The Laryngoscope

Pyramidal Eminence and Subpyramidal Space: An Endoscopic Anatomical Study

Daniele Marchioni, MD; Matteo Alicandri-Ciufelli, MD; Alberto Grammatica, MD; Francesco Mattioli, MD; Livio Presutti, MD

Objectives/Hypothesis: To describe retrotympanic endoscopic anatomy, especially the pyramidal eminence and contiguous spaces.

Study Design: This was an anatomical study on a prospective case series.

Methods: The anatomy of the retrotympanum was studied by endoscopy in nine patients affected by cholesteatoma who underwent tympanomastoid surgery and in six temporal bone dissections.

Results: Pneumatization of the sinus tympani and posterior tympanic sinus or both, noted in 12 ears out of 15, may give rise to a recess beneath the pyramidal eminence, which we have called the subpyramidal space. This space can manifest with a variable degree of depth, shape, or extent depending on the shape and dimensions of the pyramidal eminence.

Conclusions: Endoscopic exploration of the middle ear may guarantee a very good exposure of retrotympanic structures, allowing detailed anatomical descriptions of hidden areas. Improvement in our knowledge of the anatomy may decrease the possibility of residual disease during cholesteatoma surgery.

Key Words: Subpyramidal space, pyramidal eminence, endoscopic anatomy, retrotympanum, middle ear.

***Laryngoscope*, 120:557–564, 2010**

INTRODUCTION

The retrotympanum is located in the posterior portion of the middle ear cavity. It houses a number of important structures, although it represents an area that often cannot be completely visualized during microscopic ear surgery. One of the most important structures in this area is the sinus tympani (ST). This is a cavity lying between the medial wall of the middle ear medially and the pyramidal eminence (PE) laterally, posterolaterally delineated by the VII cranial nerve. The ST is bordered superiorly by the ponticulus and inferiorly by the subiculum.[1] It is separated by the posterolateral portion of the ponticulus from the posterior tympanic sinus (PTS), and the subiculum separates it from the hypotympanum.[2] The anatomy of this posterior space is very variable and the degree of posterior extension is mainly related to the overall status of pneumatization of the temporal bone.[3]

Surgeons have proposed a number of surgical techniques to remove disease in this region, many involving a microscope,[4–7] but it is very difficult to completely expose some areas of the posterior tympanum with a microscope, for example, in the case of a deep sinus tympani or under an incomplete ponticulus,[8] where residual cholesteatoma could be present. When cholesteatoma involves the retrotympanum and particularly the ST, there might be two clinically important risks: 1) the potential for residual disease due to incomplete removal of the pathology, and 2) the increased risk of ossicular discontinuity and hearing loss due to the repeated attempts at cholesteatoma removal within a space not easily visualized by traditional techniques.[8]

Recently, to resolve this problem some authors have proposed the use of an endoscope with varied angulations that allows the surgeon to see around corners, providing the ability to explore all of the hidden areas that are often not visible using a microscope.[8–16]

The aim of this article is to thoroughly describe the endoscopic retrotympanic anatomy, because up to the present time this has mainly been performed by microscopic cadaveric studies or has been obtained from microscopic intraoperative findings.

MATERIALS AND METHODS

From November 2008 to May 2009, 11 patients affected by middle ear cholesteatoma and six endoscopic cadaveric dissections were prospectively included in our study. All patients affected by middle ear cholesteatoma consecutively underwent endoscope-assisted tympanomastoid surgery by our team using techniques already described in the literature,[11–15] and a transcanal endoscopic approach to the retrotympanum was performed. The equipment used during surgery consisted of 0° and 45° rigid Hopkins rod telescopes with a 3-mm outside diameter (Karl Storz, Tuttlingen, Germany). A three-chip high-resolution

From the Otolaryngology Department, University Hospital of Modena, Modena, Italy.

Editor's Note: This Manuscript was accepted for publication September 14, 2009.

Send correspondence to Alberto Grammatica, MD, Otolaryngology Department, University Hospital of Modena, Via del Pozzo 71, 41100 Modena, Italy. E-mail: albertogrammatica@libero.it

DOI: 10.1002/lary.20748

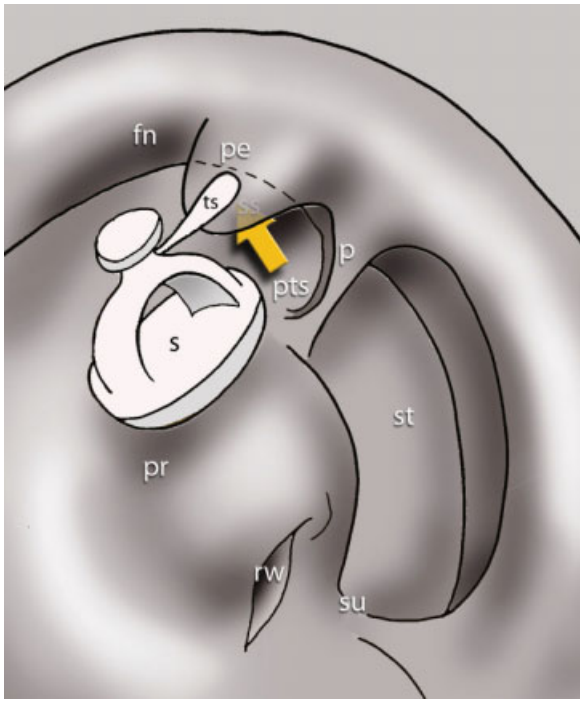

Fig. 1. Schematic drawing of subpyramidal space (ss). fn = facial nerve; pe = pyramidal eminence; ts = stapes tendon; p = ponticulus; pts = posterior tympanic sinus; s = stapes; st = sinus tympani; pr = promontory; rw = round window; su = subiculum.

monitor and camera (Karl Storz) were used for all of the procedures. The endoscopic ear surgery was performed with a set of apposite microendoscopic angled instruments (Karl Storz).

After the cholesteatoma removal, an endoscopic approach to the retrotympanum was performed as follows. The surgeon stood on the opposite side to the affected middle ear, and a 45°-angle endoscope was introduced into the external auditory canal. This position, combined with the 45°-angled endoscope used, allowed a direct exposure of the medial boundary of the sinus tympani. In this way, the ponticulus area, the PE, and the ST were all completely visible, and using the appropriate angled instruments any possible residual disease was removed. After this, any necessary middle ear reconstructive surgical steps were carried out.

Cadaveric dissections were performed in a temporal bone dissection laboratory using the same instruments as used in our surgical room, and the surgical technique for retrotympanum exploration was identical to that outlined above.

During the operations or dissections, accurate descriptions of the retrotympanic region were obtained and noted for each ear, particularly the morphology of the PE and its relationship to the ST, PTS, and ponticulus, and all of the operations were recorded in digital format for possible further revisions and analyses.

RESULTS

In nine patients out of the 11 living subjects, the PE and the retrotympanum were visualized and studied from an anatomical point of view; on the other hand, in two patients, it was not possible to adequately explore the retrotympanum because of excessive bleeding during surgery, and these two subjects were excluded from our study. Our final group was therefore composed of 15 ears (nine ears operated on for middle ear cholesteatoma and six cadaver specimens).

Intraoperative Endoscopic Evaluation of the Morphology of the PE and the Subpyramidal Space

In all 15 subjects, the PE had a triangular shape with a horizontal orientation lying anteriorly and laterally to the second genu of the facial nerve. The base of the triangular shape lay posteriorly, whereas the tip lay anteriorly in every ear, without any interpatient difference.

The presence of an anatomical space under the PE and varying in shape and depth, was noticed in most subjects (12/15) (Fig. 1). We have called this space the subpyramidal space (SS). This anatomical entity is delimited laterally by the medial aspect of the PE, and medially by the medial side of the bony wall of the retrotympanum. Posteriorly, this space is separated from the vertical tract of the bony canal of the facial nerve by a thin bony layer.

Out of 15 ears, four presented an independent space of the PE (Fig. 2A). The medial surface was completely formed and recognizable, lying laterally with respect to the medial bony boundary of the retrotympanum. The base of the triangular shape was located inferiorly and laterally to the second genu of the facial nerve. Between the medial surface of the pyramidal eminence and the medial boundary of the retrotympanum there was a hidden space with variable depth. In three of these subjects, the ponticulus was present with a bridge shape. Under the ponticulus we found a space communicating from the ST to the PTS. In one patient there was a rudimentary ponticulus. In all these cases, the SS was bounded posteriorly and inferiorly by the ST and superiorly and anteriorly by the PTS (Fig. 3A and Fig. 4). In two patients in this group the SS was very deep and the

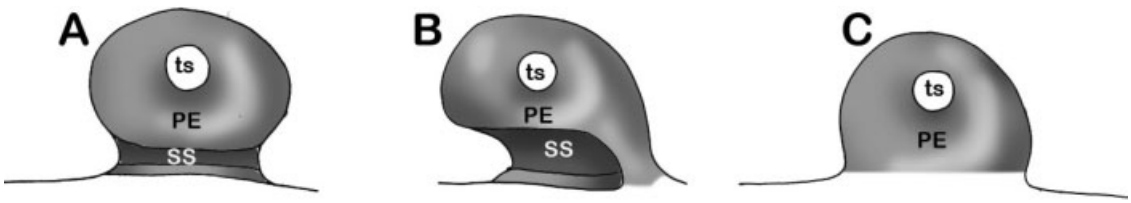

Fig. 2. Schematic drawing that shows the morphology of pyramidal eminence (PE) from an anterior perspective. (A) Independent morphology of PE. (B) Partial morphology of PE. (C) Merged morphology of PE. ts = stapes tendon; SS = subpyramidal space.

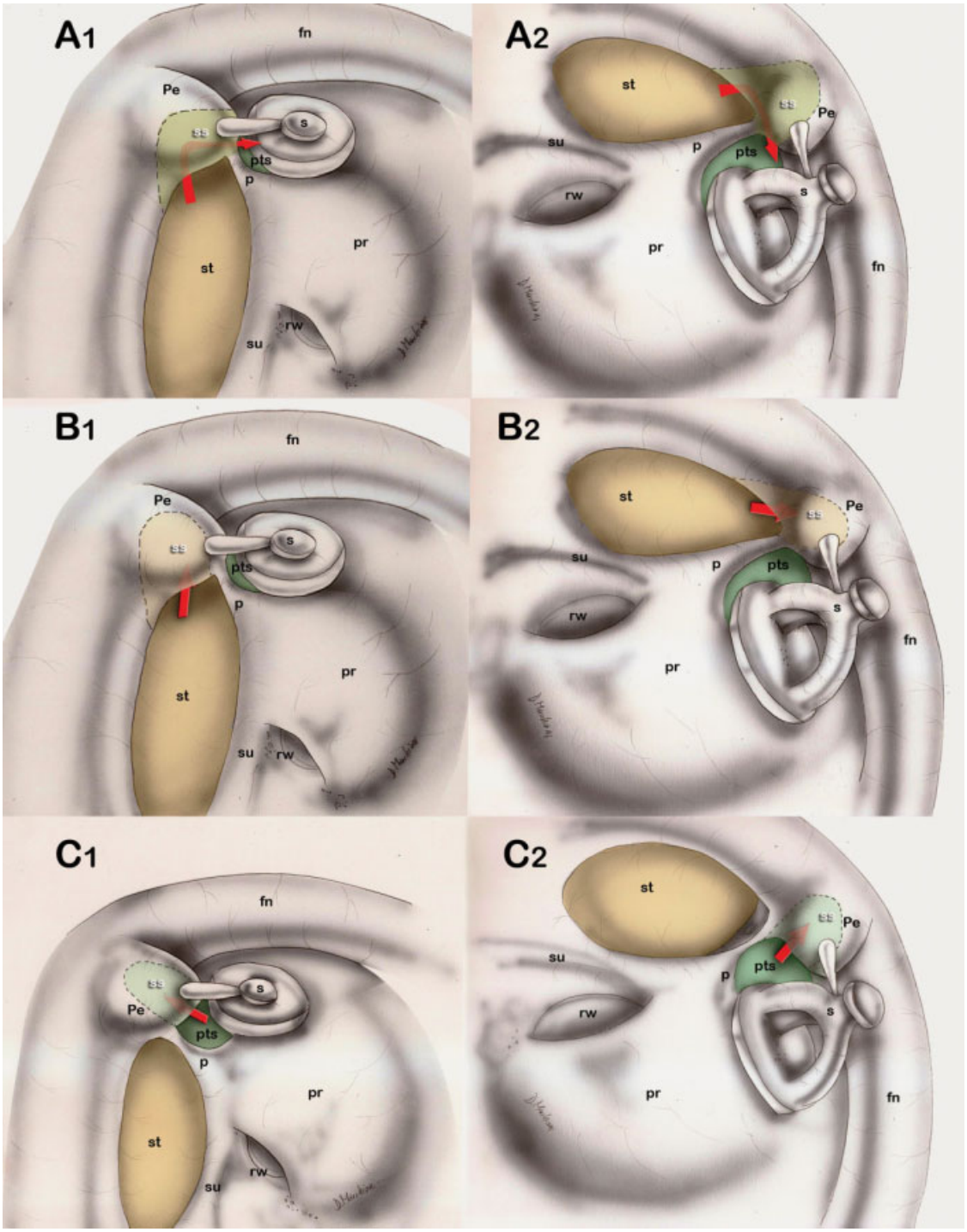

Fig. 3. Morphology of pyramidal eminence (Pe). (A) Complete morphology of the Pe and communicating sinus tympani (st) and posterior tympanic sinus (pts) through a subpyramidal space (ss) (A1 = anatomic perspective; A2 = surgical endoscopic perspective). (B) Partial morphology of the Pe, ss communicating with sinus tympani (A1 = anatomic perspective; A2 = surgical endoscopic perspective). (C) Partial morphology of the pyramidal eminence, ss communicating with posterior tympanic sinus (A1 = anatomic perspective; A2 = surgical endoscopic perspective, red arrow sowing the communication of ss). fn = facial nerve; s = stapes; p = ponticulus; pr = promontory; rw = round window; su = subiculum.

posterior limit of this sinus was not seen with the endoscope.

Out of 15 patients, three presented a contiguous space of the PE (Fig. 2B). The medial surface was completely merged with the medial bony boundary of the retrotympanum, no space was present under the PE, and the ponticulus completely separated the ST from the PTS in two subjects. The third patient presented a small bridge ponticulus communicating from the ST to the PTS (Fig. 5).

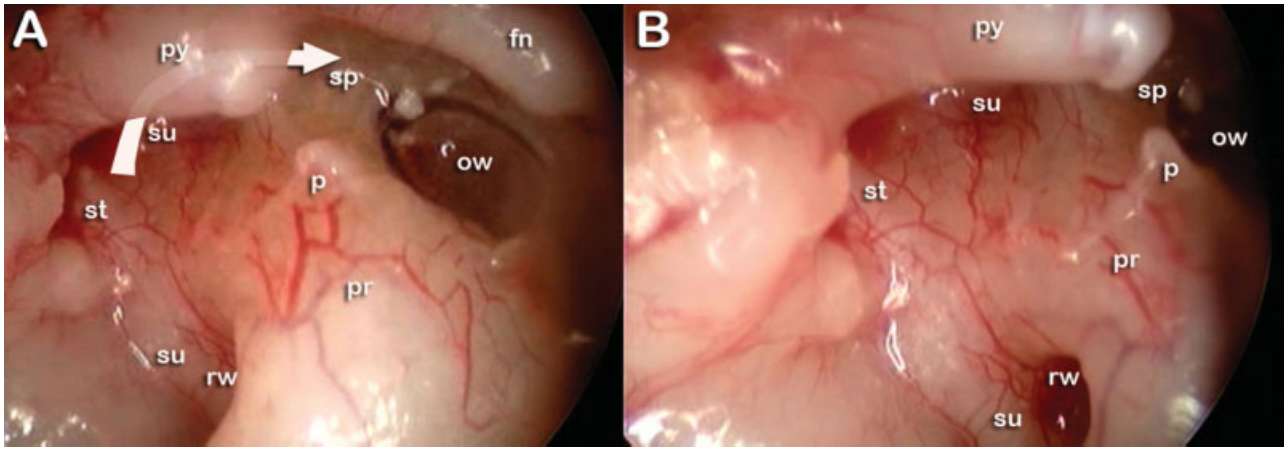

Fig. 4. Endoscopic view of a complete morphology of the pyramidal eminence in subject with a rudimental ponticulus. (A) White arrow showing a confluent space from the sinus tympani (st) to posterior tympanic sinus (pts) through a subpyramidal space (ss). (B) Exploration of the ss using a 45° endoscope. py = pyramidal eminence; fn = facial nerve; sp = posterior sinus tympani; su = subiculum; ow = oval window; p = ponticulus; pr = promontory; rw = round window.

Out of 15 patients, eight presented an underdeveloped space of the PE (Fig. 2C). The medial surface was partially formed anteriorly (in the tip and in the most anterior portion of the triangular shape), the posterior portion of the medial surface was merged with the medial bony boundary of the retrotympanum, and a SS was present under the PE with variable depth. In these subjects, four presented a ridge ponticulus separating the sinus tympani from the posterior sinus, three presented a bridge ponticulus with a communication from the sinus tympani to the posterior sinus, and one subject presented a rudimentary ponticulus (Fig. 6).

In this group of subjects, the relationship between the ponticulus and the SS was important. Actually, we found that there were different relationships of the SS with respect to the ponticulus area. In four of eight subjects the SS was superior with respect to the ponticulus area; in these cases this space belonged to the PTS (Fig. 3B and Fig. 7). In four of eight subjects the SS lay inferiorly to the ponticulus area, therefore belonging to the sinus tympani (Fig. 3C). Of these subjects, four presented a very deep SS, and the depth of this space was not able to be explored with the 45° endoscope, whereas the other four subjects presented a sinus of limited depth and the SS was completely visible with the 45° endoscope.

Finally, in six ears overall it was possible to explore the SS with the 45° endoscope, visualizing the posterior border under the PE (Fig. 8A). In six ears the SS was very deep, and the posterior limit was not completely visualized. In these cases we introduced an angulated instrument with different lengths inside this space to determine the real posterior extension (Fig. 8B). In three ears, the SS was not present (Fig. 8C).

DISCUSSION

From our experience performing endoscopic ear surgery, close and variable relationships have been noted between the ST, PTS, and the PE. In particular, pneumatization of the retrotympanum may extend to a variable degree into a recess under the PE; this space has not been described before and we have named this anatomical finding the subpyramidal space. This space is limited laterally by the medial aspect of the pyramidal

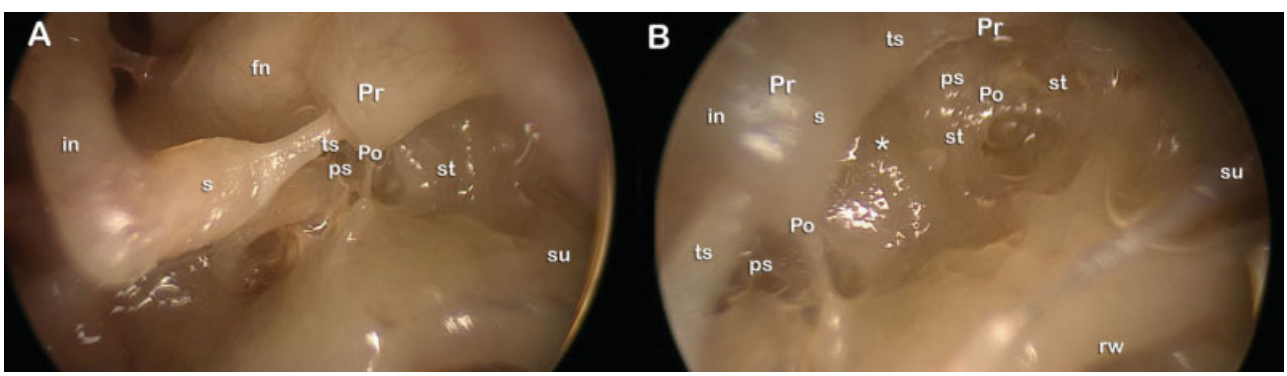

Fig. 5. Endoscopic view of a merged morphology of pyramidal eminence. (A) Endoscopic view of pyramidal eminence using a 45° endoscope. (B) The medial portion of the pyramidal eminence is merged with the medial bony wall of the retrotympanum (magnification with a 45°endoscope). *Merged region between pyramidal eminence and the medial bony wall of the retrotympanum. fn = facial nerve; Pr = promontory; in = incus; ts = stapes tendon; Po = ponticulus; s = stapes; ps = posterior sinus tympani; st = sinus tympani; su = subiculum; rw = round window.

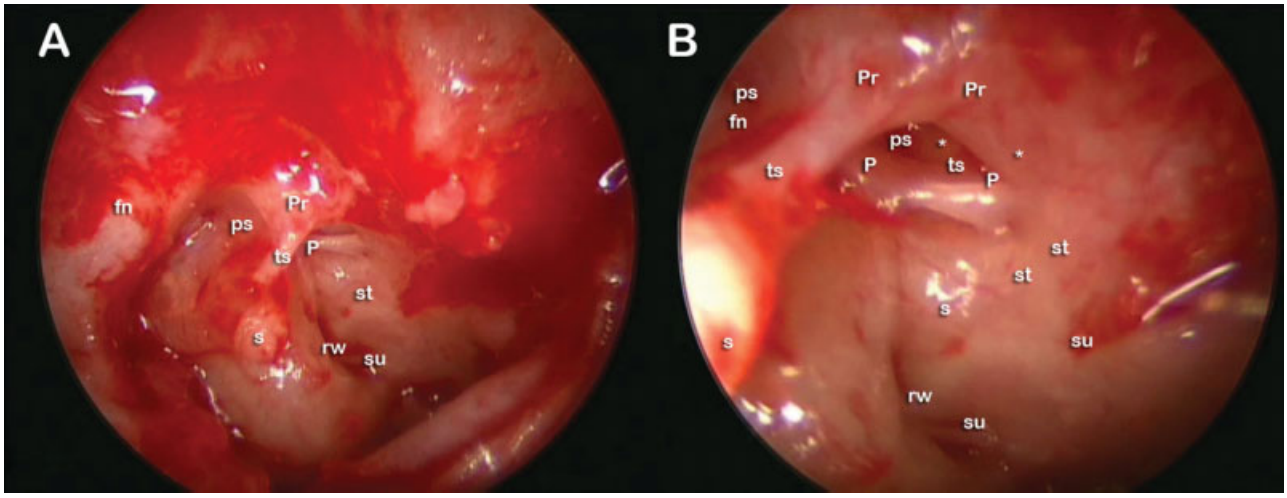

Fig. 6. Endoscopic view of a partial morphology of the pyramidal eminence. (A) Endoscopic view of retrotympanum using a 0° endoscope. (B) The depth of the subpyramidal space is explored. fn = facial nerve; Pr = promontory; ps = posterior sinus tympani; P = ponticulus; ts = stapes tendon; st = sinus tympani; s = stapes; rw = round window; su = subiculum.

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 anatomical continuity with the ST or belong instead to the PTS, depending on the position of the ponticulus. The features of this space (particularly its depth) vary significantly, and we found that it could range from a total absence due to complete development of the medial aspect of the pyramidal process, up to a clear representation of the SS with a significant depth. These descriptions could be of interest to ear surgeons, because being a hidden space, it could be one of the possible sites of residual disease during cholesteatoma surgery.

In the literature, several authors have studied the anatomy of the retrotympanum. This anatomical space was first described by Meckel in 1820[17] with particular regard to the SS and the PE, and then Steinbrugge reviewed the anatomy in 1889 describing the depth of the ST.[18] In 1960, Dworacek[19] first used the operating microscope to improve visualization of this space, and subsequently Proctor, Donaldson, and others added further surgical anatomical studies based on anatomical dissection of fetal, infant and adult temporal bones.[1,20,21] The retrotympanum houses four sinuses located around the bony canal of the facial nerve. These are the ST and the PTS, located medially and anteriorly to the fallopian canal, the facial sinus, and the lateral tympanic sinus located laterally and posteriorly.[10] The ST is a posterior outpouching, varying in depth, located on the posterior wall of the tympanum, and limited anteriorly by the promontory and the round window, posteriorly and laterally by the second genu of the facial nerve, medially by the posterior semicircular canal and vestibule, caudally by the subiculum, and superiorly by the ponticulus that rises from the PE separating the ST from the PTS. Ozturan et al. found that the depth of the ST in 327 temporal bones ranged from 0.2 to 9.9 mm (with an average depth of 2.06 mm).[22] The PTS is a small space lying superiorly to the sinus tympani. This space is bounded posteriorly and superiorly by the facial nerve and inferiorly by ST, and anteriorly it is delimited by the stapes ossicle and the oval window. The anatomy of

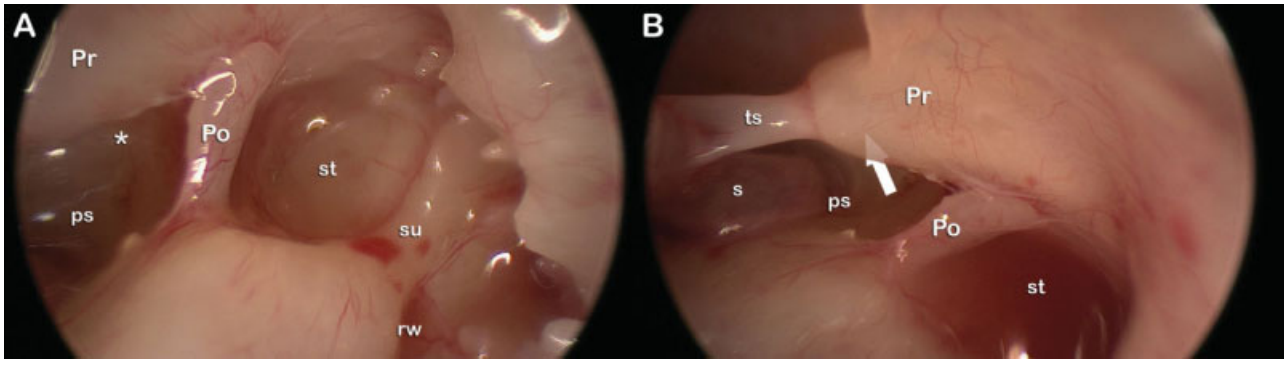

Fig. 7. Endoscopic view of a partial morphology of the pyramidal eminence. (A) Magnification of the medial boundary of the sinus tympani (st) by a 45° endoscope; the superior limit of the subpyramidal space (ss) represented by the ponticulus and the inferior limit represented by the subiculum can be seen (the ss was partially visible). (B) The endoscopic view of the ss under a partial morphology pyramidal eminence (the white arrow indicates the ss). Pr = promontory; Po = ponticulus; ps = posterior sinus tympani; su = subiculum; rw = round window; ts = stapes tendon; s = stapes.

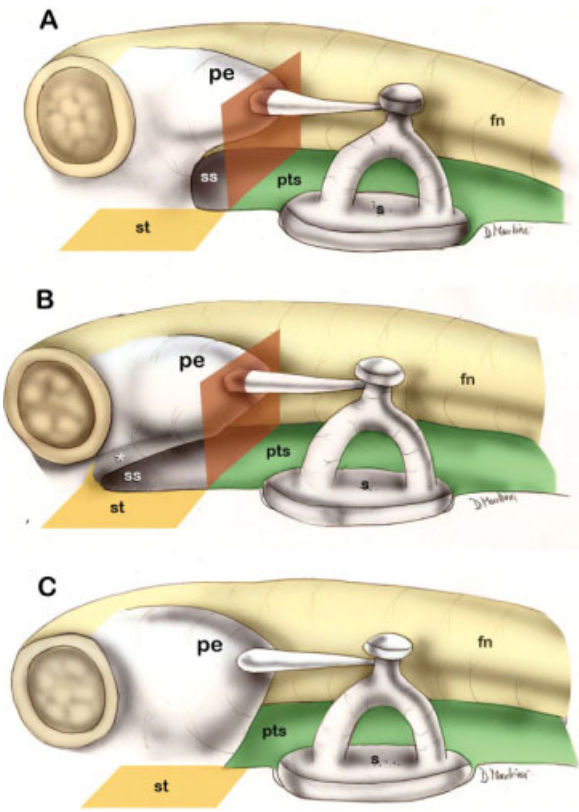

Fig. 8. Schematic drawing of subpyramidal space (ss) explorability from an inferior perspective. (A) Explorable ss space. (B) Inexplorable ss (*inexplorable portion of ss). (C) Absent ss. pe = pyramidal eminence; fn = facial nerve; pts = posterior tympanic sinus; st = sinus tympani; s = stapes.

this space is very variable and is related to the depth of the ST and the position of the ponticulus.

The ponticulus is a central structure in the retrotympanum. It is represented by a thin bony lamella bridging from the promontory to the PE that separates the ST from the PTS. Very few authors have studied this structure because of difficulties in visualization, and therefore its anatomical description has remained unclear. In 2005, in an anatomical dissection study of 50 temporal bones, Holt found that in 33 specimens there was a complete ponticulus with various thicknesses (1–7 mm or <1 mm). In seven they found a partial formation, and in 10 temporal bones they found a complete absence of this structure.[23] The ponticulus shape is also variable because it could appear like a bone or like a ridge, and this is important during ear surgery operations because it is possible that underneath could be hidden residual cholesteatoma. The surgical identification of this structure starts from the stapes, follows the tendon back, and reaches the PE, focusing on the bony bridge that links the PE to the promontory.

The hub of the retrotympanum is the PE, a triangular-shaped bone of the posterior wall of the tympanic cavity that houses the stapes tendon and shapes the roof of the ST. This anatomical structure is very important, representing the fulcrum of the retrotympanum; Actually, the ponticulus is derived from this structure, as is the chordal crest lying posteriorly and dividing the facial sinus posteriorly from the lateral tympanic sinus superiorly.

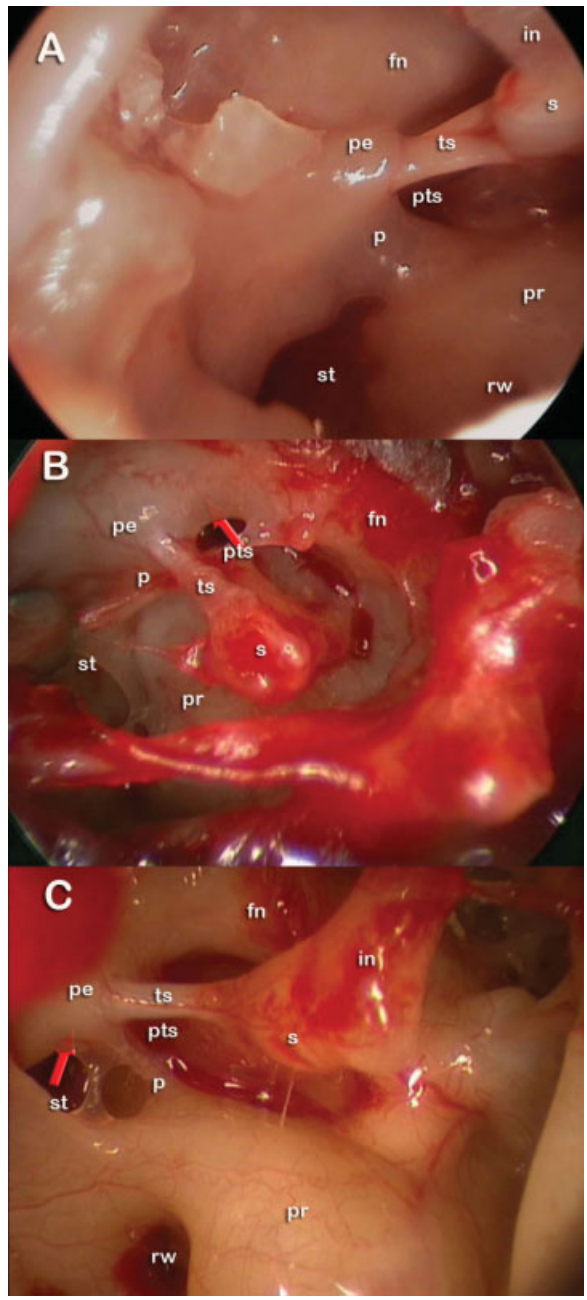

Fig. 9. Different shape of the pyramidal eminence (pe) visible during endoscopic approach. (A) Endoscopic view of merged morphology of pe. (B) Endoscopic view of a partial morphology of the pe. In this subject the subpyramidal space (ss) is deriving from the posterior tympanic sinus (pts), and the endoscopic explorability of ss was incomplete (red arrow indicates the communication from the pts to the ss). (C) Endoscopic view of a partial morphology of the pe. In this subject the ss is derived from the sinus tympani (st), and the endoscopic explorability is incomplete (red arrow indicates the communication from the st to the ss). in = incus; fn = facial nerve; s = stapes; ts = stapes tendon; p = ponticulus; pr = promontory; rw = round window.

As readers will notice, the present work describes the anatomical variations of the PE and their relationship with the structures lying beside it, such as the ST and PTS. In the systematic evaluation of these structures during endoscopic ear surgery, we found an anatomical recess never before described in the literature that we have named the subpyramidal space. We observed that the shape of the PE is variable, and in particular that the medial bony wall of the PE can be completely formed, partially formed, or absent (Fig. 9).

When the medial face of the PE was completely formed, the SS was large and bounded by both the ST and PTS (independent space of the PE), and when the medial face of the PE was partially formed (under developed space of the PE), the SS was narrow and in some cases very deep and the posterior extension of this space not explorable with an endoscope. In some cases, 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 (contiguous space of the PE).

As already mentioned above, the retrotympanum and particularly its medial part (consisting of the ST, PTS, PE, and ponticulus) can be very difficult to visualize with an operating microscope during ear surgery for cholesteatoma removal, mostly because of its depth, tightness, and the presence of many structures. To overcome this problem, several surgeons have proposed various surgical approaches.[1,4,7,24,25] Goodhill emphasized that adequate exposure of the ST may be obtained by changing the position of the surgeon or the patient's degree of head rotation, but often incomplete visualization was encountered because of the height of the external auditory canal.[5] Jansen proposed a facial recess approach dissecting the triangular bony area formed by the facial nerve, the lateral semicircular canal, and the posterior semicircular canal to better expose the retrotympanum, but in the presence of a deep sinus this technique is not feasible.[26] Classical and radical procedures such as canal wall down tympanoplasty could not always expose a deep ST.[27] To overcome these problems, some authors have suggested and used endoscopes with different angulations to improve visualization of hidden spaces, especially during ear surgery for cholesteatoma removal.[11–14,16,28–31] The use of endoscopes with various degrees of angulation (0°, 30°, 70°) enables the surgeon to see around corners to visualize hidden spaces, such as a deep ST or the ponticulus, which otherwise would not be completely visible using classical microscopes, and permits complete removal of the diseased tissue mainly in the presence of a deep sinus tympani extending underneath the facial nerve canal. Use of these optics allows the surgeon to better control the disease, thereby avoiding relapse.[8,11,12]

In a work published in 2002, Badr-el-Dine[9] found that in a total of 92 ears operated for acquired cholesteatoma (82 with canal wall up, 10 with canal wall down), there was an overall incidence of 22.8% for residual pathologic tissue detected with the systematical use of endoscopes, and in both the surgical procedures, the site of residual disease was the sinus tympani. This shows that the use of endoscopes in the armamentarium of the otologic surgeon is essential and allows inspection of hidden sites that would otherwise remain obscure. Unfortunately, currently in the case of an extremely narrow and deep SS, double curvature otoendoscopic surgical instruments are not available that can be helpful to completely explore this space and to remove pathology.

In the authors' opinion, knowledge about and identification of the SS can be important for middle ear surgeons, especially during surgery for cholesteatoma. In fact, the SS could potentially be a further place in which the cholesteatoma could remain hidden during middle ear surgery, especially if this space is very deep. For this reason, the present authors would recommend endoscopic exploration of this space in cases of suspected involvement by cholesteatoma. Actually, an alternative to the use of endoscopes for SS surgery is represented by a subfacial approach, with the magnification of the microscope that often can be unsatisfactory for an accurate exploration of the SS.

Moreover an adequate and detailed knowledge of retrotympanic spaces could enable reduction in damage to the facial nerve during surgery.[32] No quantitative measures of these spaces were performed in our case series, but further work in future could focus on clarifying this.

CONCLUSION

Endoscopy of the middle ear allows a very good exposure of the retrotympanum, and the anatomy of that space can be thoroughly described using angled optics. The PE is a variable structure in its shape and relationship with adjacent structures, whereas the SS can be defined as a pneumatization that extends under the PE between the medial aspect of the PE and the medial bony wall of the retrotympanum, and varies in shape and depth. A well-developed SS with a high degree of depth is related to a total or near total absence of the medial wall of the PE. In other cases, the SS can have a low degree of depth due to partial formation of the medial wall of the PE. On the other hand, when the medial aspect of the PE merges with the medial bony wall of the retrotympanum, the SS is absent. It is intuitive that if the SS has a high degree of depth, there is a greater chance of leaving residual pathological tissue, and for this reason the present authors would advise the systematic use of the endoscope to correctly visualize and clean this space. Correct knowledge of this anatomical space may help in reducing the risk of residual cholesteatoma during middle ear surgery.

BIBLIOGRAPHY

1. Donaldson JA, Anson BJ, Warphea RL, et al. The surgical anatomy of the sinus tympani. *Arch Otolaryngol* 1970;91: 219–227.
2. Pickett BP, Cail WS, Lambert PR. Sinus tympani: anatomic considerations, computed tomography, and a discussion of

the retrofacial approach for removal of disease. *Am J Otol* 1995;16:541–550.
3. Saito R, Igarashi M, Alford BR, Guilforti FR. Anatomical measurement of the sinus tympani: a study of horizontal serial sections of the human temporal bone. *Arch Otolaryngol* 1971;94:418–425.
4. Farrior JB. Tympanoplasty: the anterior attico-tympanotomy. Surgery of the posterior tympanic recess. *Laryngoscope* 1968;78:768–779.
5. Goodhill V. Circumferential tympanomastoid access: the sinus tympani area. *Ann Otol Rhinol Otolaryngol* 1973; 82:547–554.
6. Richards S, Kilby D. Mastoidectomy using otoplastic flap. *J Laryngol Otol* 1971;85:1007–1012.
7. Zini C. La microzympanoscopie indirecte. *Rev Laryngol Otol Rhinol* 1967;88:736–738.
8. Marchioni D, Mattioli F, Alicandri-Ciufelli M, Presutti L. Transcanal endoscopic approach to the sinus tympani: a clinical report. *Otol Neurotol* 2009;30:758–765.
9. Badr-el-Dine M. Value of ear endoscopy in cholesteatoma surgery. *Otol Neurotol* 2002;23:631–635.
10. Abdel Baki F, El Dine MB, El Saiid I, Bakri M. Sinus tympani endoscopic anatomy. *Otolaryngol Head Neck Surg* 2002;127:158–162.
11. Marchioni D, Mattioli F, Alicandri-Ciufelli M, Presutti L. Endoscopic approach to tensor fold in patients with attic cholesteatoma. *Acta Otolaryngol* 2008;25:1–9.
12. Presutti L, Marchioni D, Mattioli F, Villari D, Alicandri-Ciufelli M. Endoscopic management of acquired cholesteatoma: our experience. *J Otolaryngol Head Neck Surg* 2008;37:481–487.
13. El-Meselaty K, Badr-El-Dine M, Mandour M, et al. Endoscope affects decision making in cholesteatoma surgery. *Otolaryngol Head Neck Surg* 2003;129:490–496.
14. Tarabichi M. Endoscopic management of acquired cholesteatoma. *Am J Otol* 1997;18:544–549.
15. Tarabichi M. Endoscopic middle ear surgery. *Ann Otol Rhinol Laryngol* 1999;108:39–46.
16. Tarabichi M. Endoscopic management of limited attic cholesteatoma. *Laryngoscope* 2004;114:1157–1162.
17. Meckel JD. Cited by Steinbrugge (18).
18. Steinbrugge H. On the sinus tympani [Spaulding J, trans]. *Arch Otol* 1889;8:53–57.
19. Dworacek H. The anatomical relationship of the middle ear under the operating microscope. *Acta Otolaryngol* 1960; 51:15–45.
20. Proctor B. Surgical anatomy of the posterior tympanum. *Ann Otol Rhinol Laryngol* 1969;78:1026–1040.
21. Aslan A, Guclu G, Tekdemir I, Elhan A. Anatomic limitations of posterior exposure of the sinus tympani. *Otolaryngol Head Neck Surg* 2004;131:457–460.
22. Ozturan O, Bauer CA, Miller CC, Jenkins HA. Dimensions of the sinus tympani and its surgical access via a retrofacial approach. *Ann Otol Rhinol Laryngol* 1996;105: 776–783.
23. Holt JJ. The ponticulus: an anatomic study. *Otol Neurotol* 2005;26:1122–1124.
24. Pulec JL. Sinus tympani: retrofacial approach for the removal of cholesteatomas. *Ear Nose Throat J* 1996;75: 77–88.
25. Jansen CW. Intact canal wall for cholesteatoma. *Am J Otol* 1985;6:3–4.
26. Jansen C. The combined approach for tympanoplasty. *J Laryngol Otol Suppl* 1983;8:90–91.
27. Weiss MH, Parisier SC, Han JC, et al. Surgery for recurrent and residual cholesteatoma. *Laryngoscope* 1992;102: 145–151.
28. Thomassin JM. Endoscopic-guided otosurgery in the prevention of residual cholesteatoma. *Laryngoscope* 1993; 103:939–943.
29. Bowdler DA, Walsh RM. Comparison of the otoendoscopic and microscopic anatomy of the middle ear cleft in canal wall-up and canal wall-down temporal bone dissections. *Clin Otolaryngol Allied Sci* 1995;20:418–422.
30. Bottril ID, Poe DS. Endoscope-assisted ear surgery. *Am J Otol* 1995;16:158–163.
31. Karhuketo TS, Puhakka HJ, Laippala PJ. Endoscopy of the middle ear structures. *Acta Otolaryngol Suppl* 1997;529: 34–39.
32. Thomassin JM, Danvin BJ, Collin M. Endoscopic anatomy of the posterior tympanum. *Rev Laryngol Otol Rhinol* (Bord) 2008;129:239–243.