The Journal of International Advanced Otology

J Int Adv Otol 2023; 19(1): 45-49 • DOI: 10.5152/iao.2023.22682

Original Article

# Location of the Tympanic Nerve Relative to the Round and Oval Windows

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Cite this article as: Beger O, Güven O, Doğu S, Vayisoğlu Y, Ümit Talas D. Location of the tympanic nerve relative to the round and oval windows. *J Int Adv Otol.* 2023;19(1):45-49.

**BACKGROUND:** The aim of the study was to measure the distance of the tympanic nerve to the oval window and round window niche in adult cadavers for evaluating its usability as an anatomical landmark during middle ear-related surgeries, including stapedotomy and cochleostomy, and for preventing its iatrogenic damage during surgical practices such as otosclerosis surgery and cochlear implantation.

**METHODS:** The middle ears of 10 adult cadavers aged 74.70 ± 14.56 years were bilaterally dissected with the help of an endoscope and microscope to measure the distance of tympanic nerve to round window niche and oval window.

**RESULTS:** Tympanic nerve was found as 1.60 ± 0.86 mm (range, 0-3.11 mm) and 1.55 ± 0.38 mm (range, 1.04-2.20 mm) away from round window niche and oval window, respectively. In relation to the quantitative values of these 2 distances, neither right–left nor male–female significant differences were determined ($P > .05$). Tympanic nerve was observed in all temporal bones. In terms of the shape and twigs of tympanic nerve, extreme variations among cadaveric temporal bones were determined. Tympanic nerve-round window niche distance between 0-1 mm was defined as type 1 (20%), between 1 and 2 mm as type 2 (45%), between 2 and 3 mm as type 3 (30%), and between 3 and 4 mm as type 4 (5%).

**CONCLUSION:** Tympanic nerve may be vulnerable at round window niche- or oval window-related surgeries (e.g., cochleostomy).

**KEYWORDS:** Adult, middle ear, oval window, round window, tympanic nerve, promontory

## INTRODUCTION

The tympanic nerve (TN; origin: the glossopharyngeal nerve, synonym: Jacobson's nerve), arising from the inferior (petrosal) ganglion of the ninth cranial nerve, enters the middle ear through a small passage (the inferior tympanic canaliculus) situated on an osseous ledge dividing the jugular vein from the internal carotid artery. Tympanic nerve and the caroticotympanic nerves converge on the cochlear promontory to form the tympanic plexus. Preganglionic parasympathetic fibers within the plexus are transmitted to the otic ganglion through the lesser petrosal nerve for secretomotor supply of the parotid gland. The plexus also grants sensory twigs to the middle ear mucosa, tympanic membrane inner surface, mastoid air cells, and Eustachian tube.[1-5] Moreover, TN plays an important role in the regulation of tympanic cavity pressure.[6,7] Owing to pathological entities such as intractable otalgia, chronic secretory otitis media, Meniere's disease, Frey's syndrome, parotid sialectasis, schwannoma, crocodile tearing, otosclerosis, chronic parotitis, parotid duct stenosis, and parotid salivary fistula,[3,5,8-12] the twigs and function of TN are of great importance for otologists in terms of tympanic neurectomy. Its position also has surgical importance to prevent involuntary damage during interventions such as cochlear implantation.[13,14] These clinical implications make the twigs and location of TN a significant area of interest for otologists.

Some surgeons report that TN may be used as an anatomical landmark to guess the location of the round window niche (RWN).[13,14] As a hint for the detection of RWN in cases where the niche is not describable during the facial recess approach, Goravalingappa[13] proposes the use of TN as a reference point to perform a successful cochleostomy. For instance, in cases with ossification or obliteration at the basal turn of the scala tympani (e.g., patients with otosclerosis, or meningitis), the cochleostomy should be carried

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**Received:** January 12, 2022 • **Accepted:** May 22, 2022 • **Publication Date:** January 13, 2023
Available online at www.advancedotology.org

out anterior to TN or through the nerve.[13] The distance between RWN and TN may be thought of as a critical area for minimal invasive cochlear implantation.[13,14] This distance was measured in only 2 cadaveric studies; 1 of them was an adult,[14] and the other was a fetal investigation.[15] On the other hand, oval window (OW)-related interventions (e.g., stapes surgery) may lead to involuntary damage of TN.[15] As far as we know, TN-OW distance was not measured in any adult populations. Hence, we think that a novel adult morphometric examination focused on the location of TN relative to RWN and OW may be handy for ear surgeons to approach the windows during stapes surgery or cochlear implantation. For this reason, we aimed to measure the distances between the windows and TN.

## METHODS

### Study Population

The Clinical Research Ethics Committee approved the present cadaveric study (09/18/2019-2019/398). After ethical confirmation, the work was carried out in the gross anatomy laboratory of the university, between December 01, 2019, and March 01, 2020. The ears of 10 (5 women and 5 men) cadaver heads between the ages of 45 and 92 years (mean age: 74.70 ± 14.56 years) were included in the work.

### Dissection Technique

The senior neuro-otologist (DÜT) of the study team carried out all dissections using a micromotor (Bien Air Surgery SA, le Noirmont, Switzerland, handpiece length: 70, 95, and 125 mm, burr diameter: minimum 0.6 mm). With the help of an endoscope (Karl Storz Gmbh & Co., Tüttlingen, Germany, length: 18 cm, degree: 0°, 30°, and 70°, diameter: 2.7 and 4 mm) and microscope (Carl Zeiss f170, Carl Zeiss Meditec AG, Oberkochen, Germany), the dissections from the external auditory canal to the cochlear promontory were performed to determine the spatial relationship of TN with RWN and OW. The steps were summarized for each ear as follows: (a) the head was positioned according to otologic surgery, (b) the skin near the external auditory canal was cut with a circumferential incision, (c) the auricle was retracted anteriorly, (d) the skin of external auditory canal, tympanic membrane, chorda tympani, malleus, and incus were removed, (e) a wide canalplasty was done, (f) after cutting the stapedial tendon, the stapes pulled carefully out using a surgical hook, (g) finally, TN, RWN, and OW were exposed, and (h) from the same position and distance, the cochlear promontory was photographed with a millimeter scale using the microscope camera (Nikon d3300 digital camera, Nikon, Tokyo, Japan).

### MAIN POINTS

- The distance of tympanic nerve (TN) to round window niche (RWN) was measured in cadavers for evaluating its usability as an anatomical landmark during cochleostomy.
- Tympanic nerve-round window niche distance was classified into 4 types (type 1: between 0 and 1 mm, type 2: between 1 and 2 mm, type 3: between 2 and 3 mm, and type 4: between 3 and 4 mm).
- Patients with type 1 (TN-RWN < 1 mm), in particular, may be at risk for iatrogenic damage of TN during the cochleostomy. Therefore, tympanic neurectomy may be considered simultaneously with the cochleostomy in patients with type 1, if TN trauma is recognized with a surgical microscope under appropriate magnification.

### Morphometric Parameters

Two independent researchers measured parameters in triplicate using digital image analysis software (Rasband, WS, ImageJ, US National Institutes of Health, Bethesda, MD, USA, https://imagej.nih.gov/ij/, 1997-2018). For this purpose, the photographs were posted to ImageJ. According to previous studies,[14,15] the measured parameters were as follows: (a) TN-RWN: the shortest distance between TN and RWN and (b) TN-OW: the shortest distance between TN and OW (Figure 1).

### Statistical Analysis

The interobserver reproducibility was checked with the intraclass correlation coefficients (ICCs), while intraobserver reproducibility was checked with the repeated measures analysis of variance (post-hoc Tukey test). Shapiro–Wilk was utilized to check normality controls of distance measurements. The Pearson correlation coefficient test was used to correlate TN-RWN and TN-OW. Student's *t*-tests were employed to assess right–left (the paired sample *t*-test) and woman–man (the independent sample *t*-test) comparisons. In addition, the Pearson product–moment correlation coefficient was utilized to determine the relationship between the measurements on right and left sides. Statistical *P* value was .05.

## RESULTS

The ICC score was found as 0.990 for TN-RWN distance ($P < .001$), while 0.998 for TN-OW distance ($P < .001$). The measurements performed by the same researcher did not display significant differences ($P > .05$). These analyses displayed that the intra- and interobserver reproducibility was excellent for both parameters. Tympanic nerve-RWN ($P = .659$) and TN-OW ($P = 0.102$) measurements showed normal distributions; thus, the values were given as average ± standard deviation. Our findings were as follows:

- Round window niche was measured as 1.60 ± 0.86 mm (range, 0-3.11 mm) away from TN.
- Oval window was measured as 1.55 ± 0.38 mm (range, 1.04-2.20 mm) away from TN.
- Neither right–left nor male–female significant differences were determined in relation to quantitative values of these distances ($P > .05$).
- Tympanic nerve-RWN was strongly correlated with TN-OW ($P < .001$, $r = 0.859$).

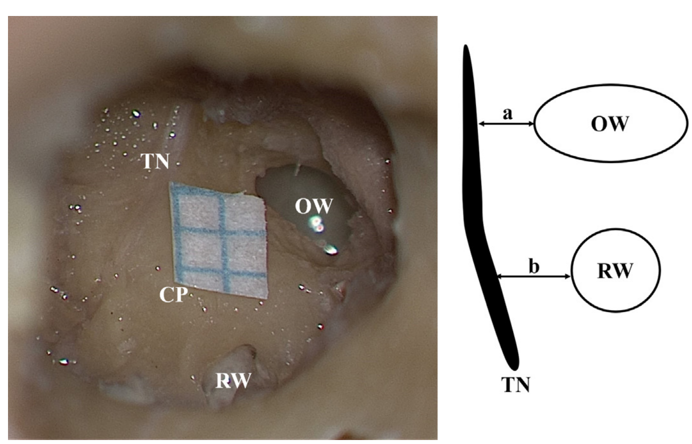


**Figure 1.** The photograph shows the middle ear and parameters. (A) TN-OW distance and (B) TN-RWN distance. CP, cochlear promontory; OW, oval window; RW, round window; TN, tympanic nerve.

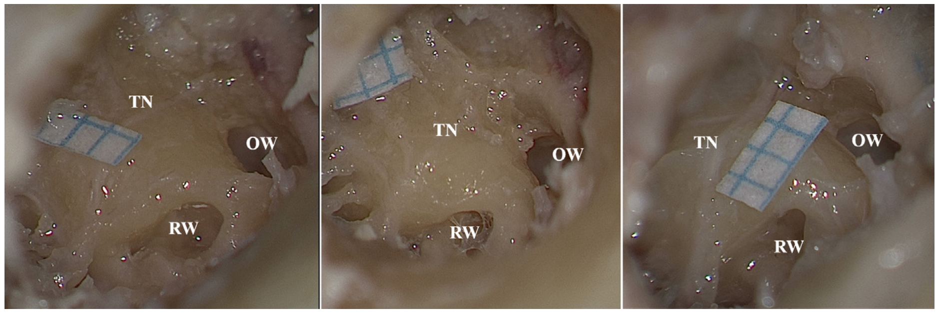


**Figure 2.** The photographs show the different branching patterns of TN. TN, tympanic nerve.

- Bilateral symmetry was not apparent for either measurement. A negligible positive correlation was found between the right and left TN-RWN ($P=.775$, $r=0.104$) and the right and left TN-OW ($P=.878$, $r=0.056$).
- Extreme variations amid cadaveric temporal bones were observed in terms of TN shape and twigs (Figure 2).
- Considering the study of Beger et al.[15] we classified the distance between TN and RWN as 4 types. The distance between 0 and 1 mm was defined as type 1, between 1 and 2 mm as type 2, between 2 and 3 mm as type 3, and between 3 and 4 mm as type 4. Type 1 was observed in 4 ears (20%), type 2 in 9 ears (45%), type 3 in 6 ears (%30), and type 4 in 1 ear (5%) (Figure 3).
- The frequency of TN-RWN distance types on the right sides, from the largest to the smallest, was as follows: the type 2 (4 sides) > type 3 (3 sides) = type 1 (3 sides), whereas on the left sides as follows: type 2 (5 sides) > type 3 (3 sides) > type 1 (1 side) = type 4 (1 side) (Figure 3).
- The frequency of TN-RWN distance types in males, from the largest to the smallest, was as follows: the type 3 (4 sides) > type 2 (3 sides) = type 1 (3 sides), whereas in females as follows: type 2 (6 sides) > type 3 (2 sides) > type 1 (1 side) = type 4 (1 side) (Figure 3).
- The distance between TN and OW was found between 1 and 2 mm in 16 ears (80%) and between 2 and 3 mm in 4 ears (20%).

## DISCUSSION

The anatomy of TN including its location relative to adjacent structures (the facial nerve, cochleariform process, RWN, OW, etc.), twigs, and function attracts otologists' attention for some reason. First, tympanic neurectomy may be preferred by ear surgeons to treat pathological entities such as Frey's syndrome, tinnitus, chronic parotitis, and crocodile tearing.[2,3,5,8,9] Second, involuntary damages may occur during OW- or RWN-related interventions such as cochlear implantation, stapedectomy, or stapedotomy.[16-19] For instance, Anand et al[17] performed laser tympanic neurectomy to stop the pain in 2 patients consulted only with pain 6 months after cochlear implantation. After diverse middle ear interventions, Naraev and Linthicum[18] encountered recurrent otalgia on account of a traumatic neuroma of TN. Some surgeons stated that the nerve stimulation during cochleostomy might result in throat or ear persistent pain.[16,17] In addition, studies in which TN was cut in animal models to examine the effect of TN function on the tympanic cavity demonstrated that middle ear gas exchange was negatively affected by nerve interruption.[6,7] Lastly, TN may be utilized as a landmark for cochleostomy.[13,14] In light of these explanations, we think that a novel algebraic investigation conducted on the distances between TN and RWN or OW may be handy for ear professionals to prevent

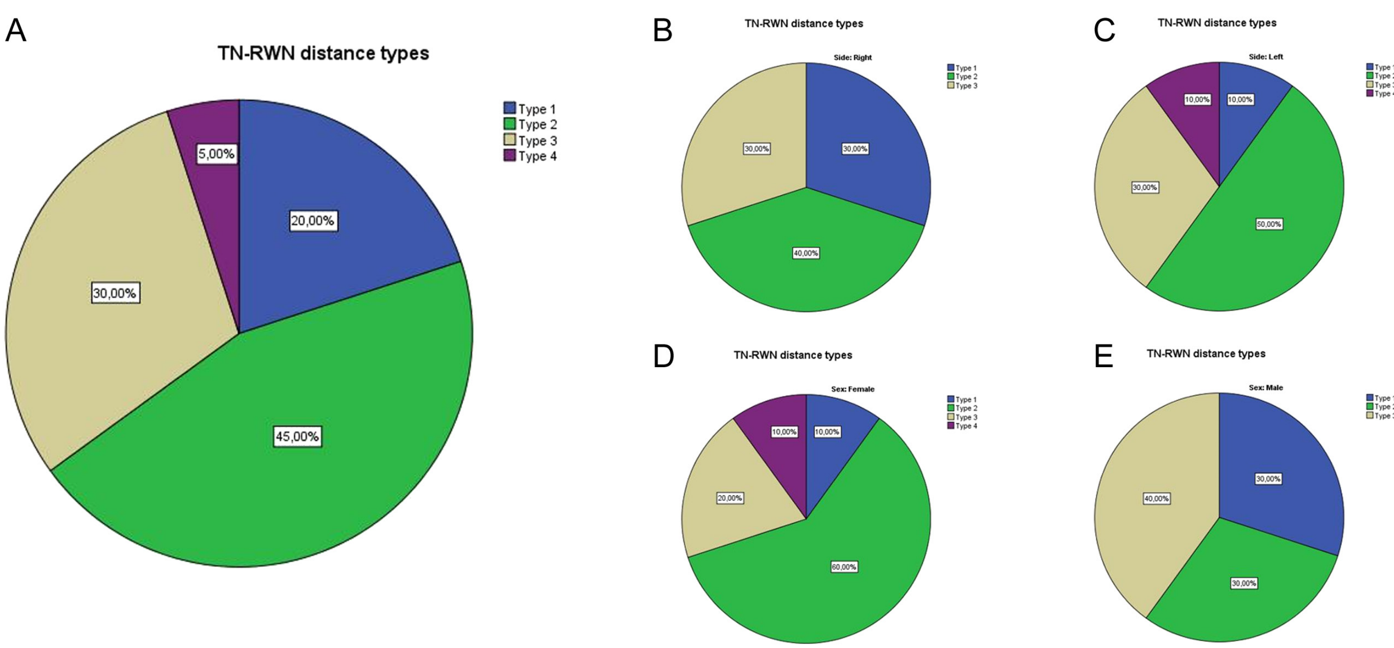


**Figure 3. A-E.** The charts show the distribution percentage of TN-RWN distance types. (A) in all samples, (B) on right sides, (C) on left sides, (D) in females, and (E) in males. RWN, round window niche; TN, tympanic nerve.

involuntary damages during window-related surgeries such as cochlear implantation.

The literature available for TN-RWN distance was limited to 2 works.[14,15] In the study by Todd[14] focused on 82 adult temporal bones, TN-RWN was measured as 2.10 mm (range: 0-3.20 mm). The other measurement was reported in the study by Beger et al[15] (mean: 1.21 ± 0.60 mm, range: 0-2.13 mm) conducted on 30 temporal bones of 15 fetuses between the ages of 19 and 30 weeks of gestation. This data seemed smaller in fetuses compared to adults[14,15]; however, Beger et al[15] suggested that this difference was not due to age but due to the extreme variation of TN. In this scope, we thought that our value (mean: 1.60 ± 0.86 mm, range: 0-3.11 mm) for TN-RWN was compatible with the previous studies.[14,15] The area between TN and RWN is considered to have surgical significance for cochlear implantation.[13,14] In patients whose cochlear basal turn is obliterated by ossification (e.g., post meningitis deafness), TN may be utilized as a reference point for the insertion of electrode array to the cochlea directly.[13] In such cases, cochleostomy carried out anterior to TN or through the nerve may enable bypassing the hook area (initial turn) of the cochlear basal turn, facilitating an electrode array insertion and reducing trauma through direct access.[13] Cochleostomy performed posterior to TN may not result in a cochlear canal and even may lead to a hypotympanic cell.[14] Not only in patients with sclerosed or obliterated basal turn but also in patients whose RWN is not visible owing to the position of the vertical part of the facial canal, TN-RWN distance may serve as a potential clue for successful electrode array placement. For this purpose, Todd[14] reports that if the main trunk of the nerve is not visible, TN location within 3.30 mm of the RWN lip should be kept in mind by otologists. His interval was close to our maximum value for TN-RWN (3.11 mm).

To the best of our knowledge, the distance between TN and RWN was classified with this cadaveric study for the first time in the literature. Tympanic nerve-RWN distance between 0 and 1 mm was defined as type 1 (4 cases, 20%), between 1 and 2 mm as type 2 (9 cases, 45%), between 2 and 3 mm as type 3 (6 cases, 30%), and between 3 and 4 mm as type 4 (1 case, 5%). In the fetal study of Beger et al[15] incidences were given according to distance interval; however, the classification was not performed. According to the present study, their incidences of distance intervals were as follows: type 1, 36.7% (11 ears); type 2, 53.3% (16 ears); and type 3, 10% (3 ears). The extreme variation of TN may trigger the difference between the 2 studies. We think that this standardization has surgical implications. The round window approach is generally preferred by otologists for cochlear implantation; nevertheless, calcification, narrow window, or invisible niche via facial recess may require the use of cochleostomy (a more invasive technique).[20-24] On the market, electrode arrays have apical ends of 0.2-0.6 mm and basal ends of 0.4-1.3 mm.[21,25] Therefore, patients with type 1 (TN-RWN < 1 mm, 20%), in particular, may be at risk for iatrogenic damage of TN during the cochleostomy. In the postoperative period, the injury or stimulation of the nerve may result in recurrent otalgia, throat or ear persistent pain, or change in middle ear pressure. A careful surgical procedure is necessary because injuries may occur in about 20% of the population. In our opinion, tympanic neurectomy may be considered simultaneously with the cochleostomy in patients with type 1, if TN trauma is recognized with a surgical microscope under appropriate magnification.

In the current study, TN was measured as 1.55 ± 0.38 mm (range, 1.04-2.20 mm) away from OW. In the fetal study of Beger et al.[15] TN-OW was found as 1.18 ± 0.54 mm (range, 0-2.67 mm). Their mean value seemed smaller than our value, but we thought that this difference was owing to the over-variation of TN. Moreover, in the study by Beger et al.[15] 0-1 mm for TN-OW was observed in 14 (46.7%) ears, 1-2 mm interval in 14 (46.7%) ears, and 2-3 mm interval in 2 (6.7%) ears. In this study, the distance was between 1 and 2 mm in 16 ears (80%) and between 2 and 3 mm in 4 ears (20%). These 2 works showed that in more than 80% of cases, TN was within an interval of 2 mm. During OW-related surgeries such as vestibular schwannoma via OW, stapes surgery, or trans-oval-window implant,[19,26-28] TN may become damaged. For example, Talas et al[19] reported the expanded transcanal supracochlear approach for the resection of vestibular schwannoma via extended OW. After the approach, they increased OW width from 2.45 ± 0.44 to 5.58 ± 1.09 mm.[19] This enlargement may lead to stimulation or injury of TN.

Our findings have to be thought in light of some limitations that could be addressed in future studies. The main limitation of this work is the failure to evaluate the relationship between TN and OW or RWN in accordance with specific surgical interventions such as the facial recess approach, or the expanded transcanal supracochlear approach; thus, we recommend future studies evaluating the possibility of injury to TN during RWN- or OW-related surgeries. The second limitation is the lack of sample size in the study. In this context, we suggest future works on more cadavers.

## CONCLUSION

As far as we know, TN-RWN was first classified with this study in the literature. Patients with type 1 (TN-RWN < 1 mm) may be at risk for iatrogenic injury of TN during cochleostomy. Otologists should keep in mind that some postoperative complaints (e.g., only pain or recurrent otalgia) after RWN- or OW-related surgeries may be associated with TN injury.

**Ethics Committee Approval:** Ethical committee approval was received from the Clinical Research Committee of Mersin University (09/18/2019-2019/398).

**Informed Consent:** N/A

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – O.B., S.D., Y.V., D.Ü.T.; Design - O.B., O.G., Y.V., D.Ü.T.; Supervision – O.B., Y.V., D.Ü.T.; Resource – O.B., Y.V., D.Ü.T.; Data Collection and/or Processing – O.B., O.G., Y.V., D.Ü.T.; Analysis and/or Interpretation – O.B., O.G., S.D., Y.V., D.Ü.T.; Literature Search – O.B., O.G., S.D., Y.V., D.Ü.T.; Writing Manuscript – O.B., O.G., S.D., Y.V., D.Ü.T.; Critical Review – O.B., Y.V., D.Ü.T.

**Acknowledgments:** The authors would like to thank all the individuals who participated in the study.

**Declaration of Interests:** The authors declare that they do not have any conflict of interest.

**Funding:** The authors declared that this study has received no financial support.

## REFERENCES


1. Standring S, Borley NR, Collins P, Crossman AR, Gatzoulis MA, Healy JC. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. London: Elsevier; 2008.
2. Donaldson I. Surgical anatomy of the tympanic nerve. *J Laryngol Otol*. 1980;94(2):163-168. [CrossRef]
3. Golding-wood PH. Tympanic neurectomy. *J Laryngol Otol*. 1962;76:683-693. [CrossRef]
4. Roberts DS, Yamasaki A, Sedaghat AR, Lee DJ, Reardon E. Tympanic plexus neurectomy for intractable otalgia. *Laryngoscope Investig Otolaryngol*. 2016;1(5):135-139. [CrossRef]
5. Tekdemir I, Aslan A, Tüccar E, Cubuk HE, Elhan A, Deda H. An anatomical study of the tympanic branch of the glossopharyngeal nerve (nerve of Jacobson). *Ann Anat*. 1998;180(4):349-352. [CrossRef]
6. Ceylan A, Göksu N, Kemaloğlu YK, Uğur B, Akyürek N, Bayazit YA. Impact of Jacobson's (tympanic) nerve sectioning on middle ear functions. *Otol Neurotol*. 2007;28(3):341-344. [CrossRef]
7. Eden AR, Laitman JT, Gannon PJ. Mechanisms of middle ear aeration: anatomic and physiologic evidence in primates. *Laryngoscope*. 1990;100(1):67-75. [CrossRef]
8. Porto AF Jr, Whicker J, Proud GO. An anatomic study of the hypotympanic branch of Jacobson's nerve. *Laryngoscope*. 1978;88(1 Pt 1):56-60. [CrossRef]
9. Frenckner P. Observations on anatomy of the tympanic plexus and technique of tympanosympathectomy. *AMA Arch Otolaryngol*. 1951;54(4):347-355. [CrossRef]
10. Aydin K, Maya MM, Lo WW, Brackmann DE, Kesser B. Jacobson's nerve schwannoma presenting as middle ear mass. *AJNR Am J Neuroradiol*. 2000;21(7):1331-1333.
11. Daud AS, Pahor AL. Tympanic neurectomy in the management of parotid sialectasis. *J Laryngol Otol*. 1995;109(12):1155-1158. [CrossRef]
12. Rosen S. The tympanic plexus; an anatomic study. *Arch Otolaryngol (1925)*. 1950;52(1):15-18. [CrossRef]
13. Goravalingappa R. Cochlear implant electrode insertion: Jacobson's nerve, a useful anatomical landmark. *Indian J Otolaryngol Head Neck Surg*. 2002;54(1):70-73. [CrossRef]
14. Todd NW. Jacobson's nerve clues to the round window niche. *Cochlear Implants Int*. 2009;10(2):63-69. [CrossRef]
15. Beger O, Vayisoğlu Y, Güven O, et al. Anatomic features of the fetal round and oval windows, and their relations with the tympanic nerve. *Surg Radiol Anat*. 2021;43(7):1203-1221. [CrossRef]
16. Broomfield S, Mawman D, Woolford TJ, O'driscoll M, Luff D, Ramsden RT. Non-auditory stimulation in adult cochlear implant users. *Cochlear Implants Int*. 2000;1(1):55-66. [CrossRef]
17. Anand V, Devi MK, Kannan T, Chenniappan S. Laser tympanic neurectomy for post-cochlear implant pain: a new technique. *Cochlear Implants Int*. 2016;17(2):105-108. [CrossRef]
18. Naraev BG, Linthicum FH Jr. Traumatic neuroma of the tympanic (Jacobson's) nerve as a possible cause of otalgia. *Otolaryngol Head Neck Surg*. 2008;138(6):735-737. [CrossRef]
19. Talas DÜ, Beger O, Vayisoğlu Y, et al. Cochleo-facial corridor to the vestibule and fundus of the internal auditory canal through oval window: a minimal invasive and cochlea sparing approach. *Eur Arch Otorhinolaryngol*. 2022;279(2):627-637. [CrossRef]
20. Ukkola-Pons E, Ayache D, Pons Y, Ratajczak M, Nioche C, Williams M. Oval window niche height: quantitative evaluation with CT before stapes surgery for otosclerosis. *AJNR Am J Neuroradiol*. 2013;34(5):1082-1085. [CrossRef]
21. Li PM, Wang H, Northrop C, Merchant SN, Nadol JB Jr. Anatomy of the round window and hook region of the cochlea with implications for cochlear implantation and other endocochlear surgical procedures. *Otol Neurotol*. 2007;28(5):641-648. [CrossRef]
22. Roland PS, Wright CG, Isaacson B. Cochlear implant electrode insertion: the round window revisited. *Laryngoscope*. 2007;117(8):1397-1402. [CrossRef]
23. Angeli RD, Lavinsky J, Setogutti ET, Lavinsky L. The crista fenestra and its impact on the surgical approach to the scala tympani during cochlear implantation. *Audiol Neurootol*. 2017;22(1):50-55. [CrossRef]
24. Seliet AM, El Hamshary AS, El Refai AM, Ali AM, Gabal SR. Human round window: morphometry and topographical anatomy and their effect on cochlear implantation. *Benha Med J*. 2018;35(2):246-252. [CrossRef]
25. Mistrík P, Jolly C, Sieber D, Hochmair I. Challenging aspects of contemporary cochlear implant electrode array design. *World J Otorhinolaryngol Head Neck Surg*. 2017;3(4):192-199. [CrossRef]
26. Sircoglou J, Gehrke M, Tardivel M, Siepmann F, Siepmann J, Vincent C. Trans-oval-window implants, a new approach for drug delivery to the inner ear: extended dexamethasone release from silicone-based implants. *Otol Neurotol*. 2015;36(9):1572-1579. [CrossRef]
27. Fernandez IJ, Bonali M, Fermi M, Ghirelli M, Villari D, Presutti L. The role of endoscopic stapes surgery in difficult oval window niche anatomy. *Eur Arch Otorhinolaryngol*. 2019;276(7):1897-1905. [CrossRef]
28. Parra C, Trunet S, Granger B, et al. Imaging criteria to predict surgical difficulties during stapes surgery. *Otol Neurotol*. 2017;38(6):815-821. [CrossRef]