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ORIGINAL ARTICLE

The Variation of Temporal Bone Neurovascular Structures in Otologic-Neurotologic Surgeries: A Cadaver Dissection Study

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OBJECTIVE: This study aims to evaluate the variations of important structures by objective means for a safe otologic-neurotologic surgery.

MATERIAL AND METHODS: Twelve temporal bones of six cadavers were dissected under surgical microscope with micro drill using jugular foramen approach. The distance between the second genu of facial nerve to the joint point of the chorda tympani (A); the distance between the nearest points of the sigmoid sinus and the facial nerve (B); the distance between the dome of the jugular bulb and the superior part of the round window niche (C) were measured.

RESULTS: The mean and the standard deviation of the measured distances of A for right and left temporal bones were 10.75 ± 2.17 mm (min = 9.30 max = 13.70) and 10.88 ± 3.04 mm (min = 7.80 max = 14.60), respectively. The mean values of B for right and left temporal bones were 5.71 ± 2.08 mm (min = 3.20 max = 7.65) and 6.03 ± 1.74 mm (min = 4.00 max = 8.20), respectively. Right and left mean values and standard deviations for C were found as 6.67 ± 2.85 mm (min = 3.40 max = 11.40) and 8.10 ± 2.17 mm (min = 4.80 max = 11.90), respectively. Significant statistical correlation was found between right and left values regarding both A and B.

CONCLUSION: The joint point of chorda tympani to the facial nerve and the nearest distance between the facial nerve and the sigmoid sinus may be useful to make a prediction of the other side of the temporal bone. The variation among the values of each parameter consisting of the minimum and the maximum measurements might be considered as a useful tool for choosing the best surgical approach for lesions of the temporal bone, jugular foramen and the posterior fossa. The surgeon may recognize serious limitations for a specific approach and may choose another access with the diagnosis of anatomic variations, such as anteriorly located sigmoid sinus and high jugular bulb, by preoperative radiological evaluation.

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The temporal bone, with its constituents and neighbor structures, carries a substantial role not just for primary otologic surgeries, but also for neurotologic, neurosurgical and skull base approaches. It may be the only surgical field for some otologic surgeries or may be a route for advanced approaches regarding deeper structures.

Its anatomical complexity with highly vulnerable and important structures in and around is another point of consideration.

The hesitation of dissecting sufficient bone for the management of temporal bone lesions, the limitation of choosing the appropriate approach, the difficulty in the preoperative differential diagnosis and unacceptably high morbidity/mortality may all be attributable to the above mentioned factors.

The success of a particular surgery may be increased by thorough theoretical and practical education. Additionally, some surgical modalities may need multidisciplinary approach. In both conditions, besides other important structures, the facial nerve and the sigmoid sinus play a central role and the relationship between them is of substantial concern [1-3].

The facial recess, formed by the chorda tympani, the mastoid portion of the facial nerve and fossa incudis, is an important access for various surgical purposes including removal of limited disease from the middle ear [4] and cochlear implantation [5]. The variation of the point of junction of the chorda tympani to the facial nerve with respect to the stylomastoid foramen or the second genu of the facial nerve is a known entity. This variation is reported by various studies [6,7]. On the other hand, the extremes of this variation may be really challenging even for the experienced surgeons leading to doubt if involuntary trauma had been already performed or not. The very limited posterior tympanotomi area due to the position of the chorda tympani may prevent comfortable access to the middle ear leading to some surgical difficulties.

Another important factor during the dissection of the temporal bone is the distance between the sigmoid sinus and the mastoid portion of the facial nerve. Extremely anterior location of the sinus may interfere with deeper dissection of the retrofacial region [8]. This difficulty may be of utmost importance when dealing with the dominant or the only flowing sinus. In these circumstances, the complete removal of the overlying bone and retracting the sinus for long periods of time may cause inadvertant and irreversible trauma leading to cerebral hemorrhage, infarctions and dural arterio-venous malformations [9,10].

High jugular bulb is another point of concern both for neurotologic and neurosurgical approaches. It may even play a substantial role in choosing the most appropriate approach for cerebello-pontine angle lesions [11]. One should also be greatly cautious when dealing with the petrosectomy procedures with high jugular bulb cases.

In this study, we aimed to evaluate some parameters among the temporal bone structures with minimum and maximum values which might influence performing neurotologic-otologic surgical approaches by probable variations through easy or difficult accessibility.

MATERIALS AND METHOD

Twelve temporal bones of six male, adult cadavers were dissected with jugular foramen approach [12] with a surgical drill. For this approach, a curved incision from the postauricular region to the upper neck is performed. After elevating the flap, mastoidectomy is performed. The antrum is widely exposed. Sigmoid sinus is skeletonized and the mastoid tip is opened and removed. The fallopian canal is identified and skeletonized. Hypotympanic bone anterior to the facial nerve is removed to expose the dome and the anterior face of the jugular bulb. The bone medial to the facial nerve is removed to interconnect the anterior and posterior exposures of the jugular bulb. The facial nerve is prepared as fallopian bridge technique. The measurements are performed step by step according to the above mentioned surgical approach and explained

below. Except the initial skin incision and the very beginning of the mastoidectomy procedure, the dissection is carried out with operating microscope (Zeiss Opmi 99, Germany). The microscope is also used during measurements for precision. After careful dissection of bone to localize the chorda tympani and the facial nerve in its bony canal with diamond burrs, the measurement of the distance between the second genu of the facial nerve and the joint point of chorda tympani was measured for each temporal bone. Although this is not necessary for live surgeries, the joint point of the chorda tympani and the second genu of the facial nerve are very well shown in our cadaver dissections for exact measurement (A) (Fig. 1).

Then, the bone covering the sigmoid sinus is drilled until it is left as an eggshell from the sinodural angle to the jugular foramen. The nearest distance between the sigmoid sinus and the mastoid portion of the facial nerve was identified and measurement was performed between the two structures at the narrowest point (B) (Fig 2).

After careful localization of the highest point of the jugular bulb (dome of the jugular bulb) with deeper dissection, the external auditory canal wall is drilled away and the chorda tympani is cut. The bone is continued to be dissected from the medial aspect of the mastoid portion of the facial nerve leaving no bone between the round window niche and the jugular bulb. Third measurement was performed between the highest point of the jugular bulb and the most superior point of the round window niche (C) (Fig. 3).

The measurements (A, B, and C) are performed with the electronic compass if it easily fits between the measured points. Otherwise, a straight cable wire, under the surgical microscope, is placed between the points and the lenght of the wire is measured with the same electronic compass.

To evaluate the relationship among the parameters, nonparametric 'Spearman's Rank Correlation Coefficient Test' was used with a statistical significance level of $p \leq 0.05$. To evaluate the left and right measurements, nonparametric Wilcoxon Sign Rank Test was used.

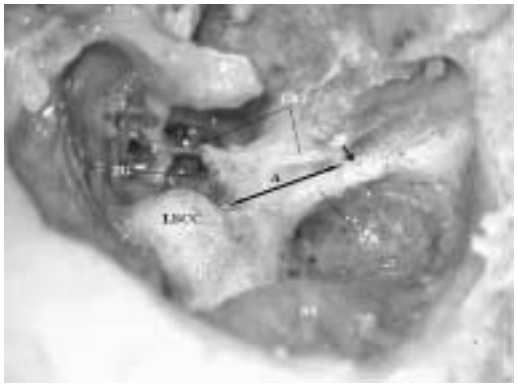

Figure-1: Cadaver dissection view of the distance between the second genu of the facial nerve and the joint point of chorda tympani and the facial nerve.
FN: facial nerve; ChT: chorda tympani; JP: joint point of chorda tympani and facial nerve; 2G: second genu of the facial nerve; LSCC: lateral semicircular canal; A: measured distance between the second genu and the joint point of chorda tympani and the facial nerve.

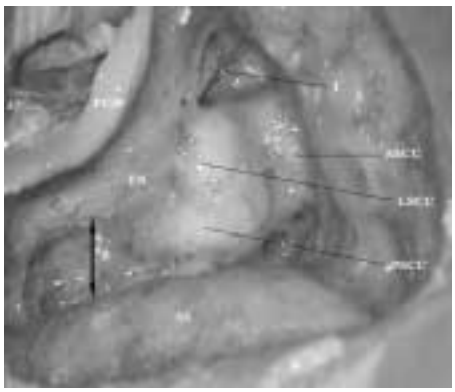

Figure-2: Cadaver dissection view that shows the nearest distance between the sigmoid sinus and the facial nerve.
PCW: posterior canal wall; I: incus; SSCC: superior semicircular canal; LSCC: lateral semicircular canal;
PSCC: posterior semicircular canal; SS: sigmoid sinus; FN: facial nerve; B: the distance between the nearest points of the facial nerve and the sigmoid sinus.

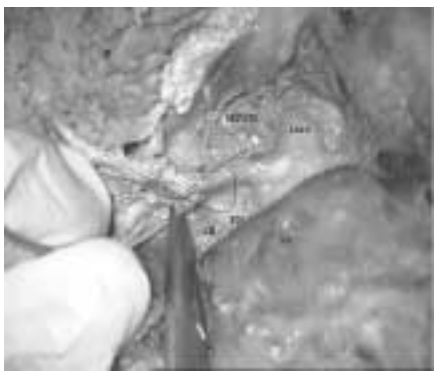

Figure-3: The cadaver dissection view that shows the distance between the jugular bulb and the superior part of the round window niche.
SRWN: superior part of the round window niche; LSCC: lateral semicircular canal; FN: facial nerve; JB: jugular bulb; P: parotid gland; C: the measured distance between the jugular bulb and the superior part of the round window niche (red wire).

RESULTS

Minimum, maximum, median, mean and standard deviation values of A, B and C are given in Table 1.

A positive correlation was found regarding the left and right sides for the mean values of the distances measured between the second genu of the facial nerve and the joint point of the chorda tympani nerves (left A to right A) (r = 0.986, p = 0.001). Similar high, positive correlation between left and right measured values are found regarding the distance between the nearest points of the sigmoid sinus and the mastoid portion of the facial nerve (left B to right B) (r= 0.943, p = 0.005).

There was no significant correlation between the right and left sides regarding the nearest distance between the jugular bulb and the superior part of the round window niche (r = 0.257 p = 0.623).

Negative correlation was found between the measured values regarding the distance between the second genu of the facial nerve and point of joint of the chorda tympani to the distance between the round window niche and the jugular bulb on the right side (right A to right C) (r = - 0.870, p = 0.024). A similar correlation was not found between left A and left C values (r = 0.257, p = 0.623). Negative correlation was found between left A and right C (r = -0.829 p= 0.042).

There was no significant correlation between the other parameters.

The left and right measured values did not show statistical significant difference for A, B, and C parameters (p = 0.67, p = 0.25, p = 0.35, respectively).

DISCUSSION

The bony architecture itself and the neurovascular structures in and around it make the temporal bone a difficult region to perform surgery. The localization of these important structures, such as the facial nerve and the sigmoid sinus in this bony framework might be challenging for the inexperienced surgeon. This difficulty may partly be overcome by preoperative radiological evaluation. However, careful dissection in light of various landmarks is still a major tool for successful surgery. Therefore, the landmarks of the temporal bone with their relation among each other should be very well known.

The position of the sigmoid sinus and the high jugular bulb have been reported to be important factors for performing posterior fossa approaches, such as retrosigmoid and translabyrinthine procedures [8]. Fisch even claimed that the translabyrinthine approach may be severely limited by the high jugular bulb, even affecting the selection of the surgical approach [11]. High jugular bulb is not only an entity limiting the surgical field or causing the dissection more difficult, but the correct differential diagnosis of herniating jugular bulb from the dehiscent bone to the

Table -1: Descriptive statistics of data .

		n	Min (mm)	Max (mm)	Median (mm)	Mean (mm)	SD (mm)
The distance from the second genu of the facial nerve to the joint point of the chorda tympani	R	6	9.30	13.70	9.41	10.75	2.17
	L	6	7.80	14.60	10.70	10.88	3.04
The nearest distance between the facial nerve and sigmoid sinus	R	6	3.20	7.65	6.12	5.71	2.08
	L	6	4.00	8.20	5.50	6.03	1.74
The distance between the jugular bulb and the niche of the round window	R	6	3.40	11.40	5.68	6.67	2.85
	L	6	4.80	11.90	7.35	8.10	2.71

R: right, L: left, SD: standard deviation, Min: minimum, Max: maximum, n: number of cadavers.

hypotympanum may be challenging with aberrant internal carotid artery or a glomus tympanicum tumor by otoscopic examination behind the tympanic membrane [13].

The facial nerve, traversing the temporal bone, is another important structure and landmark to be known and preserved. In fact, some surgical procedures greatly depend on the area, known as the facial recess, formed by the facial nerve, its branch chorda tympani and the fossa incudis [4,5].

According to the great importance and the effect on the surgical procedures of the temporal bone and related neurotologic and neurosurgical operations, continuous effort has been devoted to the investigation of the facial nerve and the sigmoid - jugular complex.

The facial nerve and the chorda tympani should be localized for the facial recess procedures including the cochlear implantation and limited middle ear pathologies [4,5]. Chorda tympani is a branch of the facial nerve and its joint is reported to be variable. Nager gathered and summarized variations of chorda tympani including bifurcations and the variable joint points to the facial nerve. Its origin from the facial nerve was reported to be from 1 mm distal to 11 mm proximal to the stylomastoid foramen. Even, a joint point at the cochleariform process in the tympanic segment had been reported [7]. The emergence point at the stylomastoid foramen even with an incidence of 25% was reported by another study [6].

In the present study, the second genu of the facial nerve, instead of the stylomastoid foramen, is chosen as the reference point to evaluate the variability of the chorda tympani to emphasize particularly on the facial recess area. Therefore, this measurement may be thought as a more direct means of evaluation for facial recess dimensions for surgeries including cochlear implantation and limited middle ear pathologies through posterior tympanotomi. In our cadaver dissections, the minimum and the maximum distances between the emergence point of the chorda tympani to the second genu of the facial nerve were found as 9.30 -13.70 mm (mean 10.75 mm) on the right and 7.80 - 14.60 mm (mean 10.88 mm) on the left sides. Significant statistical difference was not found between the left and right values ($p>0.05$) We found statistically significant positive correlation between left and right temporal bones regarding the above mentioned measurements. This data might be of substantial importance in predicting the opposite side, if surgery had already been performed in the other side of the temporal bone. This fact also points out the importance of writing the surgical notes thoroughly.

The distance between the chorda tympani joint to the second genu of the facial nerve have a statistically negative correlation compared to the distance found between the jugular bulb and the superior part of the round window niche on the right side ($r = -0.870$, $p = 0.024$). Sirikci et al, hypotesized that the shape and the distance of a temporal bone structure to the sigmoid sinus might be important factors to evaluate the temporal bone development [2]. As a related structure to the sigmoid sinus, higher position of the jugular bulb in temporal bones with the chorda tympani-facial nerve joint nearer to the stylomastoid foramen might have a developmental relation to each other. A similar relation was not found between the distance of facial nerve genu -chorda tympani joint when compared to the height of the jugular bulb on the left measurements. Jugular bulb was reported to be 5-15 mm above the point of termination of the sigmoid sinus (higher on the right side compared to the left) having a close relationship even to the internal auditory canal [14]. Right dominance of the sigmoid sinus might be the point of interest for this side to side variability. This phenomenon needs greater number of dissection and further investigation to be cleared out if it is really genetically or developmentally related or just coincidental.

Another factor still investigation goes on, is the relationhip of sigmoid sinus to facial nerve.

Boemo et al. studied the distances between the sigmoid sinus and the mastoid portion of the facial

nerve at three different levels. They found the mean distances between the sinus and the initial mastoid portion, the sinodural angle and the initial mastoid portion, and the sinus and the stylomastoid foramen 5.65 mm (typical deviation 2.08 mm), 20.15 mm (typical deviation 4.24 mm) and 6.30 mm (typical deviation 2.27 mm), respectively. They found a proportional relationship in the measured mean distances between the sigmoid sinus and the mastoid portion of the facial nerve in the different levels of these structures all through their courses. They reported this finding as a useful tool to make a projection for another level when performing surgery at another point of these structures [1].

Abreu and coworkers also used the distance between the facial nerve and the sigmoid sinus as an important measurement for further contribution to the surgical anatomy to the sinus tympani approaches. Their measurement point seems at the level of the second genu and reported as between 5.7 -17.8 mm with a mean of 12.05 mm for feasible and 7.5 mm for nonfeasible cases, respectively ($p \leq 0.004$) [3].

Our mean values that reflect the nearest point between the facial nerve and the sigmoid sinus are in accordance with the related literature and further emphasize on the narrowest region of the aforementioned structures. The present study also revealed similarity for the measured values between the left and right sides ($p>0.05$) and a statistically significant positive correlation ($r = 0.943$, $p = 0.005$). This may also mean that surgically dissected temporal bone of a case may be predictive for the other side, if any surgical approach is necessary in the future.

Although not found statistically significant, the mean distance from the jugular bulb to the round window niche was greater on the left (8.10 mm.) compared to the right side (6.67 mm.) meaning that the jugular bulb is higher on the right side. It is also known that the sigmoid sinus is dominant on the right side [15 -19]. Higher jugular bulb on the right may be attributed to the right dominance.

CONCLUSION

The temporal bone is known as one of the most difficult anatomic regions to be fully, or at least sufficiently, learnt. Preoperative radiological evaluation including computerized tomography and magnetic resonance imaging will contribute to surgical success and may play substantial role in the prevention of neurovascular injuries leading to functional loss by recognition of the variations. Besides thorough theoretical education, surgical practice on cadaver is to be strongly suggested before live surgery. It is of utmost importance to to take into consideration the anatomic variability and morphometric relationship among the neural and vascular structures within and around the temporal bone for choosing the best approach to easily reach to the lesion.

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