Received: 12 July 2022 | Revised: 5 September 2022 | Accepted: 15 September 2022

DOI: 10.1002/lio2.938

ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Chorda tympani nerve course and feasibility of its preservation during atresiaplasty for congenital aural atresia

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Funding information
Chungnam National University Hospital, Grant/Award Number: 2021; National Research Foundation of Korea, Grant/Award Number: 2021R1F1A1052263

Abstract

Objectives: The association between the chorda tympani nerve (CTN) and atresiaplasty has not been investigated. This study aimed to describe the course of the CTN observed during atresiaplasty for congenital aural atresia (CAA) and explore the feasibility of CTN preservation.

Methods: In this retrospective study, six consecutive patients who underwent atresiaplasty in a tertiary academic center were included. The course of the tympanic segment of the CTN and its preservation feasibility were evaluated. Atresiaplasty was performed using an anterior approach. The average Jahrsdoerfer score was 8.7 points (range, 8–9 points).

Results: The CTN was located in the atretic plate in all patients. It emerged from an average of 5.6 mm (range, 5.2–6.1) inferior to the incus buttress and crossed the middle ear in an anterior–superior direction. The distance between the neck of the malleus and the CTN varied in the absence of the malleus handle. However, when the malleus handle developed, the CTN passed between the incus and the malleus handle. The CTN was preserved in two of the six patients. They had a Jahrsdoerfer score of 9 and grade I microtia.

Conclusion: The CTN was located in the atretic plate, emerging from an average distance of 5.6 mm inferior to the incus buttress. The incus buttress might serve as a good anatomical landmark to identify and preserve the CTN. CTN preservation is feasible in atresiaplasty candidates with a Jahrsdoerfer score of 9 and auricular deformity of grade I.

Level of Evidence: 4.

KEYWORDS
atresiaplasty, chorda tympani nerve, congenital aural atresia, incus buttress, microtia

1 | INTRODUCTION

Congenital aural atresia (CAA) is a birth defect characterized by aplasia or hypoplasia of the external auditory canal and conductive hearing loss. Atresiaplasty is performed for CAA treatment. It includes three different steps: meatoplasty (creation of the cartilaginous external auditory canal and canal opening), canaloplasty (creation and widening of the bony external auditory canal), and tympanoplasty

(creation of the tympanic membrane and reconstruction of the ossicular chain).[1,2] It is still considered as one of the most difficult otologic procedures because of the lack of surgical landmarks and association with other abnormalities of the auricle, middle ear, and facial nerve.[3–5] The poorer postoperative hearing outcomes of atresiaplasty compared to those in other surgeries for congenital conductive hearing loss also add to the challenges of atresiaplasty.[6–8]

The chorda tympani nerve (CTN) provides taste sensation from the anterior two-thirds of the ipsilateral tongue and regulates salivary secretion of the sublingual and submandibular glands. It branches off from the facial nerve and then passes through the middle ear cavity before joining the lingual nerve. During a middle ear surgery, it is vulnerable to injury because it is exposed to the middle ear without a bony covering. CTN-related symptoms and/or CTN dysfunction occur in 14%–33.5% of patients after a middle ear surgery, and they may persist.[9,10] Despite the clinical significance of the CTN, no study has investigated the association between the CTN and atresiaplasty. In addition, little is known about the feasibility of CTN identification and preservation during the procedures.

The objectives of this pilot study were to describe the course of the CTN identified during atresiaplasty for the treatment of CAA and to explore the feasibility of CTN preservation.

2 | MATERIALS AND METHODS

2.1 | Study population

The Institutional Review Board and Hospital Research Ethics Committee of Chungnam National University Hospital (Daejeon, Korea) approved this study. Six consecutive atresiaplasty procedures for CAAs were included between January 2017 and June 2019. Patients with Jahrsdoerfer score ≤6, a low tegmen mastoideum, and those who underwent revision surgery were excluded.

2.2 | Surgical procedures

Atresiaplasty was performed using an anterior approach, as described in previous studies.[1,2,7] The mastoid was briefly exposed after a retroauricular skin incision. The epitympanum was entered by drilling the bone between the linea temporalis superiorly and the glenoid fossa anteriorly, following the tegmen. After the malleus–incus complex was identified, the atretic plate was removed, during which a diamond burr at low speed was used to avoid damage to the surrounding structures. When a structure, presumably, the CTN came out, precautions were taken to preserve it as much as possible. A new canal was created to center the ossicles in the middle of the canal. The integrity of the ossicular chain was checked, and disconnected ossiculoplasty was performed using either partial or total ossicular prosthesis. The temporalis fascia was placed over the malleus–incus complex, and a thin split-thickness skin graft was placed on the fascia, creating a new canal. A silicone button was inserted into the external canal over the new tympanic membrane, and meatoplasty was performed after the elevation of the anterior-based concha flap. The concha flap was secured to the periosteum, and a split-thickness skin graft was sutured to the metal skin. The external canal and meatus were packed with Merocel® (Medtronic XOMED, Jacksonville, FL, USA) wicks.

2.3 | The CTN course and relationship with surrounding structures

The course of the CTN was thoroughly evaluated at the time of surgery, and the photographs of the CTN acquired during surgery were reviewed to illustrate its course and to analyze its relationship with surrounding structures. The following four parameters were evaluated using the photographs: (1) location of the CTN, (2) distance between the CTN and incus buttress, which was obtained by measuring the distance between the emerging point of the CTN and incus buttress speculated along the incus body shape, (3) distance between the CTN and inferior aspect of the malleus, and (4) direction of the CTN course (Figure 1). The distances were measured using Photoshop software (Adobe Systems, San Jose, CA, USA).

2.4 | Clinical variables

Demographics, microtia severity, atresia type, preoperative imaging findings including Jahrsdoerfer score, operative findings, and

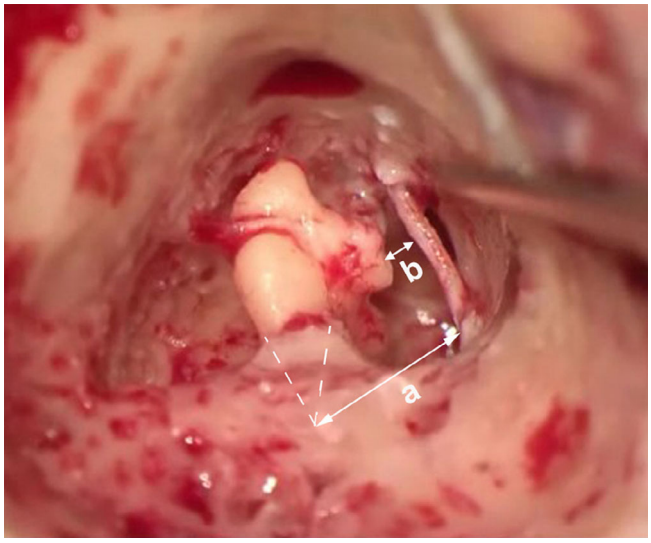

FIGURE 1 Measurement of distance between the chorda tympani nerve (CTN) and surrounding structures. The distance between the CTN and the incus buttress (A) was obtained by measuring the distance between the emerging point of the CTN and incus buttress speculated along the incus body shape (white dotted line). The distance between the CTN and the inferior aspect of the malleus (B) was obtained by recording the direct distance between the CTN and mid portion of inferior aspect of the malleus

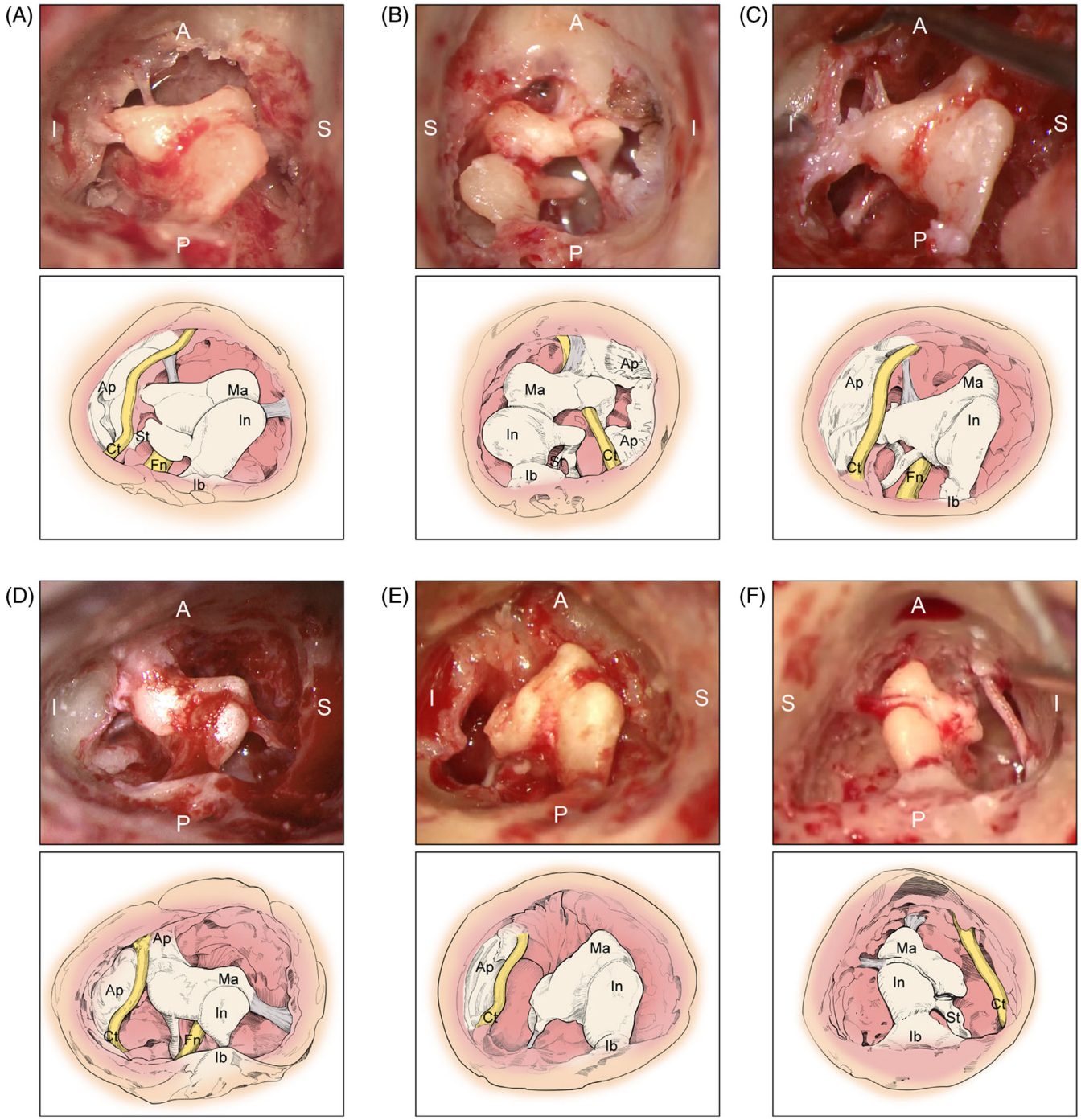

FIGURE 2 Intraoperative images and schematic drawings illustrating the course of the tympanic segment of the chorda tympani nerve (Ct). The chorda tympani nerve located in the atretic plate (Ap). It runs across the middle ear, emerging from inferior to the incus buttress (Ib). It is preserved in patient 2 (B) and 6 (F), and not in patient 1 (A), 3 (C), 4 (D), and 5 (E). Fn, facial nerve; Ma, malleus; In, incus; St, stapes; A, anterior; P, posterior; S, superior; I, inferior

audiologic data were also analyzed. The severity of the microtia was graded according to Marx's classification. Grade I represents an auricle smaller than normal with all anatomical structures distinguishable. Grade II represents an abnormally small auricle with some distinguishable anatomical structures. Grade III represents only a rudiment of soft tissue, often the shape of a peanut.[11] Atresia was classified into four types according to the Schuknecht classification. Type A represents meatal atresia. Type B is a partial atresia with a small or hypoplastic canal. Type C is total atresia, including both the cartilage and bony external auditory canal. Type D is total atresia with a hypopneumatic mastoid.[4] Pure-tone average values for air conduction and bone conduction were calculated using 500, 1000, 2000, and 3000 Hz, as recommended by the American Academy of Otolaryngology Committee on Hearing and Equilibrium.[12]

TABLE 1 Demographic and clinical characteristics of the patients

Patient	1	2	3	4	5	6
Age, years	19	24	15	20	25	20
Sex	F	F	M	M	F	F
Side	L	R	L	L	L	R
Microtia grade	III	I	II	III	II	I
Schuknecht type	C	C	C	C	B	B
Jahrsdoerf score	8[a]	9[b]	8[b]	9[b]	9[b]	9[b]
Pure-tone threshold						
Preoperative BC, mean, dB HL	18.8	16.3	16.3	13.8	17.5	25
Preoperative AC, mean, dB HL	67.5	67.5	75	53.8	70	70
Postoperative BC, mean, dB HL	16.8	16.5	15.5	23.8	23.8	23.8
Postoperative AC, mean, dB HL	32.5	27.3	31.5	36.8	41.3	42.3
Follow-up, months	31	28	22	20	18	17

Abbreviations: AC, air conduction; BC, bone conduction: F, female; M, male; L, left; R, right.
[a]Connection between the incus and stapes is not identified.
[b]Appearance of the external ear is abnormal.

TABLE 2 Course of the tympanic segment of the chorda tympani nerve and its preservation

		Distance (mm)			
Patient	CTN location	CTN to incus buttress	CTN to malleus	Direction	CTN preservation
1	AP	5.3	1.4	PI to AS	No
2	AP	5.7	Under the malleus handle	PI to AS	Yes
3	AP	6.1	0.2	PI to AS	No
4	AP	5.2	0.5	PI to AS	No
5	AP	5.5	0.3	PI to AS	No
6	AP	5.9	1.2	PI to AS	Yes

Abbreviations: AP, atretic plate; AS, anterior superior; CTN, chorda tympani nerve; PI, posterior inferior.

3 | RESULTS

Atresiaplasty was performed on patients in the age range of 15–25 years, with two male and four female patients. Four of the six patients had total atresia (type C) in combination with class III auricular deformity, and the other two had partial atresia (type B). The average Jahrsdoerfer score was 8.7 points (range, 8–9 points). All patients except one had hypoplastic malleus–incus complex with an absence of the malleus handle. One patient had both a malleus handle and an incus long process, although these ossicles were slightly hypoplastic (patient 2). Stapes were present in all the patients (Figure 2, Table 1).

CTN was identified within the atretic plate in all the patients. It emerged from an average distance of 5.6 mm (range, 5.2–6.1) inferior to the incus buttress and crossed the anterior middle ear superiorly (Figure 2, Table 2). In patients with an absent malleus handle (patients 1, 3, 4, 5, and 6), the distance between the neck of the malleus and the CTN averaged 0.7 mm (range, 0.2–1.4) (Figure 2A,C–F). When the malleus handle developed (but still hypoplastic) (patient 2), it passed medial to the malleus handle (Figure 2B). Of the six patients, CTN was preserved in two patients (patients 2 and 6) (33.3%) (Figure 2B,F). The two patients had both grade I microtia and a Jahrsdoerfer score of 9. Postoperatively, patients with CTN preservation did not complain of taste change. Among the four patients with no CTN preservation, only one (25%) complained of taste disturbance.

4 | DISCUSSION

We illustrated the course and feasibility of CTN preservation, which has not been studied during atresiaplasty. The CTN was present in the atretic plate in all the patients. It emerged inferior to the incus buttress and ran across the middle ear in an anterior–superior direction. The average distance between the CTN and the incus buttress was 5.6 mm. The CTN could be preserved during the removal of the atretic plate in two of six patients with both Jahrsdoerfer score 9 and grade I microtia. To the best of our knowledge, this study is the first to observe the CTN course during a CAA surgery.

Although the tympanic segment of the CTN has some anatomical variation in normal ears,[13,14] the overall course of the CTN observed in this study was similar to that of the normal ear. It runs across the middle ear cavity in an anterior–superior direction and leaves the middle ear through the anterior canal wall. Embryologically, CTN appears

in the early embryonic stage. The CTN branches off from the facial nerve around the fourth and fifth weeks of gestation. It passes between the incus and malleus, and enters the first branchial arch at the seventh week of gestation. The development of ossicles occurs in similar periods. The malleus and incus appear fused from the interbranchial bridge at the fourth or fifth week of gestation. Separation into two distinct ossicles and formation of the incudomalleolar and incudostapedial joints is completed by the seventh or eighth week of gestation.[15,16] For auricular development, the auricle forms earlier than the middle ear. The better the external ear forms, the better the middle ear develops.[3] Atresiaplasty is usually considered when the Jahrsdoerfer score, based on both the middle ear structure and the external ear, is 7 or higher, in which case favorable ossicular and auricular structures exist.[2] Therefore, CAA patients undergoing atresiaplasty are likely to have a normal CTN development.

The CTN was always located inferior to the incus buttress in all patients. In addition, the distance between the two structures ranged between 5.2 and 6.1 mm (an average of 5.6 mm), which did not vary significantly among the patients. Considering these findings together with the surgical principle that the incus buttress should be preserved for the stability of the ossicles during atresiaplasty,[1] the incus buttress is likely to be a good anatomical landmark for the identification of the CTN. The distance observed in our CAA patients was shorter than that observed in normal ears (mean: 7.8 mm, range: 5–11 mm).[17] This can be attributed to the short and anteriorly displaced vertical segment of the facial nerve resulting from hypoplasia of the second genu of the facial nerve.[4,5,18]

In CAA patients, a preoperative high-resolution temporal bone computed tomography is very important for planning and implementing atresiaplasty. Location of the tegmen mastoideum, course of the facial nerve, and developmental status of the middle ear including the ossicles can be identified before surgery. However, it does not seem to provide any information about the course of the CTN. Here, the CTN could not be identified by computed tomography in any patient. Therefore, to preserve the CTN, it is necessary to become fully conversant with the path of the CTN that can be encountered at the time of surgery. Our findings provide data that may help the otologic surgeon identify and preserve the nerve.

The incidence of CTN-related symptoms after middle ear surgery depends on either middle ear pathology or the severity of nerve injury. Patients with noninflammatory diseases experience taste changes or dry mouth more frequently than those with inflammatory diseases.[19] Stretching or transection of the nerve is more likely than preservation to lead to these symptoms.[20] In this study, 1 of 4 patients with CTN severance complained of taste disturbance postoperatively, while the others did not. This is consistent with the results of previous studies. A prospective study reported that among 16 cholesteatoma patients with CTN severance, only 5 (31%) were symptomatic.[19] In another study on 93 patients with middle ear disease, CTN was sectioned in 32 patients, but only 4 of them (13%) experienced symptoms.[9]

There are several limitations to this study. First, although this study was conducted at a tertiary university hospital, the number of patients was small. This can be attributed to both the low birth rate and low incidence of CAAs in Korea. Future studies employing a larger cohort from multiple institutions are needed to validate our findings. Second, surgeon experience can affect the results because a surgical learning curve exists in CAA surgery as in stapes surgery.[21,22] Lastly, postoperative evaluation of CTN dysfunction was based only on patients' self-reported symptoms. A recent study in microtia patients demonstrated that approximately 10% (18/172) of patients with an average Jahrsdoerfer score of 7 points had abnormal electrogustometry thresholds indicating CTN dysfunction.[23] Therefore, the status of CTN function before surgery may affect postoperative patient complaints.

In conclusion, we demonstrated that the CTN was located in the atretic plate and its overall course was similar to that of the normal ear. It emerged from an average distance of 5.6 mm inferior to the incus buttress. It ran across the middle ear in the anterior–superior direction. We could preserve it in patients with both a favorable Jahrsdoerfer score and milder degree of microtia. The incus buttress might serve as a good anatomical landmark to identify the CTN. Our findings may help otologic surgeons have a better understanding of the CTN in patients with CAA.

FUNDING INFORMATION

This research was supported by Chungnam National University Hospital Research Fund (2021) and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2021R1F1A1052263).

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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REFERENCES

1. De la Cruz A, Teufert K, Brackmann D, Shelton C, Arriaga M. Congenital malformation of the external auditory canal and middle ear. *Otol Surg*. 2010;3:55-72.
2. McKinnon BJ, Jahrsdoerfer RA. Congenital auricular atresia: update on options for intervention and timing of repair. *Otolaryngol Clin North Am*. 2002;35(4):877-890. doi:10.1016/s0030-6665(02)00058-0
3. Kountakis SE, Helidonis E, Jahrsdoerfer RA. Microtia grade as an indicator of middle-ear development in aural atresia. *Arch Otolaryngol Head Neck Surg*. 1995;121(8):885-886. doi:10.1001/archotol.1995.01890080053010
4. Schuknecht HF. Congenital aural atresia. *Laryngoscope*. 1989;99(9):908-917. doi:10.1288/00005537-198909000-00004
5. Takegoshi H, Kaga K. Difference in facial canal anatomy in terms of severity of microtia and deformity of middle ear in patients with microtia. *Laryngoscope*. 2003;113(4):635-639. doi:10.1097/00005537-200304000-00009
6. Chung J, Kang JY, Kim MS, Kim B, Choi JW. Microscopic vs endoscopic ear surgery for congenital ossicular anomaly. *Otolaryngol Head Neck Surg*. 2020;162(4):548-553. doi:10.1177/0194599819900489
7. De la Cruz A, Teufert KB. Congenital aural atresia surgery: long-term results. *Otolaryngol Head Neck Surg*. 2003;129(1):121-127. doi:10.1016/s0194-5998(03)00531-x

8. Lambert PR. Congenital aural atresia: stability of surgical results. *Laryngoscope*. 1998;108(12):1801-1805. doi:10.1097/00005537-199812000-00007
9. Gopalan P, Kumar M, Gupta D, Phillipps JJ. A study of chorda tympani nerve injury and related symptoms following middle-ear surgery. *J Laryngol Otol*. 2005;119(3):189-192. doi:10.1258/0022215053561657
10. Saito T, Manabe Y, Shibamori Y, et al. Long-term follow-up results of electrogustometry and subjective taste disorder after middle ear surgery. *Laryngoscope*. 2001;111(11 Pt 1):2064-2070. doi:10.1097/00005537-200111000-00037
11. Marx H, Henke F, Lubarsh O. *Handbuch der spez path anatomie histologie*. Springer; 1926.
12. Committee on HEARing and Equilibrium guidelines for the evaluation of results of treatment of conductive hearing loss. American Academy of Otolaryngology-Head and Neck Surgery Foundation, Inc. *Otolaryngol Head Neck Surg*. 1995;113(3):186-187. doi:10.1016/S0194-5998(95)70103-6
13. Molinari G, Yacoub A, Alicandri-Ciufelli M, et al. Endoscopic anatomy of the chorda tympani: systematic dissection, novel anatomic classification, and surgical implications. *Otol Neurotol*. 2021;42(7):e958-e966. doi:10.1097/MAO.0000000000003143
14. Uranaka T, Matsumoto Y, Hoshi Y, Iwasaki S, Kakigi A, Yamasoba T. Classification of the chorda tympani: an endoscopic study. *Otol Neurotol*. 2021;42(3):e355-e362. doi:10.1097/MAO.0000000000002998
15. Jin ZW, Cho KH, Abe H, Katori Y, Murakami G, Rodríguez-Vázquez JF. Fetal facial nerve course in the ear region revisited. *Surg Radiol Anat*. 2017;39(8):885-895. doi:10.1007/s00276-017-1818-y
16. Sataloff RT, Selber JC. Phylogeny and embryology of the facial nerve and related structures. Part II: Embryology. *Ear Nose Throat J*. 2003;82(10):764-766, 9–72, 74 passim. doi:10.1177/014556130308201010
17. Calli C, Pinar E, Oncel S, Tatar B, Tuncbilek MA. Measurements of the facial recess anatomy: implications for sparing the facial nerve and chorda tympani during posterior tympanotomy. *Ear Nose Throat J*. 2010;89(10):490-494.
18. Jahrsdoerfer R. Congenital malformations of the ear. Analysis of 94 operations. *Ann Otol Rhinol Laryngol*. 1980;89(4 Pt 1):348-352. doi:10.1177/000348948008900410
19. Clark MP, O'Malley S. Chorda tympani nerve function after middle ear surgery. *Otol Neurotol*. 2007;28(3):335-340. doi:10.1097/01.mao.0000247820.16325.f0
20. Ziylan F, Smeeing DPJ, Bezdjian A, Stegeman I, Thomeer HGXM. Feasibility of preservation of chorda tympani nerve during noninflammatory ear surgery: a systematic review. *Laryngoscope*. 2018;128(8):1904-1913. doi:10.1002/lary.26970
21. Patel N, Shelton C. The surgical learning curve in aural atresia surgery. *Laryngoscope*. 2007;117(1):67-73. doi:10.1097/01.mlg.0000240163.73601.27
22. Yung MW, Oates J, Vowler SL. The learning curve in stapes surgery and its implication to training. *Laryngoscope*. 2006;116(1):67-71. doi:10.1097/01.mlg.0000184509.01049.06
23. Takano K, Takahashi N, Ogasawara N, Yotsuyanagi T, Himi T. Chorda tympani nerve dysfunction associated with congenital microtia. *Acta Otolaryngol*. 2017;137(7):686-689. doi:10.1080/00016489.2016.1278306

How to cite this article: Yeon E-K, Kim M-K, Im SY, Heo DB, Moon SJ, Choi JW. Chorda tympani nerve course and feasibility of its preservation during atresiaplasty for congenital aural atresia. *Laryngoscope Investigative Otolaryngology*. 2022;7(6):2029-2034. doi:10.1002/lio2.938