SECTIONAL ANATOMY OF AUDITORY TUBE

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List of abbreviations
TVPM - tensor veli palati muscle
LVPM - levator veli palati muscle

ABSTRACT

Background and purpose: The auditory tube connects the tympanic cavity with nasopharynx. Due to its structure and position it is difficult to demonstrate the auditory tube in its whole length, and to study its topography on anatomical specimens. The purpose of our study was to present sectional anatomy of auditory tube in order to facilitate understanding of its structure and topography.
Materials and Methods: We utilised serial sections of cadaveric head in four planes: transverse, oblique, frontal and sagittal.
Results: The osseous part of the auditory tube was demonstrated on transverse sections, and most of the cartilaginous part on oblique sections of head and neck. The tensor veli palati muscle was found to consist of bilaminar muscle sheet: the outer part originating from the scull base and the inner part originating from lateral cartilaginous lamina and membranous part of the tube. Topographic relations seen on four section planes were described in detail.
Conclusion: The structure, course and topography of auditory tube are well demonstrated on sectional images. Detailed knowledge of sectional anatomy of the auditory tube is important for interpretation of corresponding computerised tomographic and magnetic resonance images, and in understanding the disorders and diseases affecting middle ear and mastoid.

INTRODUCTION

The auditory tube is about 36-mm long canal that connects the tympanic cavity and the nasopharynx. It allows the passage of air between these spaces to equalize the air pressure on both aspects of the tympanic membrane. The tympanic orifice is 2-2.5 cm higher than the pharyngeal orifice and the tube thus runs downward, medially and anteriorly. The posterolateral part or tympanic part has a bony wall and is referred to as the osseous part, while the anteromedial two parts have the cartilaginous and connective tissue wall and are referred to as cartilaginous part (1).
The auditory tube is situated partly inside the temporal bone and partly below the scull base. It is surrounded by muscles originating from the scull base and vessels and nerves transversing the scull base. Neither its structure nor topography is easy to imagine. New imaging techniques, computerised tomography and magnetic resonance in particular, have opened new visions of morphology in two-dimensions, also of the auditory tube and its surroundings (2, 3, 4), and increased the importance of sectional anatomy of this area. To our knowledge no reports on macroscopic sectional anatomy of auditory tube and its topography on cadaveric material in four different planes are available.
The purpose of our study was to demonstrate the structure and topographic relations of the auditory tube on transverse, oblique, frontal and sagittal sections of head with the aim to facilitate understanding of the composition and structure interrelationships of this complex area.

MATERIALS AND METHODS

Four formalin-fixed cadavers, three females and one male, aged from 75 to 85 years, were utilized for serial sections of head in four planes: transverse, oblique, frontal and sagittal. The inclination of the oblique section was about 35 degrees with respect to the hard palate. Before sectioning the tissue was deep frozen at -25 ^{o}C. Consecutive sections were obtained at approximately 6-mm intervals with minimal saw path loss. Those including the auditory tube were precisely analysed under 2-time magnification.
For data acquisition the anatomical sections were scanned using a high-resolution scanner (optical resolution 1200 x 2400 dpi) and saved as image files.

RESULTS

From consecutive sections of head, which included the auditory tube, two transverse sections (Figs. 1A, 1B), one oblique (Fig. 2), one frontal (Fig. 3) and one sagittal section (Fig. 4) are presented to illustrate some characteristics of the structure, course and topography of the auditory tube. The image of the whole section was used to indicate the area, which was magnified and analysed. The attached scheme shows the plane and the level of sectioning, and the arrow points to the actual viewing direction of the particular section (either from superior/inferior, front/behind, or lateral/medial direction).

Structure and course of auditory tube

Osseous part

Bony part of the auditory tube lies inside the petrous part of temporal bone. It begins with the tympanic orifice in

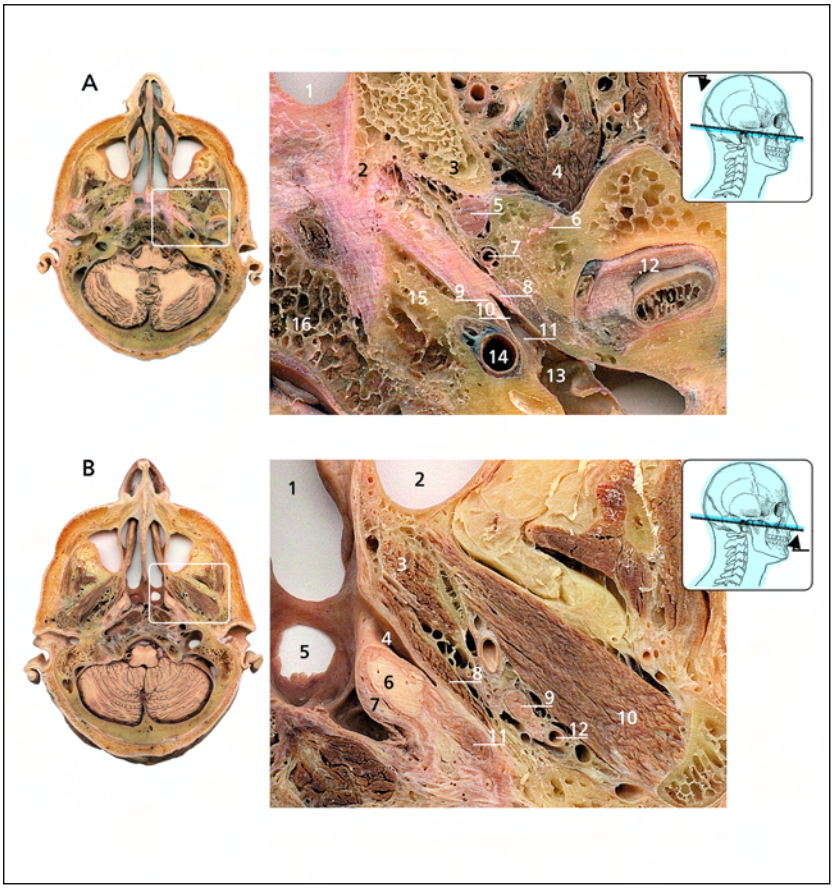

Figure 1A. Tympanic orifice of the auditory tube; transverse section, superior view, magnified 1.5-x.
Nasal cavity (1), medial lamina of pterygoid process (2), lateral lamina of pterygoid process (3), lateral pterygoid muscle (4), mandibular nerve (5), sphenosquamous suture (6), middle meningeal artery (7), lateral lamina of cartilaginous part of auditory tube (8), medial lamina of cartilaginous part of auditory tube (9), isthmus of auditory tube (10), osseous part of auditory tube (11), articular discus of temporomandibular joint (12), tympanic cavity (13), internal carotid artery (14), petrous part of temporal bone (15), basilar part of occipital bone (16).

Figure 1B. Pharyngeal orifice of the auditory tube; transverse section, inferior view, magnified 1.5-x.
Nasal cavity (1), maxillary sinus (2), medial pterygoid muscle (3), pharyngeal orifice of auditory tube (4), nasopharynx (5), medial lamina of cartilaginous part of auditory tube (6), torus tubarius (7), tensor veli palati muscle (8), mandibular nerve (9), lateral pterygoid muscle (10), levator veli palati muscle (11), middle meningeal artery (12).

the anterior part of tympanic cavity where the osseous part is the widest and gradually narrows throughout its length. Its anteromedial end forms the narrowest part of the entire tube, the isthmus. From tympanic orifice the direction of the tube is anteromedially towards the nasopharynx. Below the tympanic orifice the wall of the tympanic cavity falls steeply. On the transverse section the lumen of bony part is oblong with its greater dimension in the horizontal plane. The bony part is rather horizontal and ends at the junction of the squamous and petrous parts of the temporal bone with the jagged margin for the attachment of cartilaginous part (Fig. 1A).

Cartilaginous part

Cartilaginous part is fixed to the cranial base in the groove between the petrous part of the temporal bone and the posterior border of the greater wing of sphenoid bone. Its apex is firmly attached by fibrous tissue to the circumference of the jagged rim of the bony tube at the isthmus. In comparison to the osseous part it is approximately 4-times longer (Fig. 1A).

The cartilaginous part of the auditory tube is composed of broad medial lamina, which is superiorly continuous into the thin lateral lamina (Figs. 1A, 3, 4). Because of the oblique anteromedial direction of the auditory tube, the medial lamina faces posteromedially and the lateral lamina anterolaterally (Fig. 1A). The rest of the lateral wall of the auditory tube is being completed by dense fibroconnective tissue (lamina membranacea), joining the edges of cartilaginous plates (Figs. 2, 4). In addition to the single twisted sheet of cartilage forming the main support of the tube two accessory cartilages are presented above the main cartilage in the frontal section (Fig. 3).

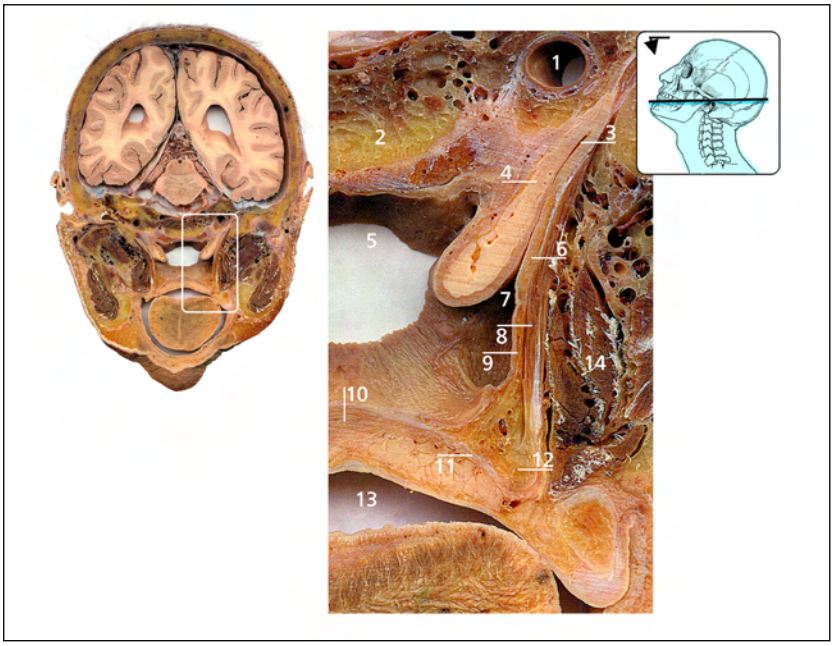

Figure 2. Cartilaginous part of the auditory tube and division of the tensor veli palati muscle; oblique section of the head, superior view, magnified 1.5-x.
Internal carotid artery (1), basilar part of occipital bone (2), lumen of auditory tube (3), cartilaginous part of auditory tube (4), nasopharynx (5), membranaceous lamina of auditory tube (6), pharyngeal orifice of auditory tube (7), tensor veli palati muscle - outer part (8), tensor veli palati muscle - inner part (9), insertion of tensor veli palati muscle in the soft palate (10), palatine aponeurosis (11), pterygoid hamulus (12), oral cavity (13), medial pterygoid muscle (14).

Pharyngeal orifice of the tube in the lateral wall of nasopharynx is surrounded superiorly and posteriorly by cartilage (Figs. 1B, 2, 3) bulging under the mucosa as torus tubarius.

Unlike the bony part, which is completely surrounded by bone and consequently remains permanently open, the cartilaginous part is not completely surrounded by cartilage; in the resting conditions the lumen is converted into a closed, slit-like cavity (Fig. 2). On sagittal section (Fig. 4) running slightly obliquely with respect to the auditory tube, lumen of cartilaginous part is clearly visible. It gradually increases in diameter from the tubal isthmus to the pharyngeal orifice, which is the widest part of the tube (Figs. 1B, 2, 3).

The transverse (Fig. 1A) and oblique sections (Fig. 2) show that the cartilaginous and bony parts are not in the same plane. The superior view of the transverse section (Fig. 1A) shows the lumen of the bony part in its whole length, the initial lumen of the cartilaginous part and the roof of the cartilaginous part. The osseous part is almost or nearly horizontal, the cartilaginous part descends approximately at the angle of 30-40 to the plane of the hard palate. On oblique section (Fig. 2), oriented at the angle of approximately 35° to the plane of the hard palate, most of the cartilaginous part is seen.q

The peritubal muscles

Two palatal muscles, tensor veli palati muscle (TVPM) and levator veli palati muscle (LVPM) can cause changes of tubal lumen, which is collapsed at rest (Fig. 2).
Two parts of TVPM were demonstrated. The outer or external part of the TVPM is a thin triangular muscle that arises from the scull base (scaphoid fossa at the root of the medial pterygoid lamina (Fig. 3), posteromedial margin of the greater wing of the sphenoid bone as far as spine of the sphenoid bone posteriorly). Inferiorly, the fibres converge on a tendon, which turns medially around the pterygoid hamulus to pass to the palatine aponeurosis and the osseous surface behind the palatine crest on the horizontal plate of the palatine bone (Fig. 2). The inner or deep part of TVPM arises from the auditory tube - from the membranaceous lamina (Figs. 2, 4) and from the hook of the lateral lamina (Fig. 3). It inserts on the pterygoid hamulus (Fig. 2). Both parts of TVPM descend almost vertically and anterolaterally (Figs. 1B, 2) and inferiorly to the tube (Figs. 2, 4).
LVPM is cylindrical and arises from the inferior aspect of the cartilaginous part of the auditory tube (Fig. 1B) and from the inferior aspect of the petrous part of temporal bone in front of the carotid canal. It descends almost parallelly and inferiorly to the auditory tube (Fig. 4). It curves medially to be partly joined to the opposite muscle and partly inserted in the superior surface of the palatine aponeurosis (Fig. 3).

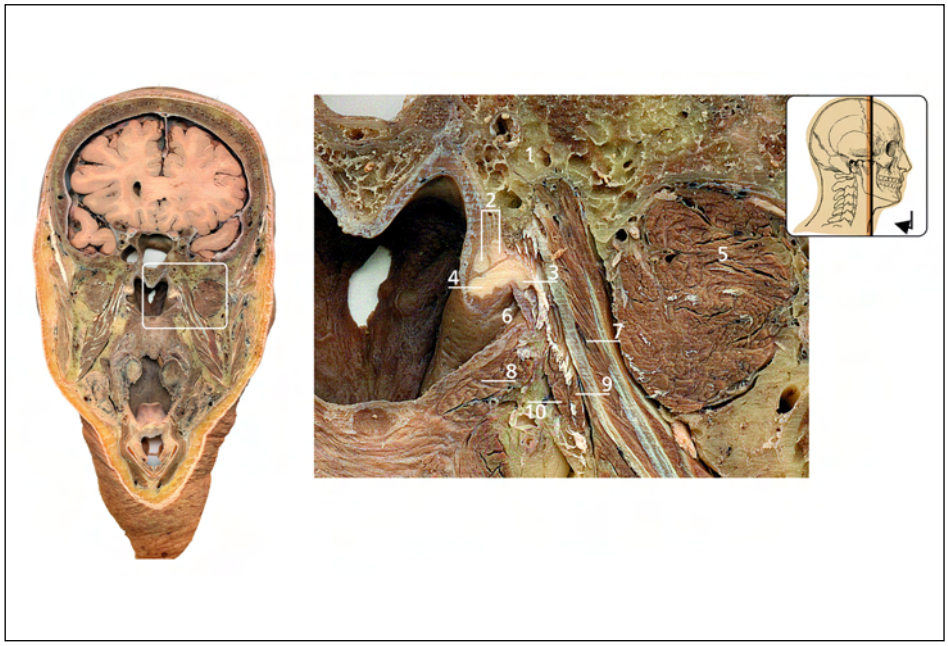

Figure 3. Pharyngeal orifice of the auditory tube and its relation to the levator and tensor veli palati muscle; frontal section, anterior view, magnified 1.5-x.
Base of pterygoid process (1), accessory tubal cartilages (2), lateral lamina of cartilaginous part of auditory tube (3), medial lamina of cartilaginous part of auditory tube (4), lateral pterygoid muscle (5), pharyngeal orifice of auditory tube (6), medial pterygoid muscle (7), levator veli palati muscle (8), tensor veli palati muscle - outer part (9), tensor veli palati muscle - inner part (10).

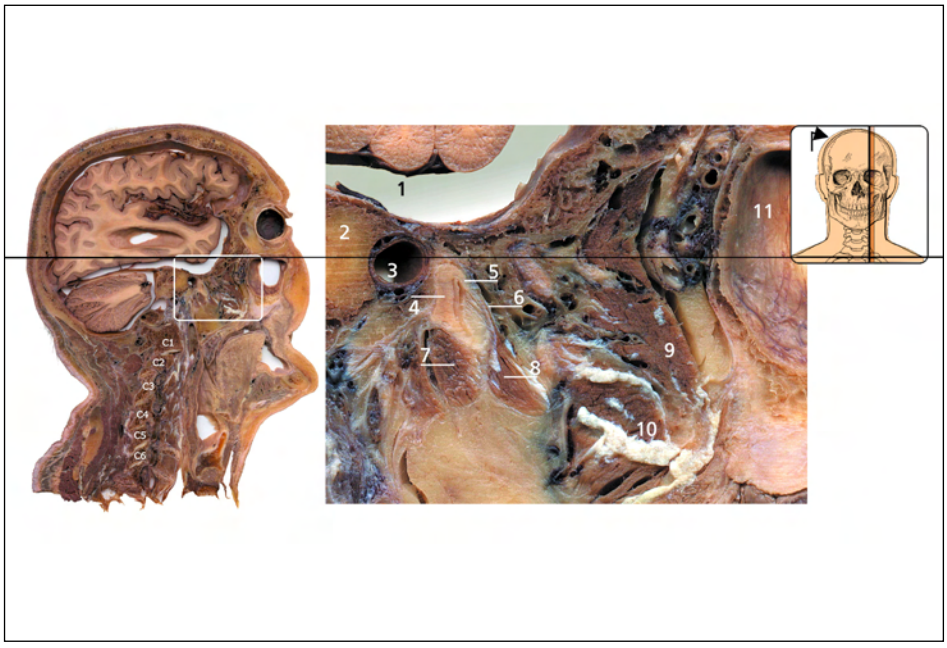

Figure 4. Cartilaginous part of the auditory tube; sagittal section, medial view, magnified 1.5-x.
Middle cranial fossa (1), petrous part of temporal bone (2), internal carotid artery (3), medial lamina of cartilaginous part of auditory tube (4), lateral lamina of cartilaginous part of auditory tube (5), membranaceous lamina of cartilaginous part of auditory tube (6), levator veli palati muscle (7), tensor veli palati muscle (8), lateral pterygoid muscle (9), medial pterygoid muscle (10), maxillary sinus (11).

Topographic relations of auditory tube seen in the presented sections

Topographic relations of osseous part of auditory tube

The osseous part is separated medially by a very thin lamina of bone from the initial part of the carotid canal with internal carotid artery in it. The lateral wall of the osseous part of the auditory tube is thick and close to the mandibular fossa of the temporal bone (Fig. 1A).

Topographic relations of cartilaginous part of auditory tube

Posterolateral end of the cartilaginous tube borders anterolaterally on the two openings in the greater wing of the sphenoid bone: spinous and oval foramen. Spinous foramen with the middle meningeal artery is situated anteromedially from the junction of the greater wing of the sphenoid bone with the temporal bone (sutura sphenosquamosa). Only a thin bony plate separates the tubal cartilage from the middle meningeal artery. The oval foramen with the mandibular nerve is anteromedially to the spinous foramen. The bony plate separating it from the cartilaginous part of the tube is thicker than the plate between the spinous foramen and the lateral cartilaginous wall of the tube (Fig. 1A). Medial lamina of the cartilaginous part borders the petrous part of temporal bone. The anteromedial end of the tube is close to the origin of pterygoid process of the sphenoid bone, and is directed to the root of its medial plate (Fig. 1A).
Laterally to the membranaceous lamina runs the TVPM, what is clearly visible on the transverse and oblique sections (Figs. 1B, 2); on the sagittal section only a few of its fibres are seen laterally to the membranaceous part (Fig. 4). TVPM separates the membranaceous lamina from the mandibular nerve and its branches, otic ganglium, middle meningeal artery and medial pterygoid muscle (Figs. 2, 3). LVPM passes below and parallel with the tube (Figs. 1B, 3, 4).
Superiorly the auditory tube borders on the medial cranial fossa. Just posterior to its cartilaginous part the internal carotid artery in the middle part of the carotid canal is situated. Anteriorly to the tube are the structures of the infratemporal region: lateral and medial pterygoid muscles, pterygoid venous plexus and branches of the maxillary artery (Fig. 4).
On oblique section the attachment of the cartilaginous part of auditory tube to the petrous part of temporal bone and to the spine of sphenoid bone is seen. Internal carotid artery is seen in the horizontal part of the carotid canal being positioned posteriorly, medially and in the level of the middle third of auditory tube.
The TVPM lies close to the uppermost part of the lateral wall of the nasopharynx. Its lateral surface contacts the upper and anterior parts of the medial pterygoid muscle, the mandibular nerve and middle meningeal artery (Fig. 1B).

DISCUSSION

Due to the position of the auditory tube (partly inside the temporal bone and partly bellow the scull base) and its structure (different types of tissues: bone, cartilage, fibroconnective tissue) it is difficult to demonstrate the auditory tube in its whole length on an anatomical specimen and to study its topography. Using anatomical sections the auditory tube could be studied in its natural position and the relationship with its surrounding could be observed. Detailed knowledge of sectional anatomy of the auditory tube is clinically important especially since the introduction of computerised tomographic and magnetic resonance imaging of this area for the evaluation of nasopharyngeal and middle ear diseases (2, 3, 4). The interpretation of obtained images requires a comprehensive knowledge of both conventional and sectional anatomy (5). Earlier studies presented sectional anatomy in one sectional plane (3, 6), two (7) or three sectional planes (4). Besides, the former two studies deal with histologic specimens that are subjected to errors related to tissue processing (8).
Using a high-resolution scanner we succeeded in obtaining high resolution digitalised images of anatomical sections of the auditory tube and surrounding structures. We presented the auditory tube on transverse, oblique, frontal and also sagittal sections.
The course of the auditory tube was well demonstrated on oblique and transverse sections. The osseous part of the tube, running anteromedially, was presented in its whole length on transverse section (Fig. 1A), it did not seem to be inclined downwards, or its inclination was only minimal. The course of cartilaginous part was demonstrated to be continued anteromedially towards the lateral wall of nasopharynx (Figs. 1A, 1B) and to be inclined downwards. On the presented oblique section most of the cartilaginous part was almost longitudinally transected (Fig. 2). This was accomplished since the inclination of the oblique plane we used was approximately 35 with respect to the plane of the hard palate, which has been reported to be the inclination of cartilaginous part of auditory tube measured by nuclear magnetic resonance imaging (3, 4). The inclination of cartilaginous part was confirmed by its almost paralel course with oblique section level and with the fact that the respective lumens of the cartilaginous part and the bony part were not demonstrated simultaneously in their entire length on the same transverse section (Fig. 1A).
Descriptions of the length of the osseous and cartilaginous parts of the tube in the literature are not consistent. Earlier studies suggested the ratio of the osseous and cartilaginous part to be about 1:3 (1), a recent study of Ishijama and co-workers (9) involving computer-aided three-dimensional reconstruction showed the ratio of 1:4. On sections presented in our study the cartilaginous part of the tube seemed to be four times the length of the osseous part.

Accessory tubal cartilages (Fig. 3) close to the pharyngeal orifice of the auditory tube were described in the literature to be present above the main cartilage of the tube (10). On the frontal section two accessory cartilages were demonstrated above the pharyngeal orifice. Their function was probably to help facilitate the movement of the tube (1), since sliding joints between cartilages persisted throughout life permitting free movement of the pharyngeal end of the tube while the tympanic end remained fixed (10).

The isthmus between the osseous and cartilaginous parts of the tube has been described in the literature as its narrowest part, but only when the tube is open. At rest the auditory tube was passively closed, as made visible on the oblique section; its lumen was slit-like (Fig. 2).

In humans, the origin and function of the peritubal muscles remain controversial to some extent (11). TVPM and LVPM are the chief muscles that vary the lumen of the cartilaginous part of the auditory tube. At rest the auditory tube is passively closed (Fig. 2) and is opened by swallowing, yawning or sneezing. Most researchers agree that the TVPM is the primary dilator of the auditory tube (12, 13). Morphologically there is doubt, whether the TVPM is a single muscle (14, 15) or is split into two separate anatomic parts (16, 17). In our study the TVPM was found to consist of bilaminar muscular sheet (well-documented on oblique and frontal sections) running anterolaterally to the auditory tube. The outer part of the TVPM originated from the scull base (Fig. 3). It was fan-shaped and tendinous in its lower part. It bended around the pterygoid hamulus and continued medially to be inserted into the posterior part of the hard palate and into palatine aponeurosis above other palatal muscles (Fig. 2). From the origin and course of its muscle fibres it has been concluded that its purpose is the tension of the soft palate (1). The inner part of the TVPM was demonstrated to originate from the lateral cartilaginous lamina (Fig. 3) and from membranaceous lamina (Figs. 2, 4), and to insert on the pterygoid hamulus (Fig. 2). Its purpose was most probably pulling the hook of the lateral cartilaginous lamina and mebranaceous lamina downwards, thus dilating the tubal lumen (18).

On the frontal section (Fig. 3) it was evident that the TVPM and medial pterygoid muscle ran in their upper part parallelly, touching each other, what might be functionally important as concluded in the study of Leuwer and co-workers (19). From their study of functional imaging of the auditory tube and its surroundings at mouth closed (contraction of the medial pterygoid) and opened (relaxation of the medial pterygoid) it has been concluded that the contraction of the medial pterygoid muscle results in posteromedial movement of the TVPM, thus increasing the tubal opening pressure (19). Relaxation of the medial pterygoid muscle results in an anterolateral movement and simultaneous rotation of the TVPM, leading to a decrease in opening pressure (19).

No agreement exists on the function of the LVPM: some investigators believe that it opens the tube (15, 20, 21) others share the opinion that the LVPM has no effect on tubal lumen (22, 23). LVPM originates at the scull base on the temporal bone in front of the carotid orifice, and in its posterior third also from the medial cartilaginous lamina of the auditory tube. The latter origin was well documented on the transverse section we obtained (Fig. 1B). In its anterior two-thirds the muscle had no direct relation with the tube; it descended in parallel below the tube (Fig. 4) and was inserted in a radiating fashion into the dorsal surface of the soft palate below the pharyngeal orifice (Fig. 3). From the course demonstrated on the anatomical sections LVPM function of pulling the soft palate up, back and laterally (1) was evident. Its function regarding the lumen of auditory tube - elevating and rotating the medial tubal cartilage with increased dimensions of the muscle body when it contracts and thus assisting in tube opening - described by Huang and coworkers (24) could be accepted.

CONCLUSIONS

Sectional anatomy of the auditory tube in transverse, oblique, frontal and sagittal sections well demonstrates the structure, course and topography of the auditory tube. The bony part of the auditory tube is clearly demonstrated on transverse sections, while the cartilagineous part is presented in almost its whole length on the oblique section. The division of TVPM in bilaminar muscular sheet is demonstrated on oblique and frontal sections.

Detailed knowledge of sectional anatomy of the auditory tube is important for the interpretation of corresponding images obtained by magnetic resonance and computed tomography and in understanding the disorders and diseases affecting the middle ear and mastoid.

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