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ORIGINAL PAPER

Intratemporal course of the facial nerve: morphological, topographic and morphometric features

NICOLETA MĂRU[1)], A. C. CHEIŢĂ[2)], CARMEN AURELIA MOGOANTĂ[3)], B. PREJOIANU[4)]

[1)]Department of Anatomy, Faculty of Dental Medicine
[2)]PhD candidate, ENT specialist
"Carol Davila" University of Medicine and Pharmacy, Bucharest
[3)]ENT resident,
Emergency County Hospital, Craiova
University of Medicine and Pharmacy of Craiova
[4)]Tehno Electro Medical Company, Bucharest

Abstract

The purpose of this study is to present some morphological and morphometric aspects of the facial nerve and especially of the tympanic and mastoid segments of this nerve. The authors follow up a mesoscopic study concerning the tract (length, angulation, width) of these segments and the anatomic relations with the important structures of the middle ear. At the same time, some anatomical variations which involve the canal of the facial nerve (dehiscences, tract deviation or other anatomical deviations) are presented. To evaluate the risk of the facial nerve injury during operations for chronic otitis media with or without cholesteatoma, stapedectomy in otosclerosis, exploratory tympanotomy, tympanoplasty, canaloplasty, osteomas surgery or other otologic surgery that involve facial nerve area. The intricate course of the facial nerve through the temporal bone is of vital concern to all otologic surgeons, since it often traverses the surgical field. Therefore, authors will review the course of the facial canal through the petrosal portion of the temporal bone from the internal auditory meatus to the stylomastoid foramen, paying particular attention to its relations to adjacent structures.

Keywords: intratemporal part, facial nerve.

Introduction

The facial nerve is the nerve of the second branchial arch. It serves several functions – motor and sensory. It supplies the striated musculature of the face, neck, and stapedius muscle of the middle ear, parasympathetic fibres to the lacrimal, submandibular and sublingual glands, seromucinous glands of the nasal cavity and it conveys taste sensations from the anterior two-thirds of the tongue, the palate and the tonsillar fossae. It also has a small cutaneous sensory component. Its intrapetrous part has three main branches: the greater superficial petrosal nerve, the nerve to the stapedius and the chorda tympani [1].

Intrapetrous course of the facial nerve has two portions: (a) in the internal auditory canal and (b) in the facial canal or Fallopean aqueduct [2].

The internal auditory segment is 7 to 8 mm in length [3]. The first part of the facial canal – the labyrinthine segment of the nerve (3–5 mm) is the narrowest part of the facial canal and extends from the internal auditory canal to the geniculate ganglion [4]. When the nerve reaches a point just lateral and superior to the cochlea, it angles sharply forward, nearly at right angles to the long axis of the petrous temporal, to reach the geniculate ganglion. At this level, the direction of the nerve reverses itself, executing a hairpin bend so that it runs posteriorly. This is the 'first turn' of the facial nerve. The greater superficial petrosal nerve arises from the geniculate ganglion. The second part or the tympanic segment (10–12 mm) extends from the geniculate ganglion to the second turn of the facial nerve. It passes posteriorly and laterally along the medial wall of the tympanic cavity, perpendicular to the long axis of the petrous bone. Here it lies above the oval window and below the bulge of the lateral semicircular canal. The third part or the mastoid segment (13–15 mm) extends from the second genu to the stylomastoid foramen. Here the nerve assumes a vertical position, dropping downward in the posterior wall of the tympanic cavity and the anterior wall of the mastoid to exit at the base of the skull the stylomastoid foramen. The nerve to stapedius muscle is a small twig given off from the facial nerve as it descends in the posterior wall of the tympanic cavity behind the pyramidal eminence. The chorda tympani originates about 5 mm above the stylomastoid foramen. The nerve travels between the stapes and lateral semicircular canal, then into the mastoid cavity. It exits the mastoid cavity via the stylomastoid foramen and enters the parotid gland [3].

Material and Methods

Thirty-five temporal bones harvested from cadavers or human dried skulls were dissected under the microscope and others were sectioned in different planes, with an electric saw and diamond disc. Then the temporal bones were analyzed on a stereomicroscope type Olympus SZ60 and photographed with a Camedia C7070 digital camera. The samples were illuminated with reflected and, in some cases, transmitted LED light. For macro pictures obtained using the macro function of the digital camera, halogen light illumination has been used. The images were filtered and corrected with the image analysis software DP-Soft. Measurements on X- and Y-axis (horizontal plane) were performed using a caliber and the software measuring features. The vertical movement of the microscope body was measured using a Mitutoyo dial micrometric indicator.

In order to discover the bony dehiscenses and other anatomic variations of the tympanic segment of the facial nerve, the temporal bones were examined through the small anterior dissection approach to allow a good microscopic or rigid endoscopic view to the posterior and medial wall of the tympanic cavity (FlexiScope 180X–CC Schoolly + rigid endoscopes 4 mm, 2.7 mm; 0^0, 30^0). After the facial canal had been identified, its morphological features and the morphological features of the neighbouring structures were evaluated. Significant findings were photographed.

Results

As it leaves the internal auditory canal, the first part of the facial canal – the labyrinthine segment crosses the temporal bone in an anterior direction and almost perpendicular to the long axis of the temporal bone to reach the geniculate fossa. In our study, its length varied from 3.14 to 5.27 mm. This segment describes a curve with internal concavity. This first segment of the facial canal includes in this curvature the top of the first cochlear turn. The geniculate fossa contains the geniculate ganglion, where the greater superficial petrosal nerve leaves it in an antero-internal direction. (Figure 1, a and b). The angle between the labyrinthine segment and the greater superficial petrosal nerve was usually of 142^0 (Figure 1b). Superior wall of the labyrinthine segment we found in many specimens very thin.

The facial canal then makes a turn and continues posteriorly with the tympanic segment. The angle between the first and the second segment of the facial nerve varied from 48 to 86^0. The length of the tympanic segment (Figure 2a) varied between 9.15 and 12.03 mm (main average 10.25±0.75 mm). The width of the tympanic segment varied between 1.16 and 1.58 mm (Figures 1b and 2b). The nerve passes behind the cochleariform process and the tensor tympani (Figures 1, 3a, and 3b). The distance between the cochleariform process and the tympanic segment of the facial nerve varied between 0.36 and 1.98 mm (Figures 1b and 2a). The cochleariform process is an useful landmark for finding the facial nerve. The bony wall can be very thin or dehiscent in this area, and the middle ear mucosa may lay in direct contact with the facial nerve sheath.The foregoing end of the tympanic segment of the facial nerve was slightly medial and over the cochleariform process in 60% of the cases while in 40% of the cases it was even adjacent to it. The tympanic segment was oblique posterior descending in 80% of the cases, and in 20% of the cases it presented a horizontal tract from the geniculate ganglion of the second genu; the angle between this segment and the lateral semicircular canal varied between 5^0 and 37^0 (Figure 2c).

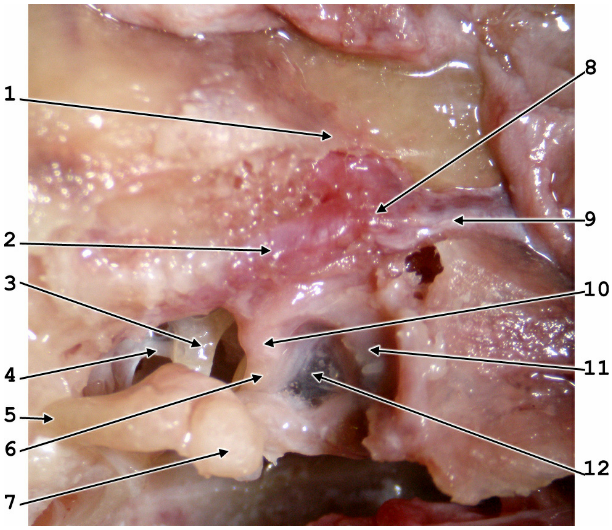


Figure 1a – ***Superior approach dissection of the right temporal bone; highlighting of the intra-petrosal facial nerve. 1. The thin ceiling of the labyrinthine portion of the facial nerve; 2. Dissection of the tympanic portion of the facial nerve (the external wall of the canal was thin); 3. Stapes; 4. Tendon of stapedius muscle; 5. Incus – short process; 6. Tensor tympani tendon; 7. Malleus head; 8. Geniculate ganglion; 9. Greater superficial petrosal nerve; 10. Cochleariform process; 11. Insertion ring of the fold of the tensor tympani muscle; 12. Tensor tympani muscle.***

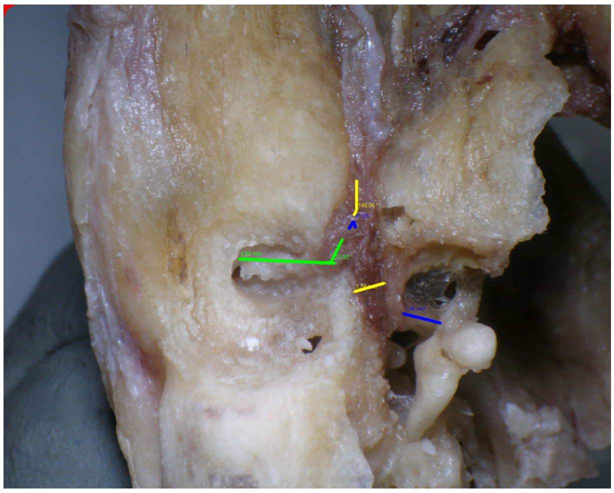


Figure 1b – ***Superior approach dissection of the right temporal bone; highlighting of the intra-petrosal facial nerve. The length of the labyrinthine segment is 4.93 mm; the width of the tympanic segment is 1.58 mm; upon entering the facial canal, there is an immediate angulation forward, 123^0; the angle between the labyrinthine segment and the tympanic one at the level of the geniculate ganglion is 48^0, with the greater superficial petrosal nerve is of 150^0.***

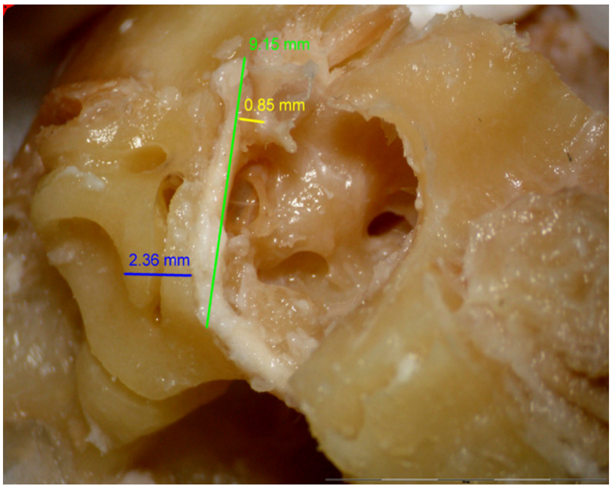


Figure 2a – ***Superior approach dissection of the temporal bone; the length of the tympanic segment of the facial nerve is 9.15 mm; the distance up to the cochleariform process is 0.85 mm; the width of the lateral semicircular canal: 2.36 mm.***

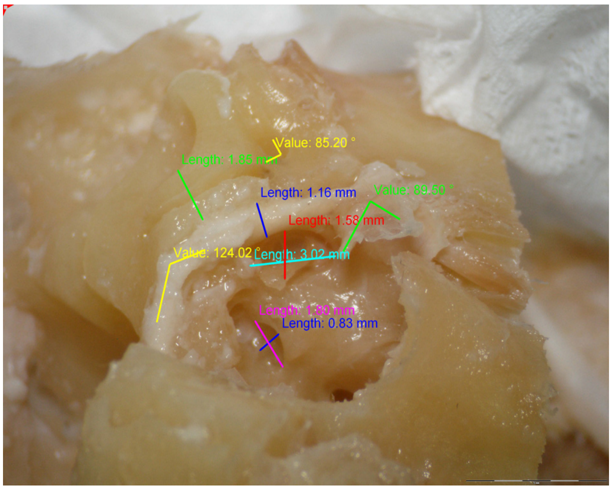


Figure 2b – ***Superior approach dissection of the right temporal bone; the angle between the tympanic segment and the mastoid segment of the facial nerve: 124^{0}; the width of the tympanic segment: 1.16 mm.***

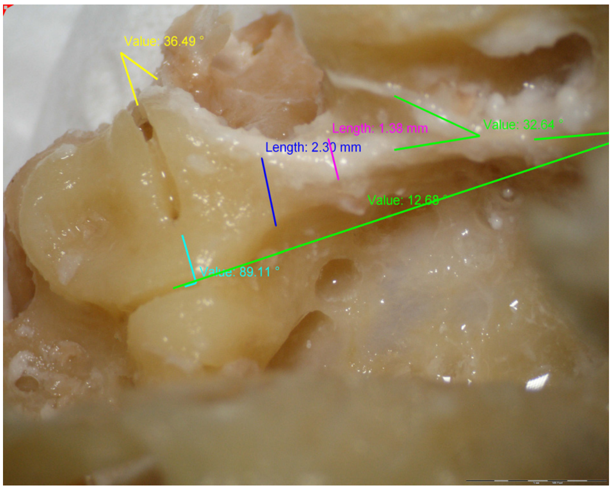


Figure 2c – ***Superior approach dissection of the right temporal bone; the angle between the tympanic segment and the axis of the lateral semicircular canal: 12.7^{0}; the angle between the mastoid segment and the chorda tympani: 32.64^{0}; the angle between the axes LSC and SSC: 90^{0}.***

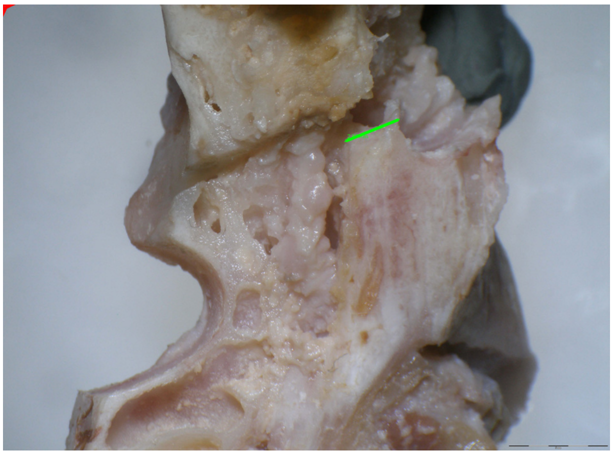


Figure 3a – ***Coronal section at the level of the right annulus tympanicus, the facial nerve is taken out of the facial canal: the distance between the facial nerve canal and the annulus tympanicus is 2.87 mm at eight o'clock position.***

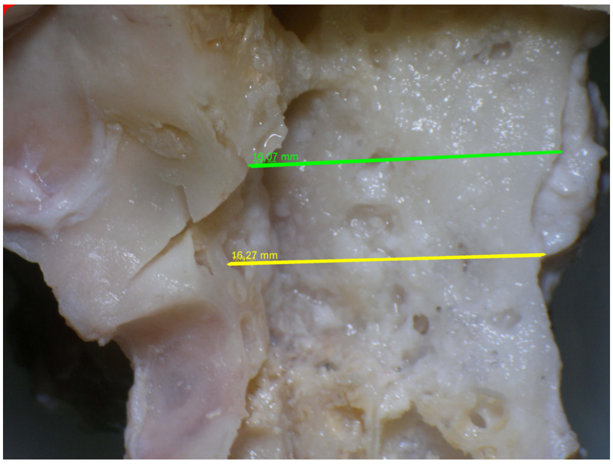


Figure 3b – ***Longitudinal section parallel with the lateral wall of the external auditory canal: the distance between the tympanic segment of the facial nerve and the mastoid surface: 16.27 mm.***

The distance between the ampular end of the lateral semicircular canal and the genu was of 2±0.5 mm. In the middle part of the tympanic segment, the facial nerve was situated over the oval window and the stapes. The mean distance between the facial nerve and the oval window at the level of its posterior edge was of 3±1.15 mm (limits between 2 and 4.5 mm). The posterior-inferior part of the tympanic segment was observed in the vicinity of the pyramidal eminence in all the cases and then it changed the direction through its second genu, becoming vertical.

In two cases, we have founded a tympanic segment which covered more than a half of the oval window (Figure 4a).

In two cases, a prominent and intact facial canal traversed the sinus tympani or made its external wall (Figure 4b).

The second genu marks the beginning of the mastoid segment. The angulation at the level of the second genu was of 92–125^{0} (Figure 2b). The second genu is lateral and posterior to the pyramidal process. The nerve continues vertically down the anterior wall of the mastoid process to the stylomastoid foramen. The mastoid segment was the longest part of the intratemporal course of the facial nerve, its length varied from 11.23 to 15.07 mm (main average 13.78±1.12 mm). The third segment of the facial nerve emerges from the middle ear between the posterior wall of the external auditory canal and the horizontal semicircular canal.

Minimum distance from annulus tympanicus to facial nerve we have founded at nine o'clock position and it was 0.85 mm. Both towards 12 o'clock and towards six o'clock the distance grows (Figure 3a). The distance between the mastoid segment and the sigmoid sinus was of 4 mm average (Figure 4c), and compared to the mastoid surface it was of 16.22±1.34 mm (Figure 3b).

The two branches that exit from the mastoid segment of the facial nerve are (1) the nerve to the stapedius muscle, (2) the chorda tympani nerve. In one case we have founded two separated origins of the stapedius nerve(Figure 5, a–d).

The chorda then runs laterally in the middle ear, between the incus and the handle of the malleus. The angle between the chorda tympani nerve at its emerging and the mastoid segment of the facial varied between 26–35^{0} (Figure 2c). In all specimens the chorda tympani nerve began its tract in an ascendant way at an average distance of 7.2±2 mm from the stylomastoid foramen. In two specimens (5.7%), the chorda was found to have an origin outside the stylomastoid foramen.

The width of the three segments of the facial nerve varied between 0.82 and 1.64 mm, where the labyrinthine segment was the thinnest.

The rate of facial canal dehiscence was 17.1% (six of 35 cases), and the tympanic segment was the most commonly found region at 83.33% (five of six cases). Of the five cases with tympanic segment dehiscence, in four cases involved the lateral aspect of the facial canal in the oval window area (Figure 6). There was one case of facial canal dehiscence in the mastoid segment. We have not founded any dehiscence at the geniculate ganglion. A facial canal dehiscence with protrusion of the facial nerve was more common than a dehiscence without protrusion, 4, respectively 2. Their greatest diameter ranged from 0.4 to 2.8 mm.

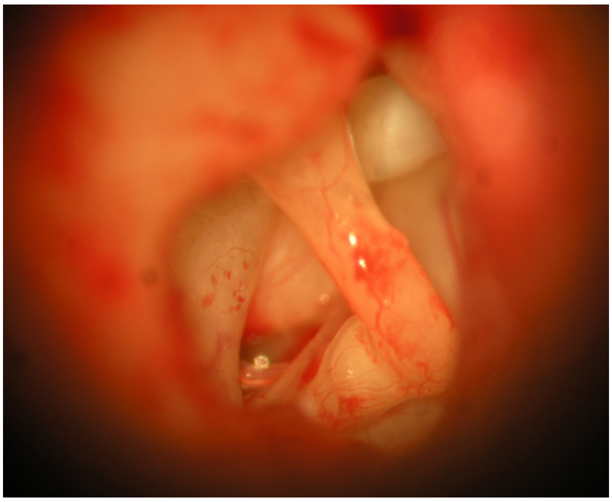


Figure 4a – ***Intraoperative image: aberrant course of the facial nerve: the tympanic segment covers more than a half of the oval fossa and makes practicing a stapedotomy difficult.***

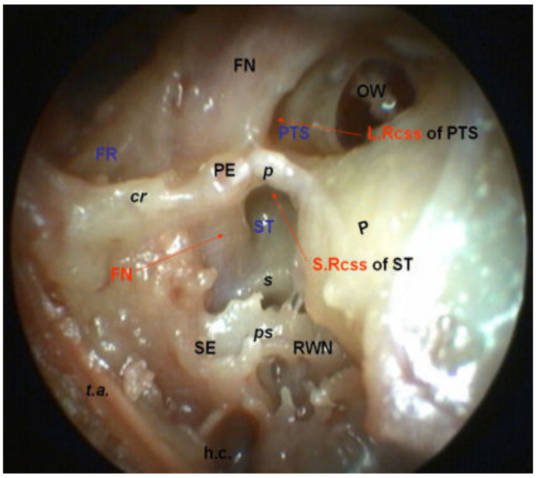


Figure 4b – ***Endoscopic view of the right retrotympanum. Photograph showing a large sinus tympani which in its lateral half is traversed by an intact and prominent facial canal; FN – facial nerve, L.Rcss – lateral recess, PTS – posterior tympanic sinus, S.Rcss – superior recess, ST – sinus tympani, FR – facial recess, P – promontory, PE – pyramidal eminence, SE – styloid eminence, OW – oval window, RWN – round window niche, p – ponticulus, s – subiculum, ps – pseudosubiculum, cr – chordal ridge, t.a – tympanic annulus, hc – a large hipotympanic cell.***

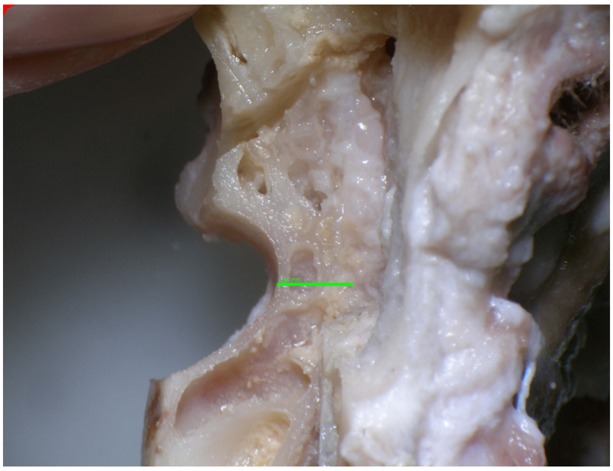
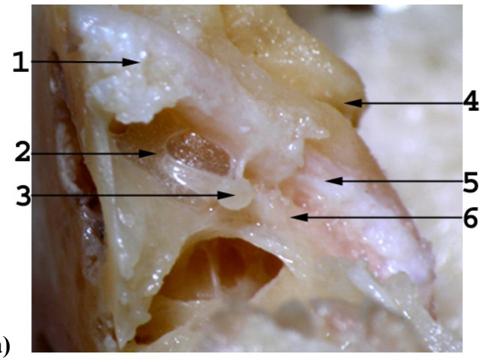


Figure 4c – ***Section that shows the distance between the sigmoid sinus and the mastoid segment of the facial nerve: 3.80 mm.***



(a)

Figure 5 – ***(a) Dissection at the level of the facial canal and of the stapes muscle, left ear. 1. Tympanic segment; 2. Stapes (subsequently oval window); 3. Stapes head; 4. Lateral semicircular canal; 5. Second turn of the facial nerve; 6. Stapedius muscle and the homonymous canal.***

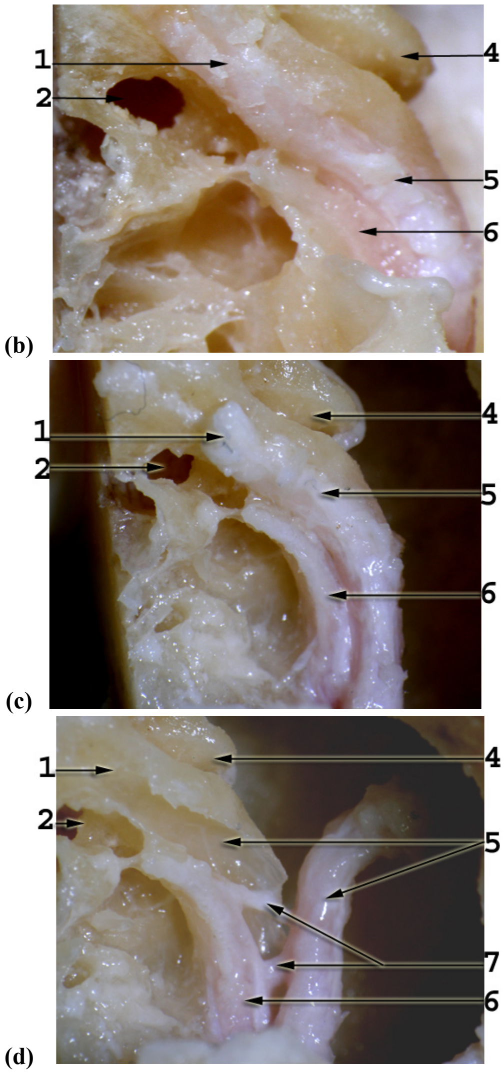


Figure 5 – ***(b–d) Series of dissections at the level of the facial canal and of the stapes muscle, left ear. 1. Tympanic segment; 2. Stapes (subsequently oval window); 3. Stapes head; 4. Lateral semicircular canal; 5. Second turn of the facial nerve; 6. Stapedius muscle and the homonymous canal; 7. Nerve of the stapedius muscle (double).***

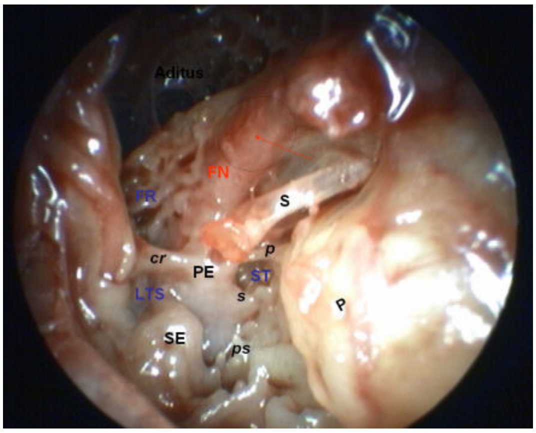


Figure 6 – ***Endoscopic view of the right retrotympanum. Photograph showing a facial nerve canal dehiscent above oval fossa; FN – facial nerve, LTS – lateral tympanic sinus, ST – sinus tympani, PE – pyramidal eminence, SE – styloid eminence, p – ponticulus, s – subiculum, ps – pseudosubiculum, cr – chordal ridge, S – stapes.***

Discussion

Knowledge of the surgical anatomy of the facial canal is essential in middle ear surgery. In many common otologic approaches, surgeons incur a high risk of iatrogenic injuring the facial nerve. As noted by Wiet RJ [5], operative facial paralysis is the second most common reason for malpractice in ear surgery today in many common otologic approaches such as complete, radical and modified radical mastoidectomy, tympanoplasty, canaloplasty, hipotympanotomy and removal exostoses and osteomas. The facial canal, as it traverses the temporal bone, may display bony dehiscenses, variations, and anomalies of its natural course. Each of these features may have clinical and surgical significance. The variations of the facial canal may involve the length and direction of each segment, the angular relation between the tympanic and the mastoid segment, and the downward course of the mastoid segment.

The length of the labyrinthine segment of the facial canal, founded by Arndt HJ [6] and Proctor B [4] was between 2.5 and 6 mm, respectively 3 and 5 mm, appropriate with our data, 3.14 and 5.27 mm. As noted Proctor B [4], the labyrinthine segment extends from fundus of the internal acoustic meatus to the geniculate ganglion across the axis of the petrous pyramid. Out of all specimens, we did not find any important anatomic variation in the course of the first segment of facial nerve. The angle between the first and the second segment of the facial nerve noted by Massa N and Westerberg BD [7], varied from 40 to 80^0 and in our study, 48 to 86^0. The tympanic segment passes behind the cochleariform process and the tensor tympani. The cochleariform process is an useful landmark for finding the facial nerve. The anterior end of the tympanic segment of the facial nerve was easily medial and over the cochleariform process in 60% of the cases while in 40% of the cases it was adjacent to it.

Agirdir BV *et al.* [8] reported that the shortest distance measured between the annulus tympanicus to facial nerve was 0.83 mm at nine o'clock position. Our findings agree with this and in our study was 0.85 mm.

Nager GT and Proctor B [9] described that chorda tympani having extratemporal origin with an incidence of only 2%. Low WK [10] noted an incidence of extratemporal origin more than 50% on Chinese specimens. Our findings was appropriate of Nager GT and Proctor B, 5.7%. Chorda tympani with intratemporal origin have been found in the present study to arise at mean of 7.2 mm (range 0.2 to 9.7 mm) proximal the stylomastoid foramen. This distance from stylomastoid foramen was similar with corresponding mean distance of 5.0 mm (range 1.0 to 11.0 mm) and 4.8 mm (range 0 to 10.0 mm) found by Nager GT and Proctor B, and Muren C *et al.* [11] respectively. We agree with Wetmore SJ that the chorda tympani can be used as a landmark to identify the facial nerve in the mastoid by tracing it inferiorly to its origin [12].

Baxter A [13] reported that in 535 temporal bones 55% of the facial nerves were dehiscent. Ninety-one percent were located in the tympanic segment and 9% in the mastoid segment. Among the cases of dehiscence in the tympanic segment, 83% were located adjacent to the oval window involving the lateral, inferior and medial portions of the canal with the nerve protruding from its canal in 26%. Their greatest diameter ranged from 0.5 to 3.1 mm, comparable with our findings (0.4 to 2.8 mm). Baxter's findings are very similar to those of Dietzel K [14], who had examined 211 temporal bones and found an incidence of 57%, identical predilective sites, and comparable dimensions. The incidence of facial canal dehiscence in our results we found it below 17.1%, much smaller than Baxter A and Dietzel K, but bigger than the one found by Kim CW *et al.* [15] (8.6%), Li D and Cao Y [16] (11.4%), and Bayazit YA *et al.* [17], (8.9%). In 1465 stapes operations, Li D and Cao Y [15] reported that there is a 29% possibility the controlateral facial canal also has a dehiscence.

We have not found any article in the literature which reports the presence of two separate origins of the nerve for the muscle of the stapes, as we found in one specimen. We consider this an important anatomical variant in the stapes surgery.

Abdel Baki F *et al.* [18] reported that sinus tympani is in the most cases bounded laterally by a constant edge of bone, anterior to the facial nerve. Our study revealed that in two cases, a proeminent and intact facial canal traversed sinus tympani or made its lateral wall. This anatomical variant suggests us the great attention that is due to the cholesteatomas with location at the level of this recess because sometimes the facial canal can be even dehiscent in this area.

Watching the tract of the segments of the intratemporal facial nerve, we noticed that in two cases the tympanic segment was covering half of the oval window, being very prominent in the tympanic cavity. A similar intraoperatory image is in Figure 4a, when the stapedotomy orifice could not be accomplished for the otosclerosis at the right ear because of the prominence of the facial nerve covering more than a half of the stapes platinum.

Conclusions

Especially, the tympanic and mastoid segment of facial nerve are subjected to variations and anomalies.

The tympanomastoid segment of facial nerve has variations in length and in its relations with various middle ear structures.

The facial canal, as it traverses the temporal bone, may display bony dehiscenses, variations, and anomalies of its naturale course. Each of these features may have clinical and surgical significance.

The knowledge of the tract and the anomalies of the intra-petrosal portion of the facial nerve can be best known through dissections on as many temporal bones as possible. Although the approximately normal course of the facial nerve is known, each temporal bone can bring surprises about it and make the otosurgeon face a less frequent or even unseen anomaly, and the operative result is a disaster.

The best surgical landmarks to locate the canal of the facial nerve were the cochleariform process, the oval window, the lateral semicircular canal, the pyramidal eminence, the annulus tympanicus, the chorda tympani, the stylomastoid foramen.

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Corresponding author

Nicoleta Măru, Senior Lecturer, MD, PhD, Department of Anatomy, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, 19 Plevnei Avenue, 010221 Bucharest, Romania; Phone +40744–506 467, e-mail: nicoletamaru@yahoo.com

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