

Inferior Retrotympanum Revisited: An Endoscopic Anatomic Study

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Objectives/Hypothesis: To describe the inferior retrotympanic anatomy from an endoscopic perspective.

Study Design: This was an anatomic study on a retrospective case series.

Methods: During November 2009 and December 2009, videos from endoscopic middle ear procedures carried out between June 2007 and November 2009 and stored in our database were retrospectively reviewed. Surgeries in which the inferior retrotympanic region was visualized were included in the study. Accurate descriptions of the anatomic findings were made for each ear included in the study group.

Results: The final study group consisted of 25 videos from 25 ear procedures. In 14/25 subjects, a bony ridge connecting the inferior portion of the styloid prominence to the anterior and inferior lip of the round window niche (Proctor's sustentaculum promontory) was identified and renamed the finiculus (from the Latin *finis*, *-is*: borderline), representing the ideal limit between the inferior retrotympanum and hypotympanum. In 14/25 patients, a complete sinus subtypanicus could be identified, lying between the subiculum and finiculus.

Conclusions: Endoscopic exploration of the middle ear might guarantee a very good exposure of the inferior retrotympanum, allowing detailed anatomic descriptions of this hidden area. Improvement in our knowledge of its anatomy might decrease the possibility of residual disease during cholesteatoma surgery.

Key Words: Finiculus, sinus subtypanicus, endoscopic approach, retrotympanum, middle ear anatomy, hypotympanum.

Level of Evidence: 4

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INTRODUCTION

In the recent literature, the present authors have already studied the anatomy of the retrotympanum, describing the variation in shape of the sinus tympani, ponticulus, and pyramidal eminence.^{1,2} However, until now few studies have focused on anatomic description of the retrotympanic region lying inferiorly to the subiculum.^{3–6} We will define that space as the inferior retrotympanum, representing the border between the retrotympanum itself and the hypotympanum.

In the English literature, Proctor was the first to describe in detail the anatomy of the inferior retrotympanum,³ and in an article focused on the anatomy of the round window niche, he refined his former description of the structures around this area.⁴ He observed that during embryogenesis in the 4-month-old embryo, ossification has started in the otic capsule, and the round window niche is surrounded by a thickened ring of cartilage. This circular structure prevents closure of the niche during ossification of the otic capsule and ultimately forms the posterior pillar of the niche (or postis posterior) representing the superoposterior edge of the round window niche entrance, the tegmen fossula fenestra rotunda, formed by the oblique dorsolateral edge of the promontory that forms a convex edge superiorly, and the anterior pillar of the niche (or postis anterior) consisting of the thinner column in the anterior aspect of the niche entrance. Proctor³ also pointed out that between the oval and round window niches lies the subiculum, the bony ridge going from the styloid eminence posterolaterally to the promontory medially and merging with the posterior pillar of the round niche. Moreover, in the relationship with the anterior pillar of the round niche he described a ridge of bone connecting the basal helix of the cochlea to the jugular wall of the tympanum, and called this structure the sustentaculum promontorii. He also observed the presence of an anatomic area between the subiculum posteriorly and superiorly, the sustentaculum promontory anteriorly and inferiorly, lying laterally and inferiorly to the round window niche. He called this space the area concamerata, defining it as a sort of antechamber to the round window niche.⁴ He also defined the fustis, the bony column of the area concamerata lying under the round window niche and forming its floor (Fig. 1).

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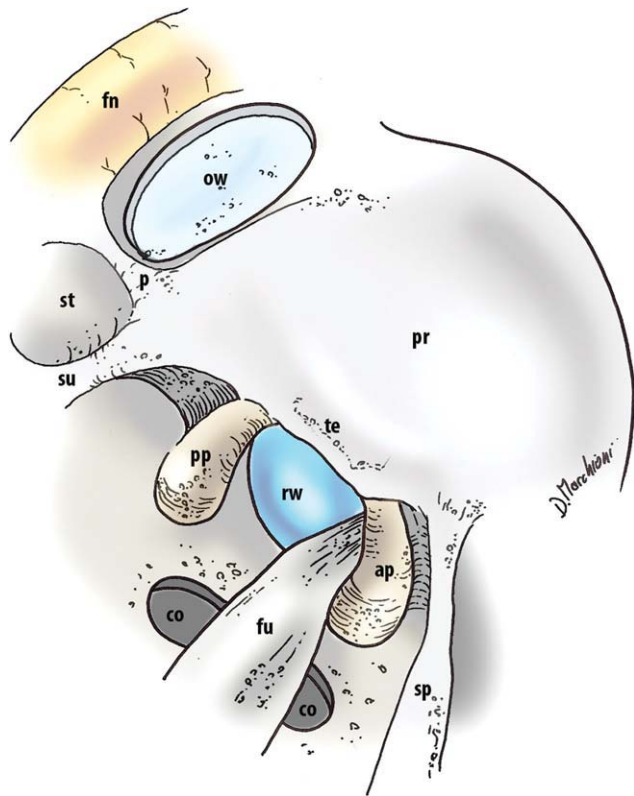


Fig. 1. Representation of right round window niche in 1-year-old child from Proctor et al.⁴ Right side. fn = facial nerve; ow = oval window; p = ponticulus; st = sinus tympani; su = subiculum; pr = promontory; te = tegmen of round window niche; pp = posterior pillar; rw = round window; ap = anterior pillar; co = sinus concameratus; fu = fustis; sp = sustentaculum promontorii. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

In 1987, Savic and Djerić, studying the surgical anatomy of the hypotympanum, defined the sinus lying between the hypotympanum and posterior tympanic wall as the sinus hypotympanicus.⁵ It is very difficult to understand from the pictures and drawings in that study whether by that term the authors meant Proctor's area concamerata or if they were referring to a separate structure. Dealing with almost the same subject in their work published in 1982, Garcia et al.⁶ focused their attention on the styloid prominence and the inferior wall of the tympanic cavity (separating the jugular bulb from the tympanic cavity). They pointed out that the styloid prominence juts out from the transition point between the jugular and mastoid walls, and that the styloid prominence and jugular bulb, depending on their level of development, establish an important relationship with the sinus tympani and round window niche area, modifying the anatomy of the retrotympaanum.⁶

As readers will notice from studying the articles mentioned above, it can be very difficult to understand the anatomy of the inferior retrotympaanum. This is due to the intrinsic difficulties of the subject, to the different perspectives with which every author has treated that topic in the past, to the different nomenclatures employed in some cases, and to the obvious limits of the images available at that time.

All of the studies mentioned were performed in temporal bone specimens, under microscopic view, and after extensive removal of petrous bone tissue so as to obtain adequate access to these areas. From our 6-year experience in endoscopic ear surgery, we believe that most of these inaccessible spaces could be easily visualized by endoscope-assisted surgery. For instance, when treating cholesteatomas surgically, we found ourselves chasing residual disease in small spaces that we would probably not have been able to explore with a microscope. So we have been observing the anatomic conformation of the retrotympaanum and of the hypotympanum in many endoscopic procedures, allowing us to better understand the complex anatomy of the posterior and inferior aspects of the tympanic cavity.

The aim of our study was to analyze and revisit the morphology and the anatomic variations of the inferior retrotympaanum from an endoscopic point of view, trying to simplify some concepts so as to make them useful for routine surgical practice. The present authors consider that 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.

MATERIALS AND METHODS

During November and December 2009, videos from endoscopic middle ear procedures carried out between June 2007 and November 2009 and stored in our database were retrospectively reviewed. Endoscopic procedures were myringoplasties and surgeries performed for middle ear cholesteatoma and retraction pockets. A three-chip high-resolution monitor and camera (Karl Storz, Tuttlingen, Germany) was used for all of the procedures. Surgeries in which the inferior retrotympaanic region was visualized were included in the study regardless of the stage of the procedure or the pathology treated. Accurate description of the anatomic findings were made for each ear included in the study group.

Endoscopic Approach to the Retrotympaanum and Hypotympanum

For patients in whom the retrotympaanic and hypotympanic anatomy was explored, 3-mm diameter, 15-cm length, 45° endoscopes (Karl Storz) were used. The endoscopes were introduced during surgery through the external meatal canal to obtain adequate visualization of the retrotympaanum and hypotympanum, and a position described in an earlier paper¹ was adopted. During the endoscopic approach, the surgeon stood on the opposite side with respect to the affected middle ear using the 45° endoscope with the left hand and surgical instruments with the right hand. This particular position allowed the surgeon a good view of the medial boundary of the sinus tympani, round window niche, the junction between the styloid eminence and jugular bulb, and all of the inferior retrotympaanum and hypotympanum. During endoscopic approaches to this region, at first the promontory was visualized, limited superiorly and posteriorly by the oval window, and inferiorly and posteriorly by the entrance of the round window niche. Then the endoscope was rotated posteriorly and inferiorly to visualize the retrotympaanum and hypotympanum.

RESULTS

The final study group consisted of 25 videos from 25 ear procedures. Out of these 25 subjects, 21 were affected

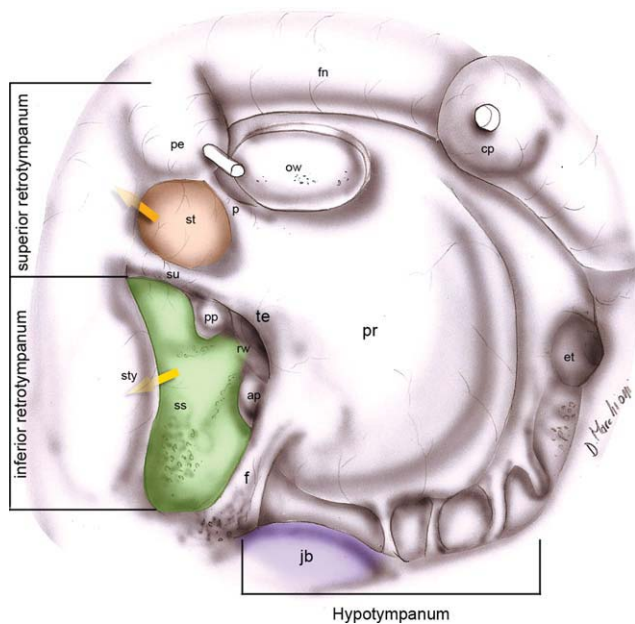


Fig. 2. Summary drawing of the anatomy of retrotympaanum and hypotympanum. Finiculus appears as a ridge of bone arising from the anterior and inferior lip of the round window separating inferior retrotympaanum from hypotympanum. Subiculum separates superior from inferior retrotympaanum. Right side. fn = facial nerve; pe = pyramidal space; ow = oval window; cp = cochleariform process; st = sinus tympani; p = ponticulus; su = subiculum; pp = posterior pillar; te = tegmen of round window niche; pr = promontory; et = eustachian tube; rw = round window; sty = styloid complex; ss = sinus subtympaanicus; ap = anterior pillar; f = finiculus; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

by cholesteatoma and four subjects were affected by a retraction pocket of the tympanic membrane.

A summary drawing of the anatomy of the inferior retrotympaanum is presented in Fig. 2.

Endoscopic Anatomic Findings

In 14/25 subjects, a bony ridge (Proctor's sustentaculum promontory) was found arising from the inferior

portion of the styloid prominence and connected to the anterior and inferior lip of the round window niche. We renamed this bony ridge the finiculus (from the Latin *finis*, *-is*: borderline) because it separated the retrotympaanum, lying superiorly and posteriorly, from the hypotympanum, lying inferiorly and anteriorly (Fig. 2). Some variations in morphology of the finiculus were also noticed. In 12/14 subjects (Fig. 3A) the finiculus was like a ridge of bone, in 2/14 subjects (Fig. 3B and Fig. 4) the finiculus was like a bridge of bone. Eleven out of 25 patients presented with no finiculus or with an incomplete one (Fig. 3C).

Two different morphologies of the subiculum were found. Nineteen out of 25 patients presented a classic morphology of the subiculum (Fig. 5A). In these patients, the subiculum was completely formed, and it was a ridge of bone extending from the styloid complex to the posterior and superior lip of the round window niche. This structure represented the inferior limit of the sinus tympani, and the superior limit of the inferior retrotympaanum. In 2/25 patients the subiculum was like a bridge of bone (Fig. 5B). On the other hand, 4/25 patients presented with no subiculum (Fig. 5C).

In 14/25 patients we found the presence of a very well-defined sinus lying inferiorly to the sinus tympani, forming a delimited space between the subiculum superiorly and posteriorly and the finiculus inferiorly and anteriorly, the styloid prominence posteriorly and laterally, and the otic capsule posteriorly and medially. We called this space the sinus subtympaanicus; this anatomic region was open anteriorly and medially toward the round window niche (Fig. 6). Of the 11/25 patients in which the finiculus could not be identified, four had a high jugular bulb reaching the round window niche. In these four patients the inferior limit of the sinus subtympaanicus could be considered to be the junction between the jugular bulb and the styloid eminence. In the remaining seven patients in whom the finiculus could not be identified, the sinus subtympaanicus was also not well defined (Fig. 7).

For the subjects in whom this sinus subtympaanicus was identifiable, the shape was triangular with the base

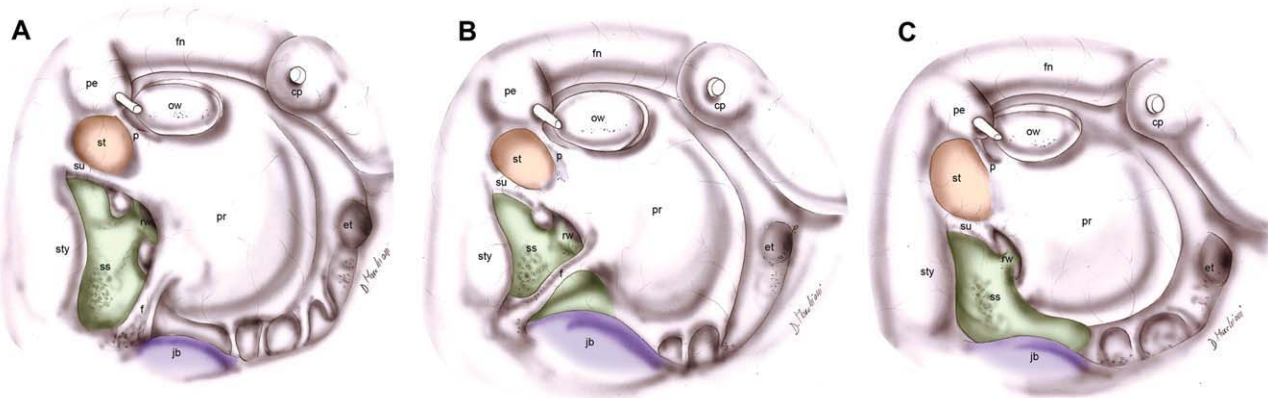


Fig. 3. Anatomical variations of the finiculus. Right side. (A) Ridge finiculus. (B) Bridge finiculus. (C) Absent finiculus. fn = facial nerve; pe = pyramidal space; ow = oval window; cp = cochleariform process; st = sinus tympani; p = ponticulus; su = subiculum; rw = round window; pr = promontory; et = eustachian tube; sty = styloid complex; ss = sinus subtympaanicus; f = finiculus; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

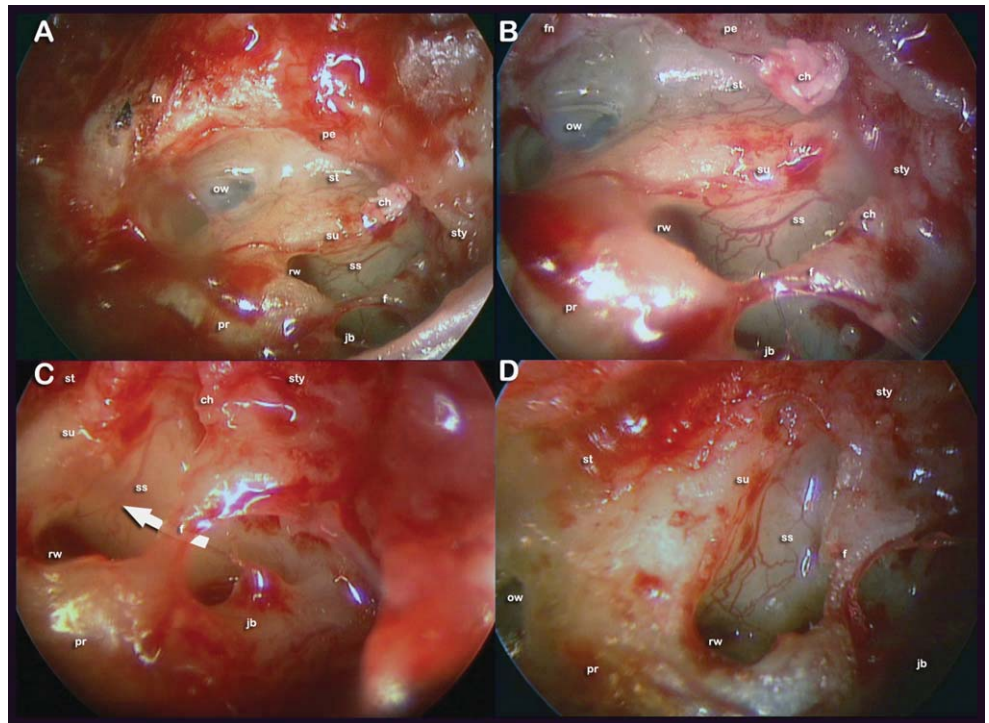


Fig. 4. A communication space (indicated by the arrow) between the sinus subtympanicus and the hypotympanum is present under a bridge finiculus. Left side. fn = facial nerve; pe = pyramidal space; ow = oval window; st = sinus tympani; ch = cholesteatoma fragments; su = subiculum; sty = styloid complex; rw = round window; ss = sinus subtympanicus; pr = promontory; f = finiculus; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

lying laterally and posteriorly on the styloid eminence and the apex confluent medially and anteriorly on the round window niche area. The depth of this space appeared variable, depending on the pneumatization of the retrotympanic spaces and on the development of the jugular bulb. In 2/14 patients (Fig. 8), a deep sinus subtympanicus was observed extending posteriorly with respect to the third portion of the facial nerve. In these cases, the posterior portion of the sinus subtympanicus was like a recess delimited by the styloid prominence and the third portion of the facial nerve laterally and the bony labyrinth medially.

In the 4/25 patients who presented with no subiculum, the sinus tympani and the sinus subtympanicus were confluent. In three of these patients (Fig. 5C) the

finiculus was absent, and a single cavity was noted confluent anteriorly and inferiorly toward the jugular bulb and hypotympanum. In the patient in whom the subiculum was absent but a finiculus was present, a confluent cavity was formed by the sinus tympani and the sinus subtympanicus, separated by the finiculus itself from the hypotympanum (Fig. 9).

Pathology

In 21 patients affected by middle ear cholesteatoma, one presented a fragment of cholesteatoma under the bridge subiculum, and three subjects presented a small fragment of cholesteatoma lying in the sinus subtympanicus. We removed the pathologic tissue under

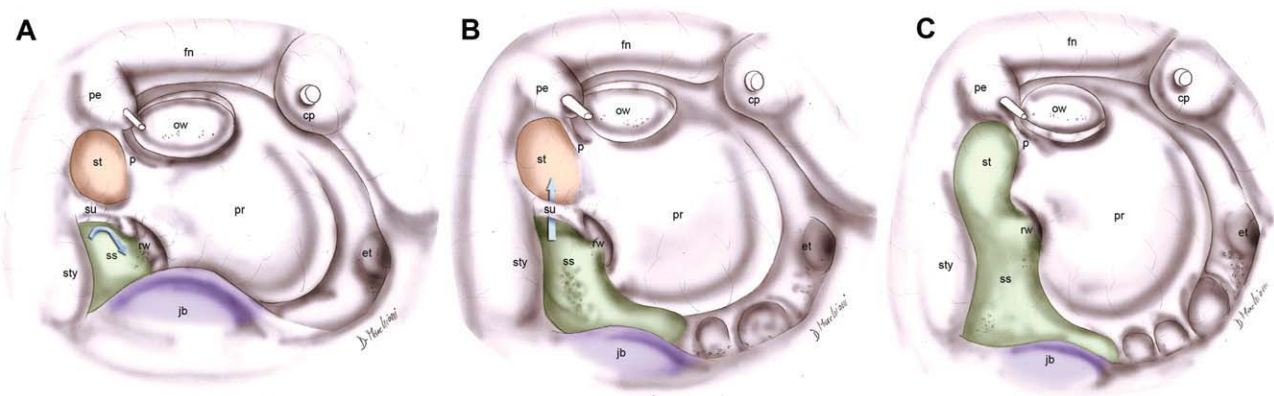


Fig. 5. Anatomical variations of the subiculum. (A) Ridge subiculum. (B) Bridge subiculum. (C) Absent subiculum, sinus subtympanicus confluent to the sinus tympani. Right side. fn = facial nerve; pe = pyramidal space; ow = oval window; cp = cochleariform process; st = sinus tympani; p = ponticulus; su = subiculum; pr = promontory; ss = sinus subtympanicus; rw = round window; et = eustachian tube; sty = styloid complex; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

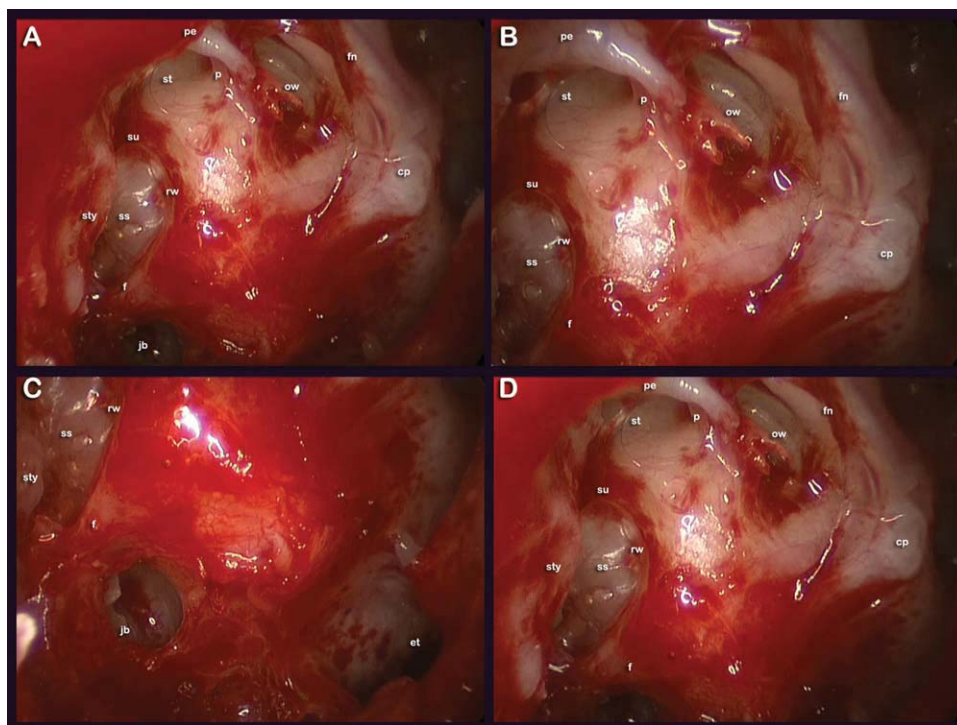


Fig. 6. Completely defined sinus subtympanicus. Right side. pe = pyramidal space; fn = facial nerve; st = sinus tympani; p = ponticulus; ow = oval window; su = subiculum; cp = chocleariform process; sty = styloid complex; ss = sinus subtympanicus; f = finiculus; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

endoscopic control with an appropriately angled surgical instrument.

DISCUSSION

Although in the past, some authors³⁻⁶ have already studied the anatomy of the inferior retrotympanium, a

region that has been quite neglected in the literature, which is probably due to the low accessibility of that space during conventional microscopic procedures. In fact, in his studies, Proctor^{3,4} had already identified almost all of the structures in that region based on several temporal bone dissections. As already mentioned

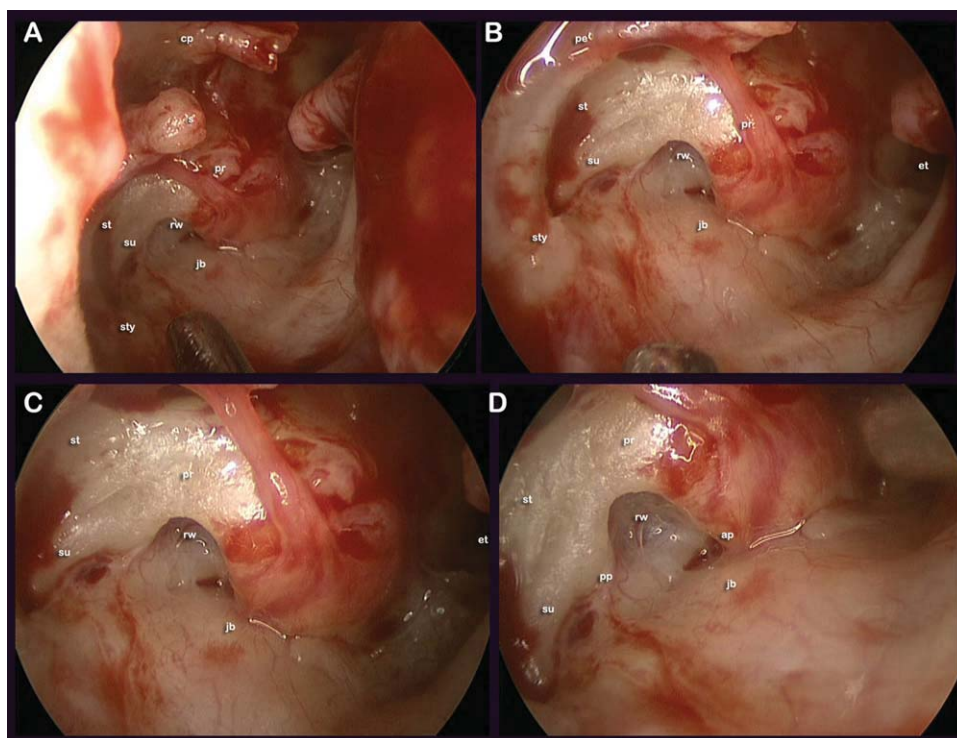


Fig. 7. Incompletely defined sinus subtympanicus. Limits cannot be clearly identified. Right side. cp = chocleariform process; pr = promontory; st = sinus tympani; rw = round window; su = subiculum; jb = jugular bulb; sty = styloid complex; pe = pyramidal space; et = eustachian tube; ap = anterior pillar; pp = posterior pillar. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

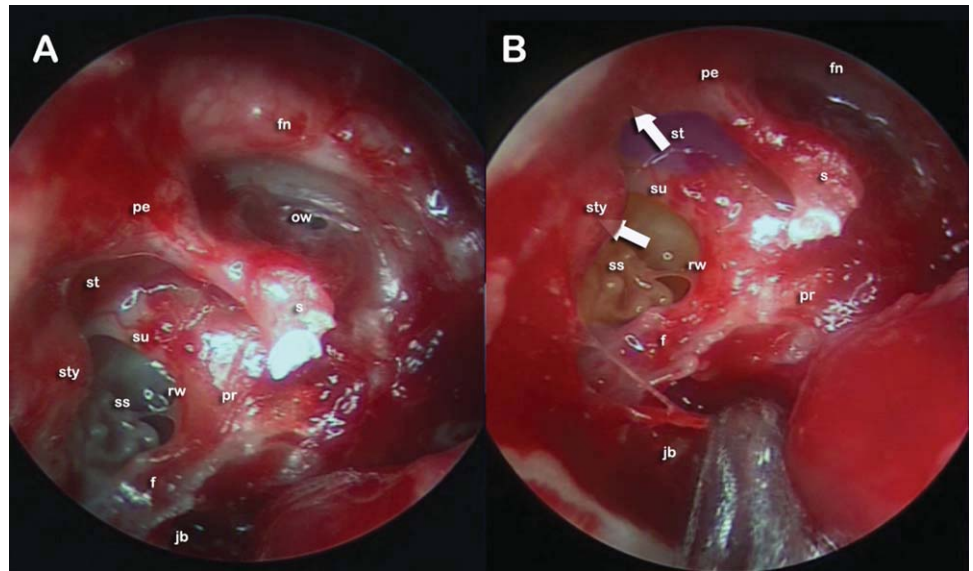


Fig. 8. Deep sinus subtympanicus. Arrows indicate the posterior extension of sinus subtympanicus and sinus tympani. Right side. fn = facial nerve; pe = pyramidal space; ow = oval window; st = sinus tympani; s = stapes; su = subiculum; sty = styloid complex; ss = sinus subtympanicus; rw = round window; pr = promontory; f = finiculus; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

in the Introduction, he 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, called 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. The present authors confirmed the presence of that structure in relation to the anterior pillar of the round niche and identified two variants, a ridge shape and a bridge shape. We decided to rename the sustentaculum promontorii the finiculus for several reasons. First of all, we deem it quite unlikely that the

inferior tympanic artery constantly lies in this structure, particularly in the case of the bridge shape, as readers will notice from our intraoperative images (Fig. 4), because it could be a very thin structure in some cases. Moreover, we wanted to identify a clear borderline between the retrotympanum and the hypotympanum, and for this we chose the name finiculus (from the Latin *finis*, *-is*: borderline).

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, could be easily identified in some of our ears, the

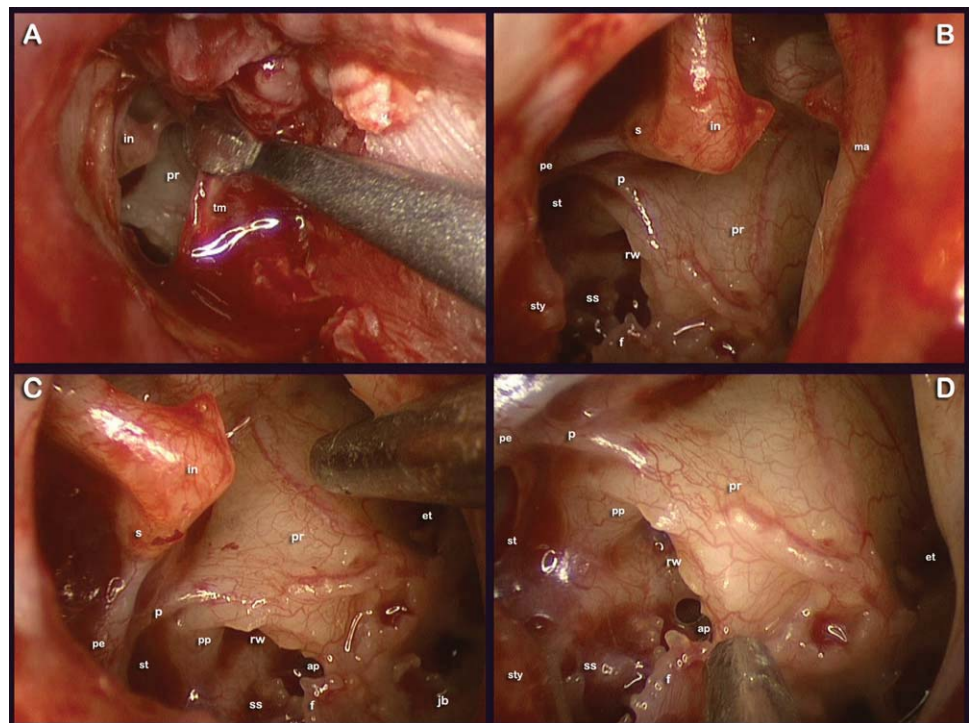


Fig. 9. (A) Transcanal endoscopic approach to the tympanic cavity. (B) Round window niche identification. (C, D) Exploration of sinus subtympanicus in a subject without subiculum and sinus subtympanicus confluent to the sinus tympani. Right side. in = incus; pr = promontory; tm = tympanic membrane; s = stapes; ma = malleus; pe = pyramidal eminence; p = ponticulus; st = sinus tympani; rw = round window; sty = styloid complex; ss = sinus subtympanicus; et = eustachian tube; pp = posterior pillar; ap = anterior pillar; jb = jugular bulb. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

other parts of the area concamerata appeared to the present authors somewhat difficult to identify. In fact, during the operations, we noticed that in several patients, a sinus lying inferiorly to the sinus tympani 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. We called this space the sinus subtympanicus. This structure was probably already identified by Savic and Djeric in 1987 studying the surgical anatomy of the hypotympanum, and who defined the sinus lying between the hypotympanum and the posterior tympanic wall as the sinus hypotympanicus.⁵ We also chose in this case to rename this sinus, because owing to the retrotympanic spaces, the term sinus hypotympanicus used by Savic and Djeric could have been quite misleading.

In our study, out of 21 patients operated on for cholesteatoma, we found some residual pathology in the sinus subtympanicus in three of these, and we had to remove this endoscopically with appropriately angled instruments. Moreover, in two subjects, as reported in the Results section, we observed a deep sinus subtympanicus extending posteriorly with respect to the third portion of the facial nerve. In these cases, the posterior portion of the sinus subtympanicus was like a recess delimited by the styloid prominence and the third portion of the facial nerve laterally and the otic capsule medially. These characteristics have some analogies with variations of the sinus tympani, already described by our team in an earlier article¹ and could have some consequences for the risk of residual disease after surgical treatment of cholesteatoma, particularly when these sinuses are deep.

In 1982, Garcia et al.⁶ also studied the anatomy of the inferior retrotympanium, focusing their attention on the styloid prominence. In their dissection study they observed that the styloid prominence had a morphological variability, and this prominence was found to jut out from the transition point between the jugular and mastoid walls. Depending on its level of development, this styloid prominence established an important relationship with the sinus tympani, round window, and the whole retrotympanium. Garcia observed a well-developed styloid prominence in 35.7% of cases, ill-developed in 25.7%, and not observed in 38.6% of cases. The vertical portion of the facial nerve was located close to the root of the styloid prominence and tended to move away from it as it advanced toward the stylomastoid foramen.

The present authors are convinced that the introduction of the endoscope to middle ear surgery gives the surgeon improved intraoperative anatomic knowledge of the retrotympanium, and this can have important consequences in surgery. In particular, the use of the endoscope in cholesteatoma surgery can provide many advantages. In an earlier study,⁷ we documented that the endoscope might improve eradication of residual cholesteatoma from hidden areas not completely visualized by the microscope. In particular, we found that the sinus subtympanicus was the most

common site of residual cholesteatoma. In another work, we described the anatomic variations of the pyramidal space² and their relationship with the structures lying beside it, such as the sinus tympani and the posterior tympanic sinus. In particular, we found an anatomic recess that we named the subpyramidal space, which can be a further site in which the cholesteatoma could remain hidden during middle ear surgery. So the present authors would suggest that to prevent residual disease, thorough knowledge and the systematic endoscopic exploration of these least-accessible sites are important during cholesteatoma surgery, looking for possible residual pathology. Eventually it should be underlined that our case series was obtained from pathologic ears regardless the stage of the procedure. Based on that we would not be able to strictly define our results as normal anatomy, but it is the present authors' belief that cholesteatoma or inflammatory pathology could have given some rather false negative findings, eroding the structures described. Therefore, finiculus and sinus subtympanicus could be even more represented in nonpathologic ears.

CONCLUSION

The inferior retrotympanium can be intraoperatively visualized by endoscopic techniques. Some anatomic variations can be found in this space. The finiculus can be defined as the bony ridge lying between the styloid eminence and the anterior lip of the round window niche. The sinus subtympanicus can be defined as the anatomic area limited superiorly and posteriorly by the subiculum, anteriorly and inferiorly by the finiculus, posteriorly and laterally by the styloid eminence, posteriorly and medially by the otic capsule, and confluent anteriorly and medially into the round window niche. This space can even form a deep recess in the posterior and inferior aspect of the tympanic cavity, which cannot be completely visualized with a microscope. The present authors would recommend the systematic endoscopic exploration of the inferior retrotympanic areas during cholesteatoma surgery looking for possible residual disease.

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