, identifying 2 variants: a ridge shape and a bridge shape. They[7,8] decided to rename the sustentaculum promontorii as the *finiculus* for the following reasons:

- It is quite unlikely that the inferior tympanic artery constantly lies in this structure, particularly in the case of the bridge shape, because it could be a very thin structure in some cases.
- Moreover, the authors wanted to identify a clear borderline between the retrotympanum and the hypotympanum, and for this they chose to rename it finiculus (from the Latin *finis*, *-is*: borderline). This anatomic structure can have some different conformations (**Figs. 6** and **7**).

Proctor also defined a bony structure, representing a kind of floor of the retrotympanic region, that he called the area concamerata. Although the pars media of the area concamerata (Proctor's "fustis"), a smooth bony column mainly forming the floor of the round window niche, can be easily identified in some of our ears, the authors found it somewhat difficult to identify the other parts of the area concamerata.

Marchioni noticed that in several patients a sinus lying inferior to the ST could be identified, forming a well-delimited space between the subiculum superiorly and posteriorly and the finiculus inferiorly and anteriorly, limited posteriorly and laterally by the styloid eminence and posteriorly and medially by otic capsule, and open anteriorly and medially to the round window niche. Marchioni called this space the "sinus subtympanicus."

ANATOMIC IMPORTANCE

When the cholesteatoma involves the ST, there might be 2 clinically important risks. One is the potential for residual disease because of incomplete removal of the disease, and the second is the increased risk for ossicular discontinuity and hearing loss because of cholesteatoma within the ST, which the surgeon cannot control.[13,14]

To avoid these risks, maximum exposure of the ST and complete removal of the disease are essential. However, the ST remains a challenging location in cholesteatoma surgery because it is made relatively inaccessible by the facial nerve and the stapedial muscle and tendon, when using microscopic traditional approaches,

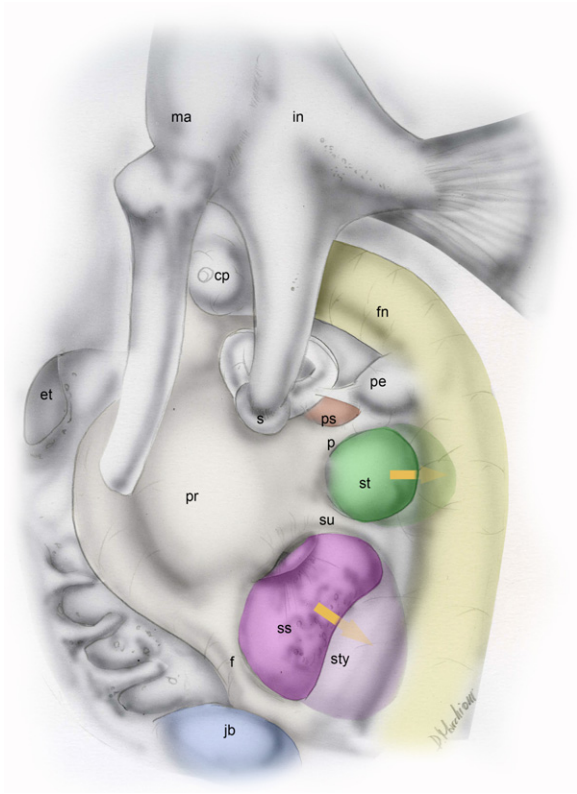

Fig. 6. Anatomy. Note the area of the finiculus. Yellow arrow indicates the depth of SS e ST. cp, cochleariform process; et, Eustachian tube; f, finiculus; fn, facial nerve; in, incus; jb, jugular bulb; Ma, malleolus; p, ponticulus; pe, pyramidal eminence; ps, posterior sinus; s, stapes; ss, sinus subtimpanicum; st, sinus tympani; sty, styloid process; su, subiculum.

because of the inherent limitations of this instrument. For this reason, the surgical management of ST cholesteatoma remains controversial. Residual cholesteatoma is among the major causes of failure in surgical treatment of cholesteatoma.[15–17]

Residual cholesteatoma occurs as a consequence of growth of a fragment of the matrix inadvertently remaining in the middle ear at the time of cholesteatoma surgery.

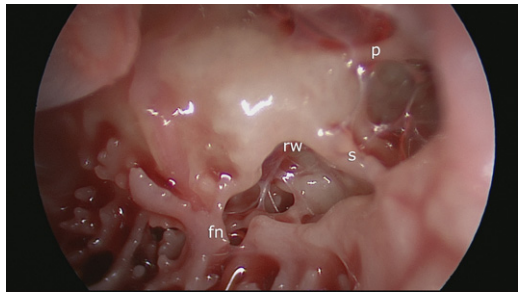

Fig. 7. Endoscopic anatomy showing the finiculus (fn), ponticulum (p), round window niche (rw), and subiculum (s).

Some investigators focused on the frequency of residual cholesteatoma detected with the intraoperative use of the endoscope after traditional microscopic surgery.[18,19] They found that the ST was the most common site of residual cholesteatoma fragments.

The problems of residual cholesteatoma depend on the surgical approach; in fact, poor access cannot permit accurate cholesteatoma removal. For this reason, the particular anatomy of the ST requires maximum surgical exposure to permit complete removal of the disease. Several surgical techniques have been described to approach the ST area, all with the help of an operative microscope.[15–17]

Recently, a posterior approach to the ST through the mastoid was proposed by several investigators.[3] The retrofacial posterior approach was performed by dissecting the triangular bony area formed by the facial nerve, LSC, and posterior semicircular canal. This approach is very difficult and requires an expert otologic surgeon because the facial nerve, the posterior semicircular canal, and the LSC are all at risk of injury.

However, the development of endoscopic techniques for the middle ear has permitted exploration of hidden recesses such as the ST. Thomassin and colleagues[19–23] found that the quality of disease eradication had significantly improved with the intraoperative use of the endoscope, which allowed a consequent reduction of residual cholesteatoma.

Using the endoscope in the middle ear recesses in cholesteatoma surgery, we may reduce the residual cholesteatoma rate, 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.

The literature[7,8] 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 these techniques may allow the surgeon to completely visualize the anatomic variations and pathologic tissues. The transcanal endoscopic approach to the ST is indicated in ST of types A and B. When the surgical field is bleeding extensively, it is often necessary to clean the optical instruments and, in some cases, the surgeon must change the approach. In type C ST, especially associated with a well-developed mastoid cell system, it is not always possible to have good control of the ST using endoscopes; in these cases, a combined (endoscopic-microscopic) posterior retrofacial approach is suggested.[7–9]

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 both medially (ST, sinus subtympanicus, subpyramidal space) and laterally (facial sinus, lateral sinus).

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