Safer Ear Surgery: Anatomical Study of Landmarks of the Tympanomastoid Segment of the Facial Nerve

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Abstract

Objectives: To study the variations of the tympanomastoid segment of the facial nerve in relation to fixed known anatomical landmarks in cadaveric temporal bone dissection to provide a more detailed description of the anatomy of the nerve.

Materials and Methods: We studied 35 adult temporal bones by dissecting them at Temporal bone lab in Ain Shams University Specialized Hospital. We studied the variations in the course of the facial nerve by exposing the nerve completely throughout its course in the middle ear. The distance between geniculate ganglion and the cochleariform process, and the distance between the facial nerve and cochleariform process were measured. Furthermore, the length of the tympanic part of the facial nerve and the distance between the second genu angle and the oval window niche were measured. The angulations of the second genu, measured using a simple protractor, were correlated with previous anatomical landmarks. The relation between the vertical mastoid segment exit to the digastric ridge was recorded.

Results: The present study observed that the tympanic segment of the facial nerve extending from the geniculate ganglion to the horizontal semicircular canal lies above the cochleariform process, with a constant distance = 1 mm in all the dissected temporal bones, while the distance of the geniculate ganglion (antero-superior) to cochleariform process was variable and ranged from 2-4 mm (mean=2.86 mm ± 1.5mm). When we measured the length of the tympanic part of the facial nerve, we found that the mean length of it equals 12.50±1.04 mm. As regards the second genu angle (SGA), it was obtuse in 28 bones (80%). On the other hand, it was a right angle in 5 bones (15%), and was acute in two bones only (5%). Expectedly, there was a wide range of variations in the measurement of the SGA with an overall mean = 116.97° (±18.07). We found that the distance between the SGA of the facial nerve and the oval window niche = 3.314 mm when the SGA = 116.97°. We were able to find a linear relation between the three variables. The more the tympanic part of the facial nerve is shorter, the more obtuse the angle is and the more the nerve comes closer to the oval window. On the other hand, the more the tympanic part of the facial nerve is longer, the more acute the angle is and the more the nerve is farther separated from the oval window. Completing the exploration of the facial nerve down to the digastric ridge, we found an angulation in the vertical part of the nerve in three specimens (12%), and we propose to name it "a third genu". Furthermore, the exit of the facial nerve varied in relation to the digastic ridge; it was medial in 51 %, or at the same level in 40%, but surprisingly it was lateral to it in 9%.

Conclusion: Our results open a new way of thinking in the anatomical variations of the course of the facial nerve. Preoperative analysis of the specific facial nerve measurements reported in the present work provide a growing evidence to help to anticipate the position of the facial nerve accurately in relation to fixed anatomical landmarks in the mastoid, thus minimizing iatrogenic facial nerve injury in various ear operations.

Key Words: Anatomy – Facial nerve – Course – Second genu angle – Tympanic segment.

Introduction

A NUMBER of different approaches can be used to expose the facial nerve. The route adopted will depend on the pathology and the portion of the nerve that requires exposure [1]. Otologists having inadequate familiarity with facial nerve usually have a tendency to do incomplete surgery in various, yet serious, ear diseases like chronic suppurative otitis media [2]. Iatrogenic facial paralysis is known to be a feared complication of ear surgery, and its incidence is reported as 0.6-3.6% in all otologic surgical procedures, and increases to 4-10% in revision surgery [3].

Facial nerve is known to have considerable anatomical variations in the temporal bone [2], to the extent that a safe surgeon should use as many of the available anatomical landmarks as feasible to perform safe facial nerve surgery [1]. Therefore, the present study was conducted to explore the variations of the tympanomastoid segment of the facial nerve in relation to fixed known anatomical landmarks in cadaveric temporal bone dissection.
Materials and Methods

35 human temporal bones (18 right and 17 left) were obtained and dissected with standard otologic instruments under magnification using Karl Kaps (Germany) microscope at temporal bone lab in Ain Shams University Specialized Hospital from March 2008 to March 2009.

In all specimens, the facial nerve was completely exposed all through its route in the middle ear. In each exposed nerve, exploring the region of the cochleariform process, geniculate ganglion, first genu and second genu, as well as the vertical segment down to the digastric ridge was carefully carried out. The distance between geniculate ganglion and the cochleariform process, and the distance between the facial nerve and cochleariform process were measured.

Furthermore, the length of the tympanic part of the facial nerve and the distance between the second genu angle and the oval window niche were measured. The angulations of the second genu, measured using a simple protractor, were correlated with previous anatomical landmarks. The relation between the vertical mastoid segment exit to the digastric ridge was recorded.

The specimens were photographed and a red thread was glued to the facial nerve for photo clarification purposes.

Results

The present study observed that the tympanic segment of the facial nerve extending from the geniculate ganglion to the horizontal semicircular canal lies above the cochleariform process, with a constant distance = 1mm in all the dissected temporal bones, while the distance of the geniculate ganglion antero-superior to cochleariform process was variable and ranged from 2-4 mm (mean = 2.86mm ± 1.5mm) (Fig. 1).

When we measured the length of the tympanic part of the facial nerve, we found that the mean length of it equals 12.50±1.04mm. As regards the second genu angle (SGA), it was obtuse in 28 bones (80%) (Fig. 2). On the other hand, it was a right angle in 5 bones (15%) (Fig. 3), and was acute in two bones only (5%) (Fig. 4). Expectedly, there was a wide range of variations in the measurement of the SGA with an overall mean = 116.97° (±18.07).

The distance from the oval window niche to the second genu of the facial nerve was measured in all the specimens, and was found to be variable ranging between 2mm and 4.1mm, with a mean = 3.314mm ± 0.435mm.

The present work observed a fixed relation between the length of the tympanic part of the facial nerve, the SGA and the distance between the SGA and the oval window niche. We found that the distance between the SGA of the facial nerve and the oval window niche = 3.314mm when the SGA = 116.97°. We were able to find a linear relation between the three variables. The more the tympanic part of the facial nerve is shorter, the more obtuse the angle is and the more the nerve comes closer to the oval window. On the other hand, the more the tympanic part of the facial nerve is longer, the more acute the angle is and the more the nerve is farther separated from the oval window.

Completing the exploration of the facial nerve down to the digastric ridge, we found an angulation in the vertical part of the nerve in three specimens (12%), and we propose to name it "a third genu" (Fig. 5). Furthermore, the exit of the facial nerve varied in relation to the digastric ridge; it was medial in 51% (Fig. 6), or at the same level in 40% (Fig. 7), but surprisingly it was lateral to it in 9% (Fig. 8).
Fig. (3): Lateral view of the left temporal bone showing right angled second genu angle.

Fig. (4): Lateral view of the left temporal bone showing acute second genu angle.

Fig. (5): Lateral view of the left temporal bone showing the third genu angle.

Fig. (6): Poster-anterior view of the left temporal bone showing the facial nerve exit medial to the digastric ridge.

Fig. (7): Poster-anterior view of the left temporal bone showing the facial nerve exit at the same level of the digastric ridge.

Fig. (8): Poster-anterior view of the left temporal bone showing the facial nerve exit lateral to the digastric ridge.
Discussion

Facial nerve paralysis is the most common major complication associated with otologic surgery. Although facial nerve injury is at times unavoidable because of the extent of disease, most cases of postoperative facial paralysis occur as a result of unrecognized facial nerve trauma at the hands of an unskilled otologic surgeon [3]. Unfortunately, minor variations and major anomalies often occur in the course of the facial nerve, predisposing the nerve to inadvertent surgical injury [4]. Moreover, normal surgical landmarks are often distorted in the diseased mastoid, and hence positive identification of vital structures is mandatory to perform a successful procedure. It is critical to identify the facial nerve throughout its course in the mastoid [3], and the surgeon should use as many of the available anatomical landmarks as feasible to perform safe facial nerve surgery [1]. The fixed anatomical landmarks of middle ear are the frame of reference of facial nerve, in which horizontal semicircular canal is the most invariable; and the safety of surgery will be improved by the reference of the facial nerve [8].

The facial nerve has been found to pass behind the cochleariform process and the tensor tympani, and it has been recently concluded that the cochleariform process is a useful landmark to locate the facial nerve [6]. In accordance with the aforementioned research, the present work found that there was a constant distance = 1mm in all temporal bones examined, while the distance of the geniculate ganglion anterior and superior to cochleariform process was variable and ranged from 2-4mm (mean = 2.86mm ± 2.1mm). Therefore, it is recommended that surgeons can depend on cochleariform process as a fixed landmark for the facial nerve but not for the geniculate ganglion.

While the current study clarified that the mean length of the tympanic part of the facial nerve = 12.47±0.435 mm, Patel and Tanna reported that the tympanic segment ranged from 8-11 mm in length [6]. That variation in length can be attributed to racial differences.

The facial nerve then lies above and posterior to the oval window, where the facial nerve makes a second turn marking the second genu. The most important landmarks for identifying the facial nerve in the mastoid are the horizontal semicircular canal, the fossa incudis, and the digastric ridge. The second genu of the facial nerve runs inferolateral to the lateral semicircular canal. This is a relatively constant relationship [6]. The results of the present work showed that the mean of the measurement of SGA = 116.97° (± 18.07). Similar [2] and nearly identical [7] results were also reported, showing a wide range of variations as well. Furthermore, the present study measured the distance of the SGA from the oval window niche and correlated it to the SGA measurement. We concluded that the distance of the second genu angle of the facial nerve from the oval window niche = 3.314mm when the angle equals 116.97° and every increase or decrease in the angle associated with a change of the distance. These results can be explained by the variations in the length of the tympanic part of the facial nerve (12.50 ± 1.04mm) reported in the present work. In that respect, the shorter the tympanic segment is, the more obtuse the angle and hence the more it becomes near to the oval window niche. On the other hand, the longer the tympanic segment is, the more the angle is acute and hence the more it becomes separated from the oval window niche. Accordingly, it is expected to see overhanging of the facial nerve over the foot plate of stapes and hence it becomes more liable to injury during stapedectomy (in subjects with extreme obtuse angles). In addition, it is expected to encounter an injury of second genu during mastoidectomy (in cases with acute second genu angles) since it bulges towards the antral floor.

Two-dimensional (2D) cross-sectional CT slice images are inadequate for otolaryngologists to completely understand 3D structure characteristics. 3D reconstruction of the temporal bone from CT images could provide a more accurate anatomical location of deep lesions, which could be used in surgery design [8]. This technology has been called a "non-injury spatial anatomy" [9]. The SGA was measured by 3D reconstruction of CT images of temporal bones of 34 healthy adults and was reported to be equal to 114.15° (± 8.51°) [7]. We assumed that by measuring the second genu angle in actual patients by using 3-D reconstruction of the CT images of temporal bones we can conclude the distance of the SGA of the facial nerve from the oval window niche accurately. This is of particular importance in stapedectomy as it will help in the preoperative assessment of the distance of the facial nerve from oval window niche accurately. Moreover, the position of the SGA in the mastoid can be preoperatively anticipated to avoid its injury during mastoidectomy or when performing posterior tympanotomy during cochlear implant surgery.

Up to our knowledge, the present study described for the first time a new variation of the facial nerve which we called "a third genu". It is observed in the vertical part of facial nerve in three
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specimens. It has a very important clinical impact as it makes the nerve liable to injury during mastoidectomy.

The digastric ridge points to the lateral and inferior aspects of the vertical course of the facial nerve in the temporal bone. In poorly pneumatized temporal bones, the digastric ridge may be difficult to identify [6]. The current study also recorded the relationship of facial nerve exit at the stylomastoid foramen with the anterior part of the digastic ridge (as an anatomical landmark). 51% of cases were medial to digastic ridge, whereas 40% were at same level of digastic ridge and 9% were lateral to it. It is therefore obvious that otolaryngologists cannot depend on digastrics ridge as a fixed landmark for facial nerve exploration. It is also recommended to do facial nerve exploration in a descending, and not ascending, direction since the upper landmark (related to the lateral semicircular canal) in the floor of antrum is rather fixed, but the lower landmark (in relation to the digastic ridge) is rather not.

Based upon the results of our cadaveric study as well as previous radiological studies [7-9], we can conclude that there are a lot of variations in the course of the facial nerve and its measurements. Accordingly, no clinical value can be gained knowing the mean measurement of the SGA or other facial nerve measurements. The actual value can only come from understanding and analyzing the measurements and their effects on relations of the facial nerve to the nearby important structures.

Conclusion:

Our results open a new way of thinking in the anatomical variations of the course of the facial nerve. Preoperative analysis of the specific facial nerve measurements reported in the present work provide a growing evidence to help to anticipate the position of the facial nerve accurately in relation to fixed anatomical landmarks in the mastoid, thus minimizing iatrogenic facial nerve injury in various ear operations.

References