Three-dimensional Anatomical Analysis of Surgical Landmarks for the Middle Cranial Fossa Approach

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Abstract This study describes the microsurgical anatomy of the middle cranial fossa approach using temporal bone three-dimensional (3D) computed tomography (CT) reconstruction, which should contribute to determining the drilling point for the internal auditory meatus (IAM) when bony landmarks are absent. Thirty temporal bone CT scans were reviewed retrospectively. We measured the shortest and longest distances to IAM from the petrous ridge, and measured the angle between the facial nerve and various labyrinth structures. Three-dimensional reconstructed images were obtained using high-resolution axial temporal bone CT (0.7-mm-thick slices, FOV 90×90 , KVp 120, 305 mA, width 2,800, and level 800). The mean shortest and longest distances to IAM from the petrous ridge were 5.22 and 10.1 mm, respectively. The mean distance to the IAM from the cochlea was 9.91 mm. The mean angle between the IAM and superior semicircular canal was 47.21° , which was more acute than previously reported. The mean angle between the IAM and geniculate ganglion

(GG) and external auditory canal was 113.8° , and the mean distance from the GG to the IAM was 15.44 mm. Understanding the 3D relationships among the microsurgical structures will help to decide the drilling point for the IAM when bony landmarks are absent. A preoperative evaluation might be useful for preserving important neurovascular structures while approaching the middle fossa.

Keywords Temporal bone · Cranial fossa · Middle · Three-dimensional · Landmark · Surgery

Introduction

The middle cranial fossa approach is used in patients that who have good hearing, small (<1.5 cm) intracanalicular tumors, and are younger than 69 years. It is also indicated for tumors extending 1 cm into the cerebellopontine angle that do not contact the brainstem [1]. The greatest advantage of this approach is that it preserves hearing and facial nerve function. It has disadvantages, however, including temporal lobe symptoms and damage to the superficial facial nerve. In old age, the dura is atrophied and vulnerable to damage. During surgery, the surgeon must try to prevent fistula formation involving the membranous labyrinth of the cochlea or vestibular structure, since perilymphatic fistulas of these structure can affect hearing and balance postoperatively.

In 1961, House first suggested a method that involved following the greater superficial petrosal nerve (GSPN) to the facial nerve, reaching the internal auditory meatus (IAM) [2]. Fisch [3] reported that the long axis of IAM can be identified by finding the superior semicircular canal (SSC) and visualizing the IAM as lying at an angle of 60° anteriorly. Garcia-Ibanez and Garcia-Ibanez [4] reported

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that the IAM can be found by bisecting the angle between the GSPN and arcuate eminence. Asem et al. [5] reported the relationships between the facial nerve hiatus and middle cranial fossa neurovascular structures.

Most studies analyzed the distances and angles between the landmarks using cadavers. In addition, three-dimensional (3D) computed tomography (CT) studies uses bony landmarks to study the relationships among the major structures [6]. Here, we generated 3D reconstructed images of the cochlea and vestibule inside the bony labyrinth to show the lymphatic space of the membranous labyrinth. We also describe the distances and angles between the IAM and various labyrinth structures to make it easier and safer to find the IAM.

Materials and Methods

Three-dimensional reconstructed images were obtained using high-resolution axial temporal bone CT with 0.7-mm-thick slices, FOV 90×90 , KVp 120, 305 mA, width 2800, and level 800. Before making measurements, segmentation and surface rendering were performed. Over the surface rendering, the IAM, SSC, cochlea, tympanic segment of the facial nerve, geniculate ganglion (GG), and ossicles were reconstructed (Fig. 1) and the following distances and angles determined:

1. Distance 1: shortest distance to the IAM from the bony surface of the petrous ridge (Fig. 2);
2. Distance 2: longest distance to the IAM from the bony surface of the petrous ridge (Fig. 2);

Fig. 1 Temporal bone three-dimensional reconstructed images using surface rendering of temporal bone computed tomography. The internal auditory meatus (IAM), superior semicircular canal (SSC), cochlea, tympanic segment of the facial nerve, geniculate ganglion, and ossicles were reconstructed. Yellow, internal auditory meatus and facial nerve contour; blue, vestibule and semicircular canals; red, cochlea

Fig. 2 Three-dimensional reconstruction of the temporal bone showing the shortest (*D-1*) and longest (*D-2*) distances from the petrous ridge to the IAM

Fig. 3 Depiction of *D-3* (distance between the IAM and GG) and *D-4* (distance between the cochlea and IAM)

Fig. 4 Depiction of angle A between the SSC and tympanic segment of the facial nerve

3. Distance 3: distance between the IAM and GG (Fig. 3);
4. Distance 4: distance between the cochlea and IAM (Fig. 3);
5. Angle A: the angle between the SSC and tympanic segment of the facial nerve (Fig. 4);
6. Angle B: the angle between the IAM and tympanic segment of the facial nerve (Fig. 5);
7. Angle C: the angle between the IAM and SSC (Fig. 6); and
8. Angle D: the angle between the external ear canal (EAC) and GG and IAM (Fig. 7).

Results

The mean shortest distance from the petrous ridge to the IAM was 5.22 ± 1.03 mm. In 80 % of cases, the distance was between 4 and 6 mm. The minimum distance between the IAM and bony petrous ridge was 2.53 mm. The mean longest distance of the IAM from the petrous ridge was

Fig. 5 Depiction of angle B between the IAM and tympanic segment of the facial nerve

Fig. 6 Depiction of angle C between the IAM and SSC

Fig. 7 Depiction of angle D between the EAC and GG and IAM

10.1 ± 1.30 mm. The longest distance was 11.58 mm. The mean distance between the IAM and GG was 15.44 ± 1.61 mm and that between the IAM and cochlea was 9.91 ± 1.01 mm. Table 1 summarizes the distances between the IAM and the petrous ridge, GG, and cochlea.

Table 2 summarizes the measured angles used to clarify the position of the internal auditory canal (IAC) in relation to other middle fossa landmarks. The mean value of angle A was 105.85° (range 99.27° – 120.04°). In 80 % of the cases, angle A was 100° – 110° . The mean value of angle B was about 60° . Angle C was $47.21^\circ \pm 7.12^\circ$. The mean value of angle D, the angle between the EAC and GG and IAM, was 113.8° .

Discussion

The middle cranial fossa approach is the only method that exposes the entire IAC and labyrinth segment, while preserving hearing. Furthermore, it is used for small tumors within the IAC [7]. The anatomy of the floor of the middle cranial fossa is variable, which causes difficulty in identifying landmarks. The surgeon should have

Table 1 Distances measured from three-dimensional reconstructed images of the temporal bone

	Distance 1	Distance 2	Distance 3	Distance 4
Mean	5.22	10.1	15.44	9.91
Range	2.53–6.76	6.13–11.58	11.99–18.22	7.39–11.59
Standard deviation	1.03	1.30	1.61	1.01

All distances are in millimeters. Distance 1: shortest distance to the IAM from the bony surface of the petrous ridge. Distance 2: longest distance to the IAM from the bony surface of the petrous ridge. Distance 3: distance between the IAM and GG. Distance 4: distance between the cochlea and IAM

Table 2 Angular measurements from three-dimensional reconstructed images of the temporal bone

	Angle A	Angle B	Angle C	Angle D
Mean	105.85	59.57	47.21	113.8
Range	99.27–120.04	42.04–77.28	31.87–59.96	95.52–130.16
Standard deviation	5.84	11.26	7.12	10.25

All angles are in degrees. Angle A between the SSC and tympanic segment of the facial nerve. Angle B between the IAM and tympanic segment of the facial nerve. Angle C between the IAM and SSC. Angle D between the EAC and GG and IAM

knowledge of the 3D anatomy of the temporal bone, and must avoid facial nerve damage and preserve the ampulla of the superior semicircular canal and basal turn of cochlea. In our study, the facial nerve was an average of 5.22 mm from the petrous ridge. The longest distance was 10.1 mm. When drilling at the *internal acoustic* opening of the IAM, one should be cautious until the facial nerve is found. If it is not identified within 10 mm, the surgeon should recheck the surgical landmarks in the operative field. The distance between the cochlea and *internal acoustic* opening of IAM was about 10 mm. Knowledge of this value might help to preserve the cochlea when the drilling is started at the *internal acoustic* opening. One study reported that the distance between the cochlea and IAM ranges from 8.06 to 13.31 mm. Our findings were similar. Given the close proximity of the SSC and basal turn of the cochlea, only approximately 120° of the circumference of the IAC can be removed safely. Fisch [3] reported that the angle between the SSC and IAM was 60°. Another study reported that this angle ranges from 54.96° to 102.97° [8]. However, our findings differed; the angle was 47.21° and ranged from 31.87° to 59.96°. This shows that IAM and SSC forms a more acute angle. Therefore, when drilling the bony roof of the IAC, caution is needed because of the close proximity of the ampulla of the SSC. The angle between the IAC and tympanic segment of the facial nerve was 60°, and we found that this value was constant. Therefore, the angle between the SSC and tympanic segment of the facial nerve is smaller than previously thought. The mean distance between the GG and IAM was 15.44 mm, while the angle between the

EAC and GG and IAM was 113.8°. Although the range of single measurements is wide, it will be useful for locating the *internal acoustic* opening of the IAM.

Conclusion

The temporal bone is a critical structure in the human body. As we see from our findings, meticulous dissection is mandatory during surgery. Compared with the translabyrinthine approach, the middle fossa approach to a vestibular schwannoma can preserve the hearing. However, this approach might be difficult due to a lack of bony landmarks. Therefore, the surgeon should use preoperative 3D CT to determine the distances and angles between the critical structures for safe surgery.

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