Anatomical Factors Influencing Selective Vestibular Neurectomy: A Comparison of Posterior Fossa Approaches

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Abstract

Objectives To identify measurable anatomical factors that may guide the surgical approach for posterior fossa selective vestibular neurectomy (SVN) and predict identification of the vestibulocochlear cleavage (VCC) plane.

Study Design Dissection of fixed cadaveric heads through retrolabyrinthine and retrosigmoid-internal auditory canal (RSG-IAC) approaches with measurement of landmarks.

Setting: Cadaveric dissection model.

Main Outcome Measures Area of the Trautmann triangle (TT) and the distance from the posterior semicircular canal to the anterior border of the sigmoid along the posterior Donaldson line (pDL). VCC planes from each approach were calculated and compared.

Results Overall mean pDL was 8.53 mm (range: 5–11.5 mm); mean TT area was 124 mm² (range: 95–237 mm²). The VCC was identified in 63% of ears through the retrolabyrinthine (RVN) approach alone, whereas 37% of ears required the RSG-IAC approach. In ears requiring IAC dissection, the VCC was found within 1 to 2 mm distal to the porus. The pDL ($p < 0.05$) and area of TT ($p < 0.05$) were significantly larger in the RVN group compared with the RSG-IAC group.

Conclusion Ears amenable to the RVN approach had a greater pDL and TT area. These anatomical measurements may have a role in surgical planning and the choice of approach for SVN.

Keywords

- ▶ vestibular neurectomy
- ▶ Meniere disease
- ▶ retrolabyrinthine
- ▶ retrosigmoid
- ▶ vertigo

Introduction

Meniere disease is a disorder of homeostasis involving the endolymphatic system of the inner ear. Affected patients experience fluctuating, progressive sensorineural hearing loss, aural fullness, tinnitus, and episodic rotatory vertigo.¹ When conservative medical management fails to control symptoms, patients may be offered surgical alternatives. Some surgical options, including selective vestibular neurec-

tomy (SVN), allow for hearing preservation and may be appropriate for patients with functional hearing.

Vestibular neurectomy was first proposed as a possible treatment option for Meniere disease by Charcot, a contemporary of Prosper Meniere. The first published report of a successful vestibular neurectomy occurred in 1904 by Frazier through a suboccipital approach.² In 1936, Dandy was the first to perform a selective nerve section separating the vestibular and cochlear portions of the eighth nerve in an

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effort to preserve hearing. Since these early forays, the procedure has experienced multiple evolutions.³ In 1961, House developed the middle fossa approach, followed by Silverstein's retrolabyrinthine (RVN), and more recently, the retrosigmoid-internal auditory canal (RSG-IAC) approach. The latter two were described in the 1980s.^{4,5} A recent report describes successful partial neurectomy via a middle fossa approach.⁶ Overall, data suggest that vestibular neurectomy provides long-term improvement or significant reduction in vertigo in 90% of patients.⁷

Each of the approaches just described may be used for SVN. The middle fossa approach offers exposure of the vestibular nerve within the IAC, where both the superior and vestibular nerve are well delineated from the cochlear nerve. However, the procedure requires high technical proficiency, and dural elevation along the middle fossa is often challenging in elderly patients. Because of the facial nerve's location in the superior aspect of the IAC when approached from the middle fossa, the risk of facial nerve paresis/paralysis and deafness may be higher when compared with transmastoid and retrosigmoid approaches.⁸ The transmastoid RVN approach offers the benefit of being a surgical dissection familiar to otologic surgeons, as well as obviating the need for cerebellar retraction. In contrast to the middle fossa approach, the facial nerve is at less risk due to its position in the IAC. The RSG approach provides a view of the VII-VIII complex entering the porus acusticus and may be combined with distal dissection into the IAC if a cleavage plane is not visualized in the cerebellopontine angle (CPA) cistern. Retrosigmoid approaches may require cerebellar retraction and have been associated with chronic headaches.⁹ In each approach, the success of both vertigo control and hearing preservation depends on the ability to confidently identify a cleavage plane between the vestibular and cochlear portions of the nerve.

The vestibulocochlear nerve arises from the lateral portion of the bulbopontine groove and travels through the CPA cistern to penetrate the porus acusticus, traversing the IAC to terminate within the inner ear. In ~ 25% of patients, a cleavage plane is not visualized in the CPA.^{9,10} When gross separation is not apparent, a cleavage plane may be imagined and then created surgically. Not surprisingly, this may lead to damage to auditory fibers with implications for surgical success and hearing preservation.

Limited attention has been paid to predicting the surgical approach that would afford the best visualization of the vestibulocochlear cleavage (VCC) plane. Although a "contracted" mastoid is known to be unfavorable for a RVN approach to SVN, the specific anatomical factors influencing surgical approach are insufficiently described. In this study, we examined the role of temporal bone anatomy in the choice of approach and likelihood of success of SVN. Specifically, we identified measurable anatomical factors in the temporal bone that may guide the surgical approach for SVN and maximize the opportunity to identify the VCC plane. We hypothesized that VCC identification will be more likely to require enhanced exposure via the retrosigmoid approach in specimens with a smaller temporal bone surgical window.

Methods

An RVN and RSG (with or without IAC) approach was performed on 16 ears (8 formalin-fixed whole heads) with the aid of a surgical microscope and an electric drill. All measurements were obtained using a standard micro-caliper. For the RVN approach, a complete mastoidectomy was performed with complete removal of all air cells between the labyrinth and the sigmoid sinus. The sigmoid sinus, semicircular canals, tegmen mastoideum, and jugular bulb were all identified and skeletonized. The dura of the posterior fossa was exposed between the dissection limits.

To assess the impact of mastoid anatomy on identification of the VCC plane, the Trautmann triangle (TT) and Donaldson line were used to estimate the size of the surgical window of exposure through the RVN approach. The area of TT extends from the sinodural angle to the otic capsule (superiorly), the petrous apex to the jugular bulb (anteriorly), and the anterior limit of the sigmoid sinus (posteriorly). The following measurements were used to define TT (►Fig. 1):

1. AT-SA: Distance (in millimeters) from the sinodural angle (SA) to the anterior tegmen mastoideum (AT), a point representing the intersection of the middle fossa dura and a vertical line drawn at 90 degrees tangent to the posterior semicircular canal
2. SA-JB: Distance (in millimeters) from the SA to the summit of the jugular bulb (JB)
3. JB-AT: Distance (in millimeters) from the JB to the previously defined AT point

The area of TT was calculated using Heron's formula:

$$A = \sqrt{s(s - (AT\ SA))(s - (SA\ JB))(s - (JB\ AT))}$$

where

$$s = \frac{(AT\ SA) + (SA\ JB) + (JB\ AT)}{2}$$

Heron's formula was chosen due to the availability of measurement of the sides of TT, as well as its use in other anatomical studies.¹¹

Fig. 1 The Trautmann triangle as measured through the retrolabyrinthine approach. AT-SA, anterior tegmen to sinodural angle; JB-AT, jugular bulb to anterior tegmen; PSCC, posterior semicircular canal; SA-JB, sinodural angle to jugular bulb.

Fig. 2 Posterior Donaldson line (pDL) as measured in the retrolabyrinthine approach. EAC, external auditory canal; FN, facial nerve; LSCC, lateral semicircular canal; PSCC, posterior semicircular canal.

For the Donaldson line, a tangential line was drawn in the plane of the horizontal semicircular canal and carried to the anterior border of the sigmoid sinus. For this study, only the posterior Donaldson line (pDL) was measured. The pDL was defined as the distance between the intersection of the line and the posterior semicircular canal and the anterior border of the sigmoid sinus (►Fig. 2). All of these measurements were recorded prior to incising the dura during the RVN approach.

Once all mastoid measurements were complete, the dura was incised using an H-shaped incision. The cochleovestibular nerve was identified in its course from the brainstem to the porus acusticus, and the presence of a cleavage plane (when visible) was identified using magnification (►Fig. 3).

All sides then underwent a retrosigmoid craniotomy using the already identified and skeletonized sigmoid sinus as an anterior limit. A 2-cm diameter craniotomy was developed, and the dura was incised curvilinearly with an anterior-based flap following complete bone removal. The cerebellum was retracted providing a view of the CPA and an unobstructed view of the cochleovestibular nerve bundle and its entry to the temporal bone. The VII–VIII nerve complex was then examined for the presence of a visible cleavage plane. If identified, the point at which the cleavage plane became visible was measured relative to the porus acusticus (►Fig. 4). When the VCC was not visualized in the CPA, the IAC was skeletonized, and bone was removed using a fine diamond burr until cleavage between the vestibular and cochlear fibers

was apparent. The distance between this separation point and the porus acusticus was then measured (in millimeters).

Specimens were grouped based on whether the VCC plane was identified through the RVN approach or whether RSG-IAC was necessary. The mean pDL and TT for each group was calculated. Differences in mean pDL and mean TT area were compared using hierarchical linear regression analysis, adjusting for correlation between right and left ear specimens taken from the same cadaver (data supporting the applicability of this analysis are found in ►Supplementary Graphs A and B). Statistical analysis was performed using Stata software v.13 (StataCorp, College Station, Texas, United States).

Results

RVN and RSG-IAC approaches were successfully performed on both sides of all eight specimens. In 10 of 16 ears (63%), the VCC plane was identified through a RVN approach. In 6 of these, the VCC was identified as the CN VII–VIII exiting the brainstem. In 4 of the 10 RVN group, the VCC was visualized within the CPA. The mean distance from this cleavage plane to the porus acusticus was 6.25 mm (range: 4–9 mm; ►Table 1).

Using the RSG-IAC approach, a cleavage plane was identified in all specimens. In 6 of 16 ears (37%), a drill-out of the IAC was necessary to identify the cleavage plane (RSG-IAC group). In these six specimens, the VCC was identified 1 to 2 mm distal from the porus acusticus (mean: 1.1 mm). In the overall sample, the mean area of TT was 124 mm² ($n = 16$; range: 95–237 mm²). The mean of the area of TT for the RVN group ($n = 10$; mean: 162 mm²) was statistically significantly larger compared with the RSG-IAC group ($n = 6$; 139 mm²; $p < 0.05$). The cluster-adjusted difference showed a statistically significant larger TT area (+ 55 mm²) favoring the RVN group compared with the RSG-IAC ($p < 0.01$). The pDL mean for all specimens was 8.53 mm (range: 5–11.5 mm) with a cluster-corrected significant difference between the mean pDL for the RVN and RSG-IAC groups (9.3 mm and 7.2 mm, respectively; $p < 0.05$).

Discussion

SVN is an accepted option for the treatment of intractable vertigo in Meniere disease when hearing sparing is indicated

Fig. 3 Retrolabyrinthine approach. (A) Wide view depicting retrolabyrinthine approach following presigmoid craniotomy with retraction of cerebellum and view of cranial nerve VIII in a left ear. (B) Same specimen with increased magnification displaying cleavage plane. Arrow points to vestibular-cochlear cleavage plane.

Fig. 4 Retrosigmoid approach. (A) Right ear depicting retrosigmoid approach with retrosigmoid craniotomy with elevation of dural flap and exposure of underlying cerebellum. (B) Retrosigmoid view in the same specimen following retraction of cerebellum and exposure of cranial nerve VIII. DF, dural flap; SS, sigmoid sinus. Arrow depicts vestibular-cochlear cleavage plane.

and medical management has failed to control vertigo. Successful hearing preservation depends on the ability to confidently identify a cleavage plane between the vestibular and cochlear portions of the nerve. Both middle and posterior fossa approaches to vestibular neurectomy have been shown to be safe and effective.^{6,12,13} Choice of approach has largely been based on the surgeon’s comfort level as well as avoidance of the previously discussed common complications. The present study examined temporal bone morphology in cadaveric specimens to assist with the choice of surgical approach for SVN. To assess mastoid size, two different measurements were used: TT and pDL. These two measurements would directly affect the size of the surgical window of exposure through the RVN approach. In general, our findings suggest that specimens with smaller pDLs and smaller areas of TT were less successful in identifying the VCC through the

RVN approach. In contrast, the RSG or RSG-IAC approach allowed access to the VCC plan in all specimens. Various anatomical landmarks have been used to help identify the cleavage plane between the vestibular and cochlear fibers. The nervus intermedius of the facial nerve often marks the presence of the cleavage plane along the anterior portion of the cochlear vestibular nerve. It carries afferent and parasympathetic fibers and, intraoperatively, can often be recognized by a difference in color compared with the eighth nerve. In addition to the nervus intermedius, an arteriole often courses along the demarcation line between the cochlear and vestibular fibers that are usually grayer compared with the former.¹⁴ The gross separation between the vestibular and cochlear nerves may not occur in the CPA cistern. In our study, 63% of specimens had an identifiable cleavage plane proximal to the

Table 1 Anatomical relationships

Cadaver	Specimen	Side	pDL, mm	AT-SA, mm	SA-JB, mm	JB-AT, mm	Semiperimeter, mm	Area of TT, mm ²	Distance from cleavage plane to porus acusticus, mm	Surgery required for identification
1	1	L	9	10	26	25	30.5	124.3983018	2	RSG-IAC
	2	R	7	9	22	25	28	97.85703858	1	RSG-IAC
2	3	R	11.5	12	26	25	31.5	148.1871705	5	RVN
	4	L	11	10	25	27	31	124.9959999	7	RVN
3	5	R	9	17	30	24	35.5	203.8122604	9	RVN
	6	L	9	20	29	24	36.5	237.6151037	Extended to brainstem	RVN
4	7	L	9	8	24	26	29	95.57719393	Extended to brainstem	RVN
	8	R	9	9	24	25	29	107.7032961	Extended to brainstem	RVN
5	9	L	5	16	26	25	33.5	193.3221082	Extended to brainstem	RVN
	10	R	7	11	21	22	27	113.8419958	1	RSG-IAC
6	11	R	7.5	17	25	29	35.5	211.7148731	1	RSG-IAC
	12	L	8	16	26	17	29.5	131.9978693	1	RSG-IAC
7	13	L	11	12	24	23	29.5	135.8526316	Extended to brainstem	RVN
	14	R	9	13	23	24	30	146.355731	Extended to brainstem	RVN
8	15	L	9.5	19	27	26	36	234.6912866	4	RVN
	16	R	5	17	19	29	32.5	154.2795758	1	RSG-IAC

Abbreviations: AT, anterior tegmen; IAC, internal auditory canal; JB, jugular bulb; L, left; pDL, posterior Donaldson line; R, right; RSG, retrosigmoid; SA, sinodural angle; TT, Trautmann triangle.

porus acusticus. This was comparable with other studies in which most individuals were shown to have a visible cleavage plane.^{15,16} As mentioned earlier, there is still a substantial minority, 37% in our study, in which the VCC was identified only after a drill-out of the IAC was performed.

In general, the retrolabyrinthine approach minimizes some known complications associated with RSG including the need for cerebellar retraction and postoperative headache.^{17,18} However, our data suggest that it is difficult to predict whether the VCC plane will be visible through a RVN approach. In contrast, the RSG approach allowed access to the VCC plane in all ears (whether through the RSG alone or in combination with an IAC drill-out).

Our data support prior assertions that “contracted” mastoids (ie, those with smaller areas of TT and pDL) are unfavorable for identification of the VCC plane through a RVN approach and offer reliable anatomical landmarks to assess temporal bone morphology preoperatively. In our study, ears amenable to the RVN approach had a greater pDL and TT area. Preoperative estimation of mastoid size (using TT or pDL) may have a role in surgical planning so as to maximize success of SVN.

Because of the added morbidity of postoperative headache and cerebellar retraction in patients undergoing the RSG-IAC approach, Silverstein et al proposed a combined retrolabyrinthine-retrosigmoid-IAC approach.¹⁹ In this approach, if a clear VCC plane was not identified via a RVN approach, the authors would proceed with a RSG-IAC approach with the goal of avoiding a RSG-IAC approach when not necessary. This study aims to provide predictive measurements to avoid additional surgery and aid in the selection of surgical approach by using anatomical features preoperatively.

This study is limited by a small sample size of 16 specimens. Additionally, the VCC in a given specimen may vary in degree of delineation, which was not reflected in our data collection. The measurements in this study may also be difficult to correlate with radiologic findings preoperatively. Future studies should focus on refinement, validation, and adaptation of these findings for clinical application during presurgical planning.

Conclusion

SVN is an accepted potentially hearing-sparing treatment for recalcitrant vertigo associated with Meniere disease. Identification of the VCC has an impact on surgical success of hearing preservation and visualization of this plane, although the RVN may be limited by “contracted” mastoid anatomy. In addition to surgeon comfort level and avoidance of complications, this study suggests that specific temporal bone anatomy may also influence the choice of approach for SVN.

Note

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