ORIGINAL RESEARCH

Laryngoscope
Investigative Otolaryngology

Variation and protection of the chorda tympani nerve in endoscopic ear surgery

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Abstract

Objective: To observe and summarize variations of the chorda tympani nerve to effectively protect it during surgery.

Methods: Surgical videos of patients undergoing endoscopic ear surgery in the past 3 years were retrospectively observed to identify chorda tympani nerve variations.

Results: In total, 237 cases were reviewed. The tympanic sulcus or annulus was the boundary between the posterior wall of the external auditory canal and chordal eminence (CE). The chorda tympani nerve was divided into three types: type I, the periannular segment was located medial to the CE and covered by the bony eminence (32.5%); type II, the periannular segment was located inferior to the CE, and the nerve did or did not contact the bony edge of the CE (62.0%); and type III, the periannular segment was located lateral to the CE and medial to the tympanic annulus, and the iter chorda posterius was located in the tympanic sulcus (5.5%). The rate of injury to the chorda tympani nerve was 2.5% of 237 cases. The location of the iter chorda posterius on preoperative computed tomography was highly reliable for prediction of type I and III nerves. Secondary exposure of the posterior canaliculus might occur in patients with external auditory canal cholesteatoma, who were specifically included in this study.

Conclusion: CE-based classification of the chorda tympani nerve can concisely describe variations of the chorda tympani nerve and provide guidance for neuroprotection during endoscopic ear surgery. Patients with external auditory canal cholesteatoma may have secondary exposure of the posterior canaliculus.

Level of Evidence: NA.

KEYWORDS
chorda tympani nerve, chordal eminence, classification

1 | INTRODUCTION

The chorda tympani nerve branches from the facial nerve, exits the mastoid segment of the facial nerve with a variable Plester's chordo-facial angle, runs anterosuperiorly through the posterior canaliculus, and enters the tympanic cavity from the iter chorda posterius (ICP) located medial to the tympanic membrane.[1,2] The chorda tympani nerve then passes between the incus and the malleus neck, enters the

Huguier canal of the petrotympanic fissure above the tensor tympanic tendon, passes through the medial surface of the mandibular fossa, and finally joins the lingual nerve in the infratemporal fossa.[1,2] As the terminal branch of the intermediate nerve, the chorda tympani nerve carries sensory afferent taste fibers to the anterior two-thirds of the tongue and secretory fibers to the anterior ganglion of the submandibular and sublingual glands.[2]

Stretching or disconnection of the chorda tympani nerve during otologic surgery can lead to taste and salivary dysfunction, which affects patients' quality of life.[3,4] Because of its anatomical course, the chorda tympani nerve is vulnerable to iatrogenic injury in the tympanic cavity in surgeries conducted through a transcanal or transmastoid approach. Therefore, understanding the variations of the tympanic segment of the chorda tympani nerve is of great significance for the protection of this nerve in middle ear surgery. The development of endoscopic ear surgery has further improved visualization of the fine structures of the middle ear,[5–9] which can allow for more detailed observations of variations of the chorda tympani nerve and thus facilitate early identification and protection of the chorda tympani nerve during surgery.

A previous study showed that the most significant variation in the tympanic segment of the chorda tympani nerve is the periannular segment,[10] which has a close anatomical relationship with the chordal eminence (CE).[2,10] Therefore, we propose a classification of the chorda tympani nerve based on the CE in order to clarify the relevant anatomical relationship, provide a more concise and practical classification system, and explore the secondary variations and corresponding neuroprotective strategies in special pathological cases.

2 | MATERIALS AND METHODS

2.1 | Patients

The surgical videos of patients who underwent endoscopic ear surgery in the Department of Otolaryngology–Head and Neck Surgery from July 2018 to August 2021 were reviewed. The inclusion criteria were (1) elevation of a tympanomeatal flap during surgery and clear observation of the structures in the tympanic cavity, (2) the presence of an intact chorda tympani nerve, and (3) no history of otologic surgery. The exclusion criterion was bony external auditory canal (EAC) enlargement or destruction of the posterior wall of the auditory canal and CE due to cholesteatoma and other lesions. In total, 237 cases were analyzed, including 216 cases of chronic suppurative otitis media, 9 cases of pars flaccida cholesteatoma, 1 case of pars tensa cholesteatoma, 1 case of congenital cholesteatoma, 3 cases of otosclerosis, 2 cases of ossicular chain malformation, 2 cases of glomus tympani tumor, 2 cases of benign tumors, and 1 case of traumatic ossicular chain dislocation. The computed tomography (CT) imaging and surgical video data of the included cases were retrospectively analyzed.

In addition, the imaging and surgical videos of four patients with secondary chorda tympani nerve variations were retrospectively analyzed. Such secondary variations can easily cause intraoperative nerve injury. All four patients were diagnosed with tympanic perforation secondary to EAC cholesteatoma. Imaging showed bony EAC enlargement. Endoscopic tympanoplasty was performed on admission.

The study was approved by the institutional ethics committee. Written informed consent was obtained from each patient.

2.2 | Surgical method

All patients underwent endoscopic surgery through the ear canal. A 0-degree endoscope (STORZ, Germany) with a diameter of 3 mm and a length of 14 cm or a 0-degree endoscope (Olympus, Japan) with a diameter of 4 mm and a length of 17.5 cm was used. The surgery was performed and recorded under a STORZ or Stryker camera monitoring system. After elevating the tympanomeatal flap, the tympanic annulus was elevated from the tympanic sulcus starting from the superior end of the tympanic annulus posterior to the posterior tympanic spine. The tympanic mucosa was lysed on the medial side of the raised tympanic annulus, and the tympanic cavity was exposed. The anatomical relationship between the chorda tympani nerve and the CE was observed after folding the tympanomeatal flap forward.

3 | RESULTS

3.1 | Anatomy of CE and tympanic annulus

In the anatomical observation of 237 affected ears, the CE was located medial to the tympanic sulcus and inferior to the posterior tympanic spine (PTS) (Figure 1). The bone of the CE continued with the PTS anterior to the tympanic sulcus (Figure 1B). The tympanic sulcus was located lateral to the CE and gradually became shallow as it progressed upward, and there was bone continuity of the PTS and tympanic sulcus superiorly. Therefore, the end of the tympanic annulus below the pars flaccida could be most easily elevated. The tympanic sulcus or annulus was the boundary between the posterior wall of the EAC and the CE. The CE had different shapes, and the extension and width of the bony eminence varied (Figure 2). However, we did not aim to classify the CE alone but to describe its structure and adjacent anatomical relationship.

3.2 | Classification of chorda tympani nerve based on CE

The intraoperative observation of 237 patients showed that all anterosuperior parts of the tympanic segment of the chorda tympani nerve were located below the malleus neck. The variation mainly existed in the periannular segment, which was the initial part entering

FIGURE 1 Adjacent anatomical relationship of CE and TS. (A, B) The TS was the boundary between the posterior wall of the bEAC and the CE. bEAC, bony external auditory canal; CE, chordal eminence; PTS, posterior tympanic spine; TA, tympanic annulus; TS, tympanic sulcus
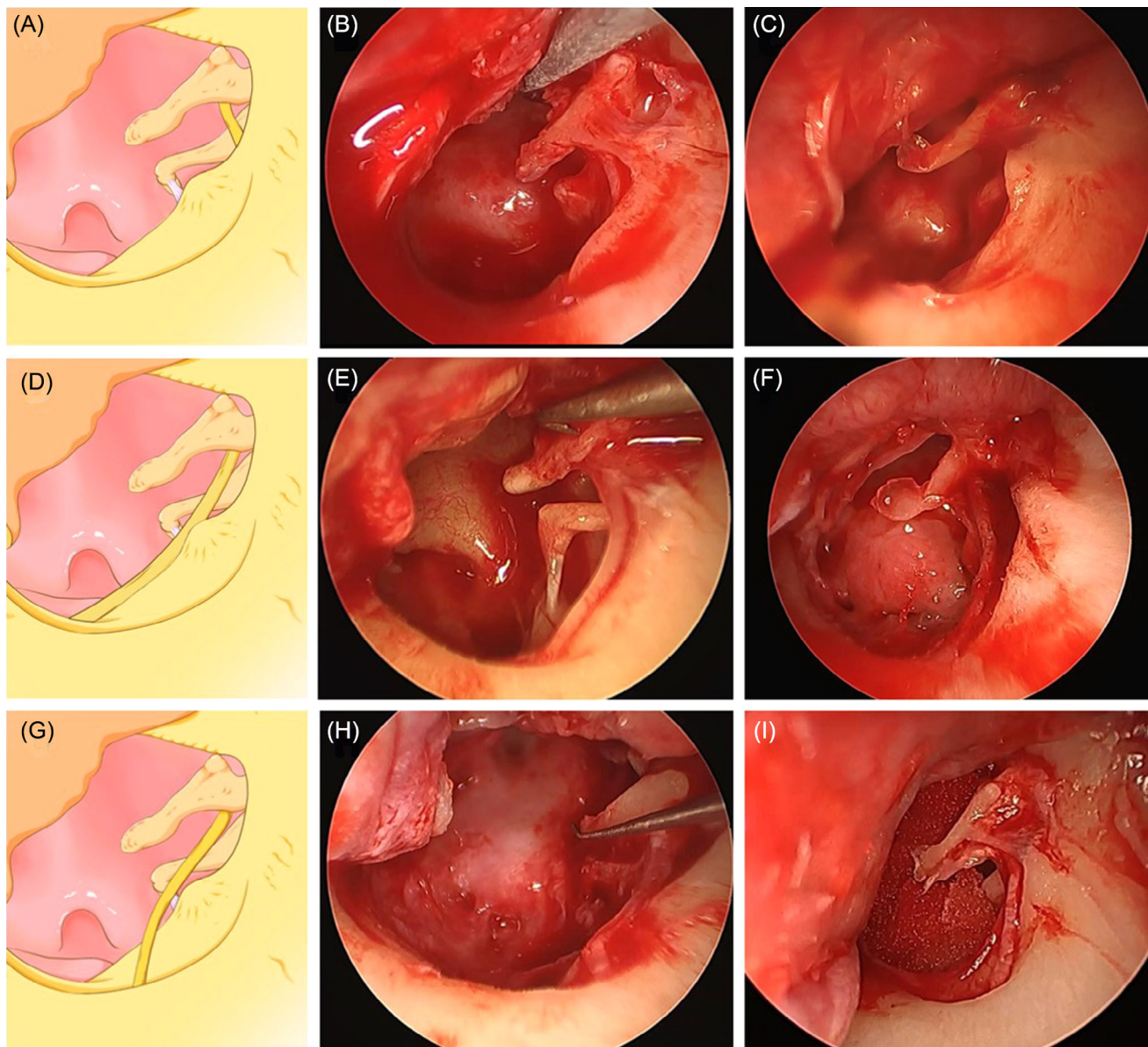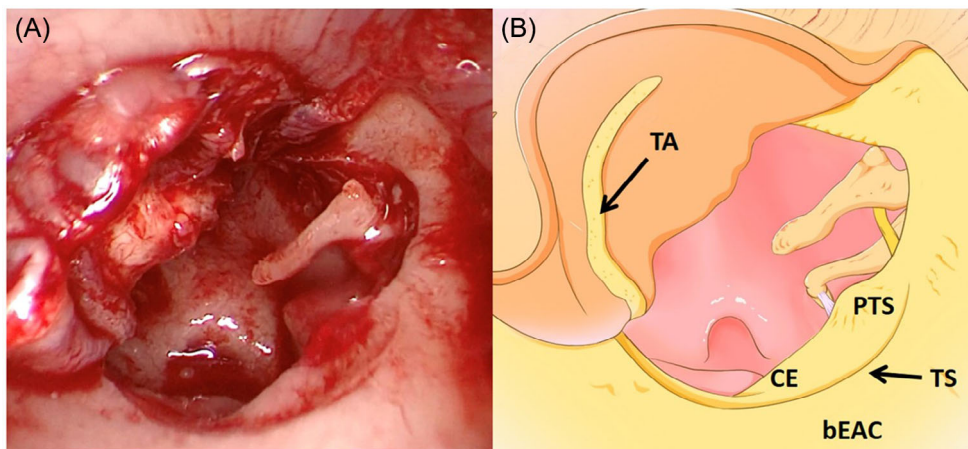
FIGURE 2 Classification of the chorda tympani nerve based on chordal eminence. Type I, the periannular segment was (A) located medial to the chordal eminence and (B, C) covered by the bony eminence. Type II, (D) the periannular segment was located inferior to the chordal eminence, and the nerve either (E) did or (F) did not contact the bony edge of the chordal eminence. Type III, (G) the periannular segment was located lateral to the chordal eminence and medial to the tympanic annulus, and (H, I) the iter chorda posterius was located in the tympanic sulcus

into the middle ear and was located medial to the tympanic annulus. According to the anatomical relationship between the CE and the periannular segment of the chorda tympani nerve, the chorda tympani nerve was divided into three types (Figure 2): (1) type I, the periannular segment was located medial to the CE and covered by the bony eminence [77 cases (32.5%)]; (2) type II, the periannular segment was located inferior to the CE, and the nerve did or did not contact the bony edge of the CE [147 cases (62.0%)]; and (3) type III, the periannular segment was located lateral to the CE and medial to the tympanic annulus, and the ICP was located in the tympanic sulcus [13 cases (5.5%)].

The chorda tympani nerve in the tympanic cavity is difficult to identify on CT, making it difficult to directly predict the relationship between the periannular segment and CE. However, localization of the ICP can indirectly guide the prediction of this relationship (Figure 3). Preoperative CT showed that the ICP was located medial to the CE in 37 cases, and the proportion of type I was 100%; that the ICP was located inferior to the CE in 187 cases, and the proportion of type II was 78.6% and type I was 21.4%; and that the ICP was located lateral to the CE in 13 cases, and the proportion of type III was 100%. The location of the ICP was highly reliable for prediction of type I and III nerves.

No iatrogenic tympanic nerve injuries occurred in the process of elevating the tympanomeatal flap and identifying the chorda tympani nerve. Six cases (2.5%) of chorda tympani nerve disconnection occurred during the management of tympanic lesions (1 case of chronic suppurative otitis media, 2 cases of pars flaccida cholesteatoma, 1 case of pars tensa cholesteatoma, and 1 case of neurogenic tumor) or atticotomy (1 case of congenital cholesteatoma, type I).

3.3 | Secondary exposure of the posterior canaliculus

The CT imaging of four patients with tympanic perforation secondary to EAC cholesteatoma showed that the bony EAC was enlarged and the posterior canaliculus was partially exposed below the meatal flap (Figure 4A, B). Therefore, the incision of the EAC flap should have

been more lateral. During the flap elevation in three patients, the exposed chorda tympani nerve and its course between the meatal flap and the posterior bony wall could be identified. One patient's flap incision was not lateral enough and was located on the exposed posterior canaliculus. The chorda tympani nerve was then cut when the flap was incised. None of the four patients had any obvious tympanic annulus structure, and the structure of the CE and tympanic sulcus was destroyed. The chorda tympani nerve could be identified from the exposed posterior canaliculus to the ICP (Figure 4C).

4 | DISCUSSION

In this study, we clarified the anatomical relationship between the CE and the tympanic sulcus and defined the tympanic sulcus or tympanic annulus as the boundary between the CE and the posterior bony wall of the EAC. Although there are morphological variations of the CE, attempting to classify the CE alone seems to offer no clinical significance. We believe that classification of the chorda tympani nerve based on the CE can concisely and effectively describe the variation of this regional anatomy and has practical significance. For type I chorda tympani nerves, elevation of the tympanic annulus and entrance into the tympanic cavity have little risk of injury to the chorda tympani nerve because the periannular segment is covered and protected by the lateral CE. However, for cases requiring atticotomy, the scutum and PTS need to be removed. During this process, iatrogenic injury may occur because of the inability to identify the obscured nerve. We recommend using a curette or drill to carefully and gradually remove the bone; use of a bone chisel for removal of large amounts of bone should be avoided. Massive bone removal may damage the hidden chorda tympani nerve or transect the posterior canaliculus, making it difficult to separate the chorda tympani nerve from the chiseled bone and obscuring the surgical field. For type II chorda tympani nerves, after carefully elevating the tympanic annulus, the instrument used to split the middle ear mucosa should not be inserted too deeply into the tympanic cavity and should be
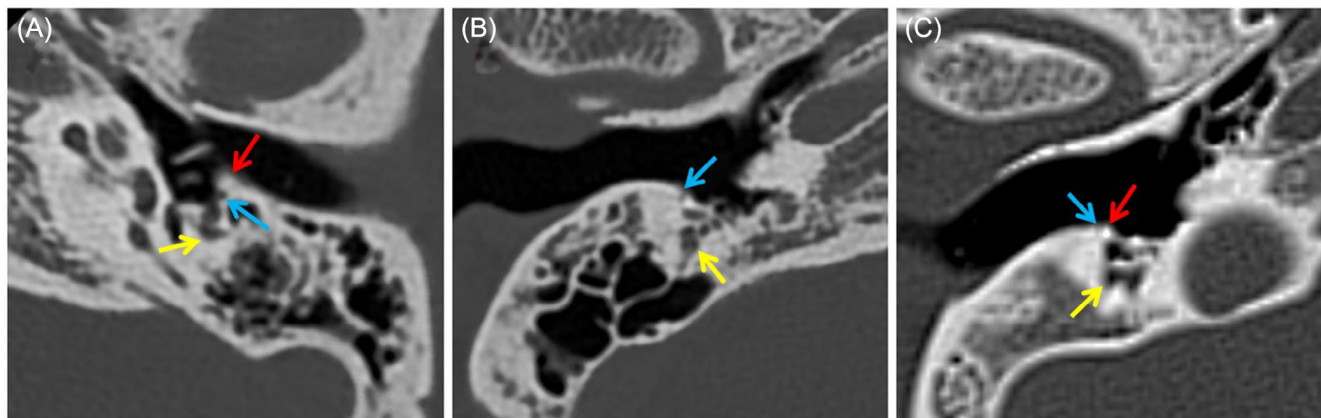
FIGURE 3 Location of the iter chorda posterius. Preoperative computed tomography showed that the iter chorda posterius could be located (A) medial, (B) inferior, or (C) lateral to the chordal eminence. Yellow arrow, facial nerve; blue arrow, iter chorda posterius; red arrow, chordal eminence

FIGURE 4 Secondary exposure of the PC in a patient with tympanic perforation secondary to external auditory canal cholesteatoma. Computed tomography indicated that (A, B) the bony external auditory canal was enlarged and that (B) the PC was partially exposed below the meatal flap. (C) During the endoscopic tympanoplasty, the chorda tympani nerve could be identified from the exposed PC to the ICP. Yellow arrow, facial nerve; blue arrow, chorda tympani nerve. ICP, iter chorda posterius; PC, posterior canaliculus
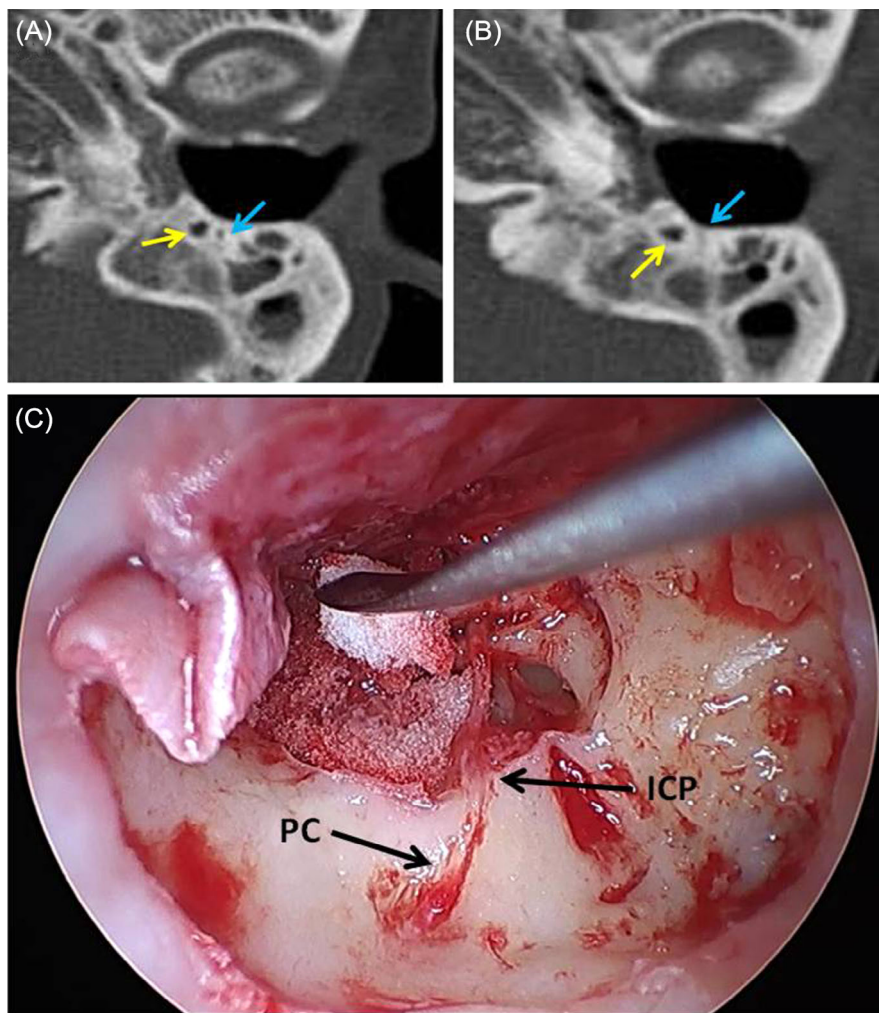
close the annulus to avoid damage to the nerve inferior to the CE. For this type of chorda tympani nerve, the surgeon should be able to clearly identify the course of the periannular segment, greatly reducing the risk of chorda tympani nerve injury caused by atticotomy. A type III chorda tympani nerve is most likely to be damaged when elevating the tympanic annulus. It is located lateral to the outer surface of the CE, and the ICP is located in the tympanic sulcus. Although type III nerves can be predicted by preoperative imaging, the specific location of the ICP cannot be determined before elevating the tympanic annulus. Therefore, we recommend our elevation method for the tympanic annulus (Video 1). Starting from the superior end of the tympanic annulus posterior to the CE, we gently elevated the tympanic annulus from the sulcus inferiorly to avoid damaging the nerve. This method is also applicable to the other two types of chorda tympani nerve variations. As in type II, the tympanic segment can be directly visualized in type III nerves, avoiding nerve injury during atticotomy. In addition, if continuous irrigation is applied during surgery,[11] the obscuration of bleeding on the surgical field can be better avoided. With continuous irrigation, the surgeon may elevate the tympanic annulus and more clearly identify the chorda tympani nerve, which may be more beneficial for protection of the nerve (Video 1). By understanding the variation of the periannular segment, the application of reasonable methods for tympanic annulus elevation and

atticotomy can effectively prevent injury to the chorda tympani nerve. However, it should also be noted that during the management of tympanic lesions, iatrogenic nerve disconnection may still occur even after the course of the nerve has been identified. This underscores the need for us to continuously improve our surgical skills.

Localization of the ICP by preoperative CT imaging can help to classify the chorda tympani nerve because the location of the ICP is highly reliable for prediction of type I and III chorda tympani nerves. Although most patients in whom the ICP was inferior to the CE had type II nerves, 21.4% had type I. This might be explained by bias in the judgment of the inferior bony extension of the CE, which can be too tiny to recognize on CT, and the ICP might have actually been located medial to the CE. Additionally, if the ICP had truly been located inferior to the CE, the initial periannular segment may have been hidden by the EAC wall in the endoscopic view.

Understanding the concept of the tympanic sulcus or tympanic annulus as the boundary between the CE and posterior wall of the EAC is very important for the correct description of chorda tympani nerve variations. Based on the images extracted from endoscopic ear surgery, Uranaka et al.[12] classified the visible tympanic segment of the chorda tympani nerve into five types: EAC, detached, attached long, attached short, and ultra-short. However, they mistakenly defined the CE as the "bony tympanic annulus" (tympanic sulcus). Their

classification of the EAC type was based on a misunderstanding of the regional anatomy among the five types proposed. Based on the surgical image provided in their article, their EAC type actually corresponds to our type III. The ICP is located in the tympanic sulcus, not in the bony EAC. Among patients without destruction of the bony EAC, we encountered no instances in which the chorda tympani nerve directly exited from the bony EAC, and the ICP did not exceed the tympanic sulcus. Compared with the classification established by Uranaka et al.,[12] our type I (prevalence of 32.5%) includes their attached short and ultra-short types (14.0% and 10.2%, respectively), our type II (62.0%) includes their detached and attached long types (4.7% and 65.6%, respectively), and our type III (5.5%) is equivalent to their EAC type (5.5%). These prevalences are similar to one another. Molinari et al.[10] ideally divided the tympanic cavity into eight 45-degree angled portions and considered a line passing along the axis of the malleus handle and a perpendicular line crossing its midpoint. The entry point of the chorda tympani fell into one of the four posterior slices, and these were categorized as type I, II, III, or IV.[10] The authors' classification was based on the entry point of the chorda tympani nerve, making comparison between their classification and our classification difficult. We believe that our classification of the chorda tympani nerve based on the CE is simple and practical, corresponds to different neuroprotective strategies, and may be a beneficial source of guidance for endoscopic or microscopic middle ear surgery.

The only exception we observed in which the chorda tympani nerve was located between the meatal flap and the bony EAC wall was in patients with tympanic membrane perforation secondary to EAC cholesteatoma. Because of the effect of the cholesteatoma, the bony EAC was absorbed and expanded until the posterior canaliculus was exposed. Therefore, the chorda tympani nerve in the posterior canaliculus was directly exposed under the flap. Similarly, the structures of the CE and the tympanic sulcus had been destroyed, and the tympanic annulus was difficult to identify. In such cases, the nerve from the posterior canaliculus to the ICP is often exposed. Therefore, the key to avoiding nerve injury lies in the incision of the meatal flap. As long as the incision is located lateral to the exposed posterior canaliculus, we can gently elevate the meatal flap and identify the course of the posterior canaliculus. For such secondary cases, CT can prompt the exposure of the posterior canaliculus and the range of exposure, providing guidance for intraoperative meatal incision planning. We recommend placing the incision as far lateral to the exposed posterior canaliculus as possible, although sometimes errors in judgment may occur under endoscopy. The enlargement of the flap caused by the more lateral incision did not affect the surgical field because the ear canal was enlarged in these cases.

5 | CONCLUSION

Classification based on the CE can concisely describe the variation of the chorda tympani nerve and provide guidance for neuroprotection in endoscopic ear surgery. Patients with EAC cholesteatoma may have secondary exposure of the posterior canaliculus.

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