The Eustachian Tube

7

Contents

The Eustachian tube (ET) or auditory tube is a slender tube that connects the middle ear cavity with the nasopharynx and serves to equalize air pressure on either side of the eardrum.

It is a hollow structure of bone and cartilage, lined with a mucous membrane, and equipped by a muscular opening mechanism.

It is part of a system of contiguous organs, including the nose, the middle ear, and the mastoid air cells. This system is devoted to middle ear ventilation, its protection, and its clearance. Impairment of this system leads to middle ear dysventilation, which is the primary cause of the development of chronic otitis media.

7.1 Eustachian Tube Development

The ET lumen develops from the persistence of the first pharyngeal pouch. Between the second and third week of gestation, the first pharyngeal pouch extends laterally between the first and the second branchial arches to make contact with the first branchial groove which is the origin of the external auditory meatus (Fig. 7.1). The distal part of this pouch expands to form the tubotympanic recess which is the primordium of the middle ear cavity. The proximal part becomes constricted to connect the future middle ear to the pharynx.

The structures associated with ET lumen develop from the mesenchyme surrounding the first pharyngeal pouch in a predictable sequence:

S. Mansour et al., *Comprehensive and Clinical Anatomy of the Middle Ear*,
DOI 10.1007/978-3-642-36967-4_7, © Springer-Verlag Berlin Heidelberg 2013

Fig. 7.1 The tubotympanic recess (TR) in a mouse embryo of gestation day 12. *HM* handle of malleus, *Ph* pharynx, *OC* otic capsule, *TTR* tubotympanic recess, *FBG* first branchial ectodermal groove. This horizontal section demonstrates the continuity between the pouch and the pharynx. Incorporation of radioactive sulfur with hematoxylin-eosin counterstaining

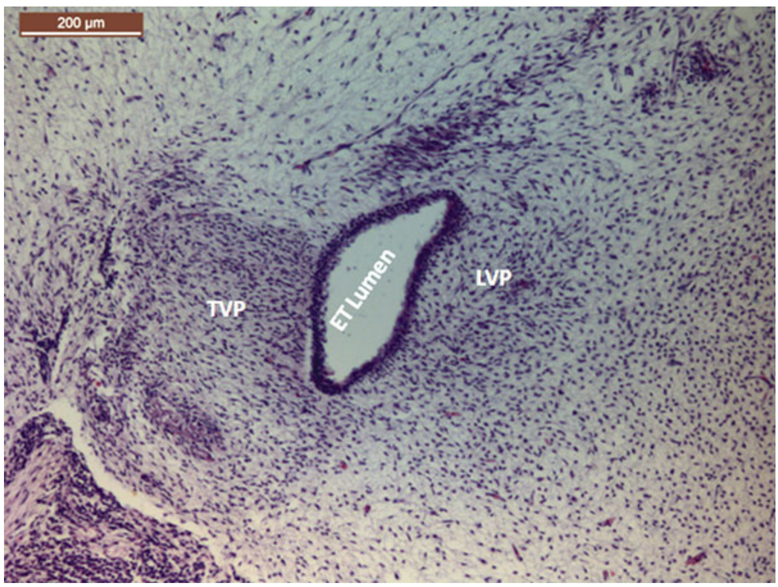

Fig. 7.2 Frontal section of the auditory tube rudiment in a 27-mm human embryo (end of the second month). *TVP* tensor veli palatine muscle anlage, *LVP* levator veli palatine muscle anlage. Hematoxylin-eosin staining

Before the 10th week of gestation, only the epithelial lining of the lumen has differentiated. Between the 10th and 12th week, the levator veli palatini (LVP) and tensor veli palatini muscles (TVP) develop and become delineated from the surrounding mesenchyme [1, 2] (Fig. 7.2).

The initial differentiation of the cartilage begins at the 14th week. By the 20th week, the initial center of chondrification has increased in size and a perichondrium is clearly differentiated in the anteromedial portion of the tube [1, 2] (Fig. 7.3).

These processes yield an ET structure very similar to that observed in an adult. Later during the rest of fetal life, morphometric changes occur among the ET structures. The most pronounced change is the increase in the length of the cartilaginous portion of the tube from 1 mm at the 10th week of gestation to 13 mm at birth.

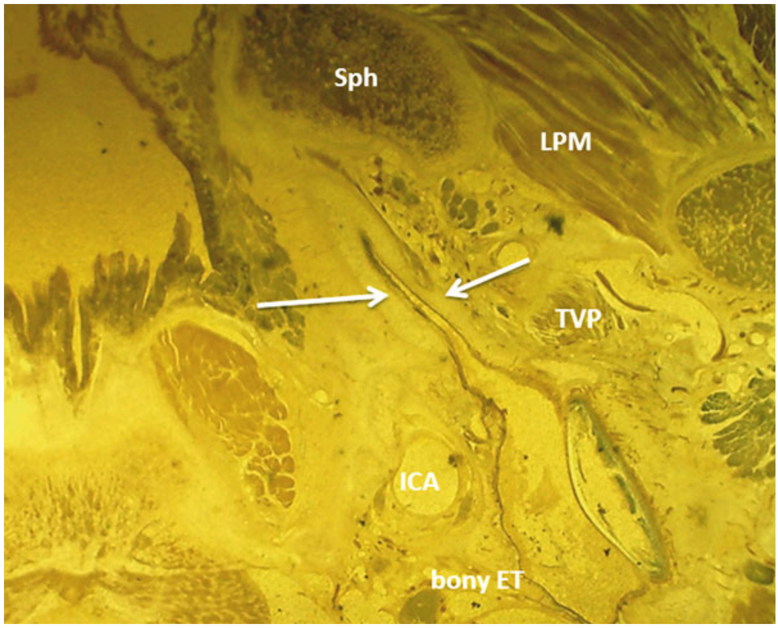

Fig. 7.3 A transverse cut of the base of skull in a 6-month fetus showing the Eustachian tube. Note the cartilaginous part is well developed (*white arrows*) and is in the same plane as the bony Eustachian tube (*ET*). *LPM* lateral pterygoid muscle, *Sph* sphenoid bone, *ICA* internal carotid artery, *TVP* tensor veli palatini muscle

While the fetus is growing, the tube deviates from the horizontal plane only about 10°, because the fetal cranial base is relatively flat; this situation persists until early childhood [1–4].

> ***Clinical Application***
> An arrest of the development of the tubotympanic recess when the normal constriction of the tube is deficient may lead to a persistent wide open Eustachian tube all over its length. This is illustrated in this case of an adult female of 35 years old (Fig. 7.4). The developmental arrest concerns the whole left ear, associated to microtia, and external auditory canal atresia.

7.1.1 Postnatal Growth (Fig. 7.5)

The ET lengthens rapidly during early childhood: In infants, it is about half as long as that in adults; it is about 18 mm [5] and it reaches adult size by 7 years of age [6, 7].

The cartilaginous portion increases dramatically: The ratio of the length of the cartilaginous portion to the osseous portion is 8:1 in the infant, but this ratio becomes 4:1 in the adult due to the growth of the bony portion [8].

In infants, the cartilaginous and bony portions are aligned with a line that connects the pharynx and middle ear; however, due to the craniofacial growth, the cartilaginous tube is angled inferiorly from the osseous portion to form an angle of approximately 45° related to the horizontal plane [1, 9].

The LVP muscle increases in cross-sectional area and in volume and assumes a more suitable vector for an efficient active tubal dilatation.

The ET of the infant is floppy, very distensible, and lacks recoil phenomena of the hinge region. With time, the tubal cartilage stiffens and the elastin component develops in the hinge region; this will result in a reduced tubal compliance and an increased recoil, which raise the protective mechanism of the ET [10].

The lumen of the ET increases almost five times from the newborn to persons aged 20 years old; the cross-sectional length of the lumen increases significantly with age, especially in the pharyngeal area of the tube.

The lumen in most of the cartilaginous portion of the ET is significantly smaller in children than in adults [11].

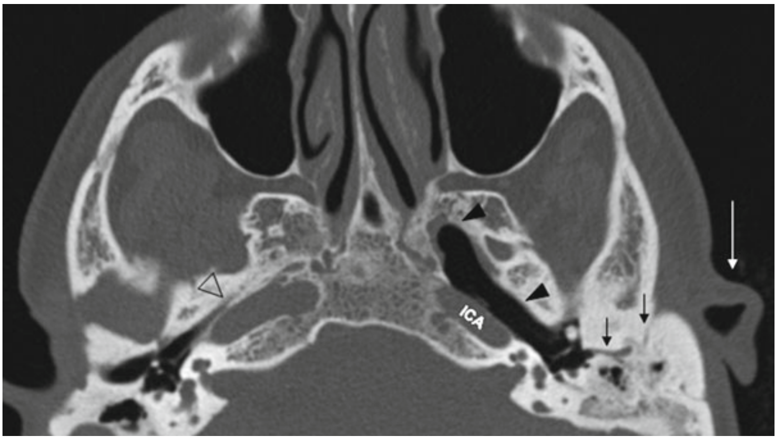

Fig. 7.4 Transversal computed tomographic view of both ears in a patient presenting left ear microtia (*white arrow*) and atresia of the external auditory canal (*black arrows*), also an abnormally large Eustachian tube (*arrow heads*) due to the arrest of constriction of the tubotympanic recess in contrast to the normal right side (*empty arrow head*). *ICA* internal carotid artery

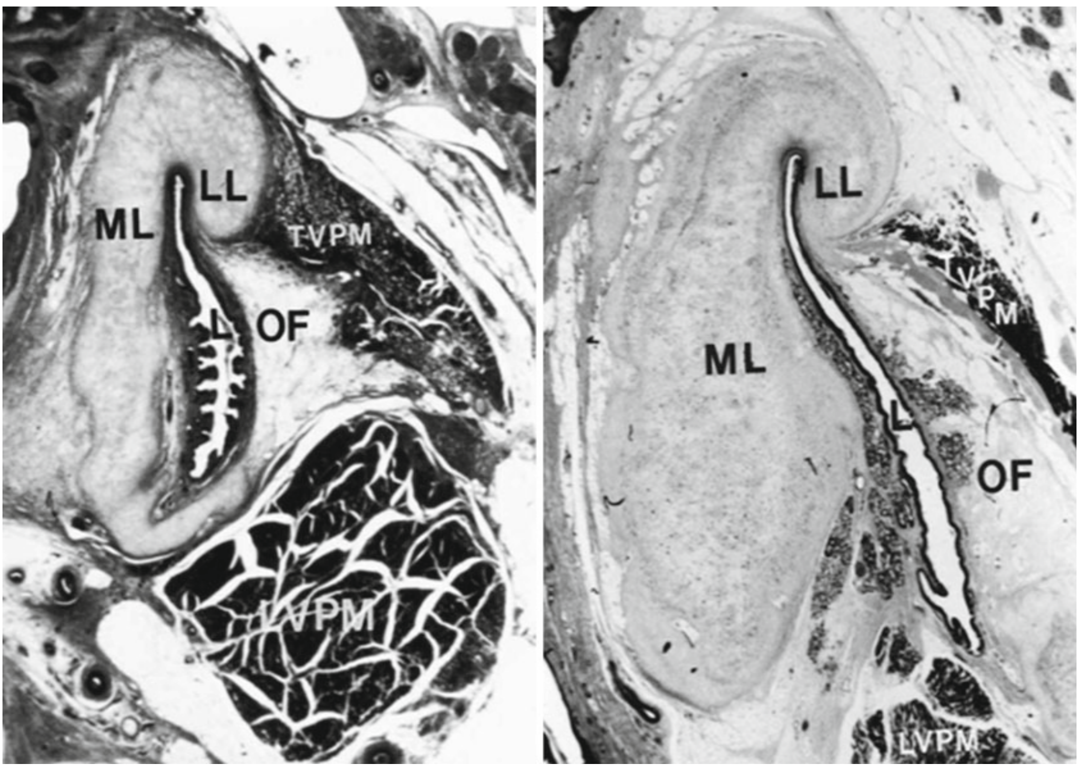

Fig. 7.5 Photomicrographs of cross sections through the midcartilaginous portion of the Eustachian tube (ET) of a 3-month-old female (*left*) and a 34-year-old male (*right*) showing the developmental difference of Ostmann's fat pad (*OF*) and the size of the ET. *L* lumen, *LL* lateral lamina of the Eustachian tube cartilage, *LVPM* levator veli palatini muscle, *ML* medial lamina of the Eustachian tube cartilage, *TVPM* tensor veli palatini muscle (Courtesy of I. Sando, MD) (Reproduced with permission from Eustachian tube: structure, Function, Role in otitis media, by Charles D. Bluestone. pmph-usa.com)

Also the Ostmann's fat pad increases in volume with age until adulthood, which may be related to better protective function in adults [12].

7.2 Eustachian Tube Anatomy

The ET is a narrow osteocartilaginous channel connecting the tympanic cavity to the nasopharynx. Its lumen allows the passage of two different physical substances: one is gaseous for middle ear ventilation, and the second is fluid for the middle ear clearance. The ET begins at the tympanic orifice of the protympanum and ends at the pharyngeal orifice situated on the lateral wall of the nasopharynx. During its trajectory, the tube takes a slow curving inverted S course.

The general shape of the ET resembles to an hourglass made of two unequal cones. The first is small and fix, the posterior third, and represents the bony ET. The other one is elongated and mobile, the anterior two-thirds, and represents the fibrocartilaginous ET. Both parts are connected at the junctional zone, forming an angle of 160°.

In adults, the tubal axis forms with the plane of the hard palate an average angle of 36°(range 31–40°); the total length of the ET is 33 mm, divided as the following: the cartilaginous part is of 23.5 mm, the junctional part is of 3 mm, and the bony part is of 6.5 mm [13, 14] (Fig. 7.6).

The bony portion is patent at all times; in contrary the fibrocartilaginous portion is closed at rest and opens intermittently.

7.2.1 The Bony Portion of the Eustachian Tube

The bony part of ET lies completely within the petrous part of the temporal bone. It runs from the tympanic orifice of the middle ear cavity in an anteromedial direction, following the petrous apex, towards the petrosphenoid sulcus on the inferior surface of the skull base.

The tympanic orifice of the Eustachian tube lies in the middle third of the anterior wall of the middle ear cavity, 4 mm above the floor of the middle ear and close to the carotid canal and the labyrinth (see Section 2.5.2). It is an oval

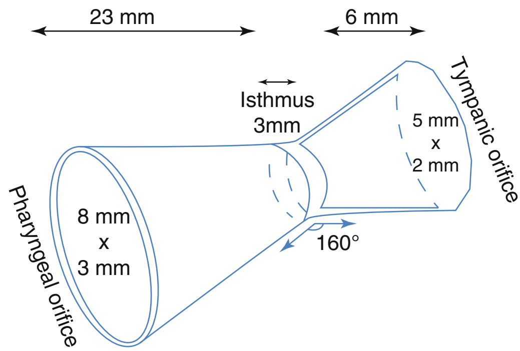

Fig. 7.6 Schematic drawing of different Eustachian tube dimensions (average)

structure that measures about 5 mm (horizontally) × 2 mm (vertically) [9] (Fig. 7.6).

Bony ET lumen is roughly triangular, measuring 2–3 mm vertically and 3–4 mm along the horizontal base [15].

The medial wall of the bony tube corresponds to the cochlea posteriorly and to the carotid canal anteriorly. The average thickness of the anteromedial portion of its bony wall is 1.5–3 mm. This bony wall is dehiscent in 2 % of individuals, exposing the carotid artery [15] (Fig. 7.7).

The upper third of the endoluminal surface of the medial wall presents the bony canal of the tensor tympani muscle. The lateral wall of the bony tube neighbors the canal of Hugier and the temporomandibular joint. The upper wall or roof of the bony tube corresponds to the tegmen tubari (Figs. 7.7 and 7.8).

On the inferior surface of the base of skull, the end of the bony tube is constricted and it opens on the posterior part of the tubal sulcus; the bony tube end is situated between the carotid canal medially and the temporomandibular joint laterally.

> ***Surgical Implication***
> The majority of temporal bone with pneumatized petrous apex harbor peritubal air cells that may open directly into the ET lumen (Fig. 7.9). This explains the probability of cerebrospinal fluid rhinorrhea after translabyrinthine approach to the cerebellopontine angle when ET obliteration is not performed sufficiently far into the lumen by the end of the procedure [16].

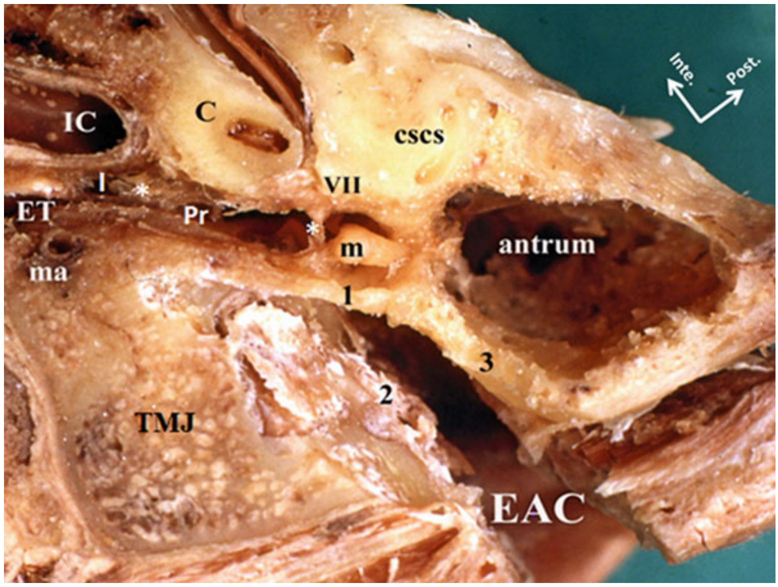

Fig. 7.7 Transverse cut of a left ear showing the bony Eustachian tube (*Pr*) housing the tensor tympani muscle (*), the cartilaginous Eustachian tube (*ET*), and the isthmus (*I*). Notice the relation of the Eustachian tube and the cochlea (*C*) and the petrous internal carotid artery (*IC*) medially and the temporomandibular joint (*TMJ*) and middle meningeal artery (*ma*) laterally. *EAC* external auditory canal, *1* attic outer wall, *2* anterior wall of EAC, *3* posterior wall of the EAC, *m* malleus, *VII* tympanic segment of facial nerve, *CSCS* superior semicircular canal

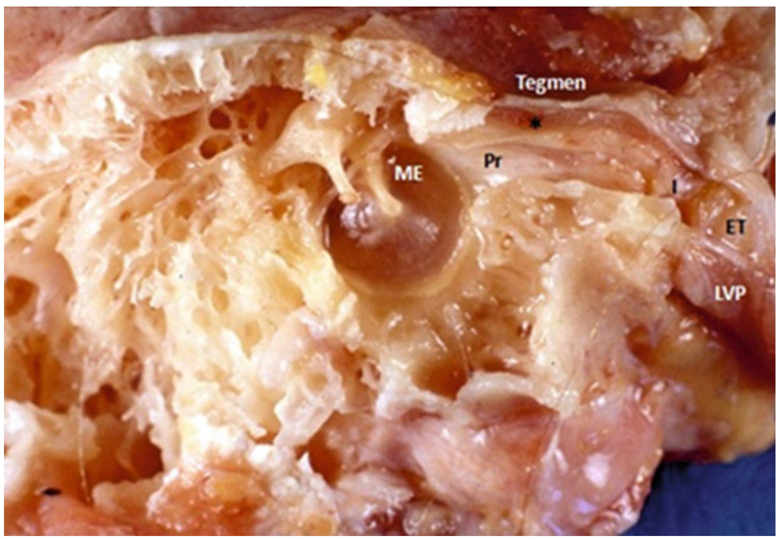

Fig. 7.8 Medial view of a sagittal cadaveric cut through a left middle ear (*ME*), showing the bony Eustachian tube (*Pr*) and the canal of tensor tympani muscle (*asterisk*), the isthmus (*I*), the cartilaginous Eustachian tube (*ET*), and its inferiorly related levator veli palatini muscle (*LVP*). The superior wall of the bony Eustachian tube is formed by the tegmen tubari

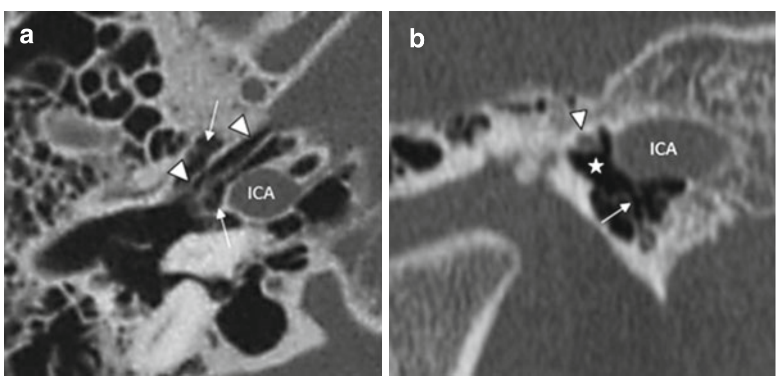

Fig. 7.9 (**a**) Transversal computed tomographic view of a right ear. Eustachian tube (*white arrow heads*), surrounded by numerous aerated cells (*white arrows*); *ICA* internal carotid artery. (**b**) Computed tomograpic reconstruction perpendicular to the Eustachian tube (*) showing an air cell opened into the Eustachian tube (*arrow*); TTM (*arrowhead*)

7.2.2 The Junctional Segment

The cartilaginous and bony portions of the ET are joined at a bottleneck area, the junctional segment of the ET.

This segment is 2 mm in height and 1 mm wide. It lies between the carotid canal medially and the temporomandibular joint and foramen spinosum with the middle meningeal artery laterally (Figs. 7.7).

Due to its reduced caliber, this segment plays a protective role for the middle ear against recurrent otitis media in preventing nasopharyngeal secretions to enter the middle ear cavity.

7.2.3 The Fibrocartilaginous Tube

The fibrocartilaginous portion of the ET is 20–24 mm long; it extends along the base of the skull from its junction with the bony portion of the tube until the medial pterygoid plate. Posteriorly this part of the ET extends about 3 mm into the bony part and is firmly attached to it by fibrous bands [17–19]. It is angled 30°–40° to the transverse plane and 45° to the sagittal plane of the base of the skull [9]. The fibrocartilaginous part is loosely attached at this level in the sphenoid sulcus (sulcus tubae) between the greater wing of the sphenoid bone and the petrous portion of the temporal bone (Fig. 7.10).

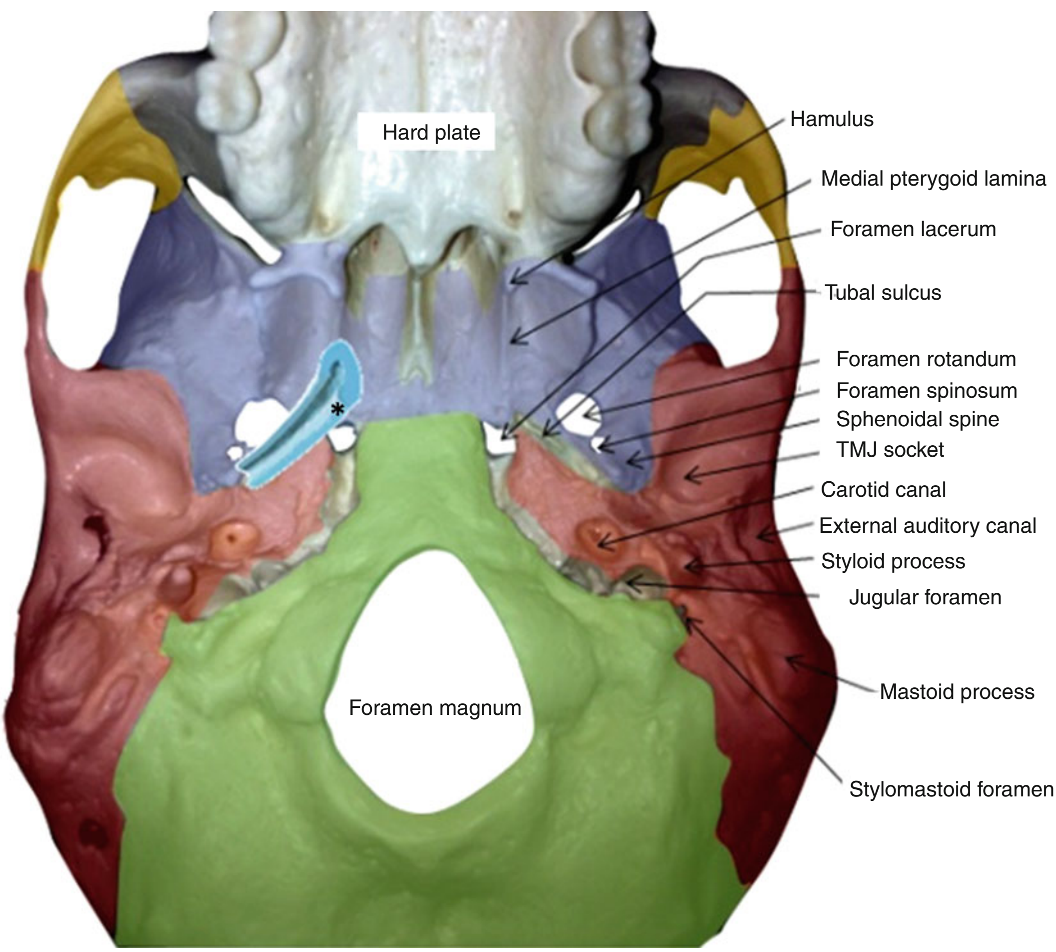

Fig. 7.10 Tubal cartilage (*) insertion in sulcus tubae

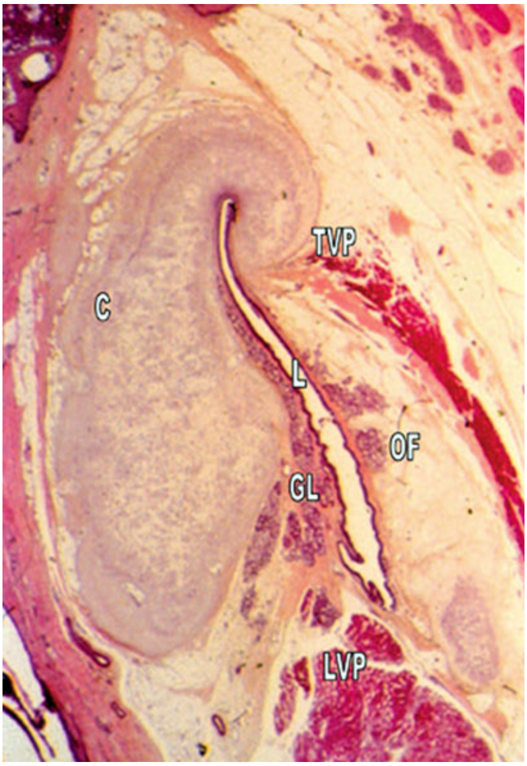

Fig. 7.11 Midcartilaginous portion of a normal left Eustachian tube of an adult temporal bone specimen. *C* cartilage, *L* lumen, *GL* submucosal glands, *LVP* levator veli palatini muscle, *TVP* tensor veli palatini muscle, *OF* Ostmann's fat pad (Courtesy of I. Sando, MD) (Reproduced with permission from Eustachian tube: structure, Function, Role in otitis media, by Charles D. Bluestone. pmph-usa.com)

The nasopharyngeal end of the tubal cartilage crosses the superior border of the superior pharyngeal constrictor muscle to enter the nasopharynx; it is tightly fixed by a broad attachment to a tubercle on the posterior edge of the medial pterygoid plate [15].

The fibrocartilaginous tube is composed of two components: the cartilaginous part, the major component that is completed laterally, and inferiorly by the fibromembranous part (Fig. 7.11).

7.2.3.1 The Cartilaginous Part

The cartilaginous portion of the ET is composed of one piece of cartilage that is shaped like a triangle at the top rear with a lower concavity. The apex or lateral end of the cartilaginous part joins the bony portion at the isthmus; the wider medial end lies under the mucosa of the nasopharynx.

The tubal cartilage is an elastic cartilage and has an inverted J shape in cross section. It is composed of a short lateral lamina, an elongated medial lamina, and a hinge at the junction of the two laminas.

The lateral lamina has a constant height. However, the medial lamina starts as a short structure of 9 mm of height at the isthmus to increase rapidly to 13 mm just posterior and lateral to the attachment of the cartilage to the medial pterygoid plate [15]. The hinge portion, rich in elastin, serves to return the lateral lamina to its original position after active opening of the tube by TVP muscle contraction.

To form a tube, the cartilaginous portion is completed laterally and inferiorly by a veiled membrane, the fibrous part of the tube or fibrous wall (Fig. 7.11).

7.2.3.2 The Fibrous Part

The fibrous part represents the lateral and the inferior walls of the fibrocartilaginous ET. It is thick and resistant and called the *salpingopharyngeus fascia of Tröltsch*. Laterally, it serves as the site of insertion of the TVP muscle. The lateral part of the fascia of Tröltsch is inserted to the base of skull at the petrosphenoid suture (Proctor ligament) close to the foramen spinosum, foramen ovale, and the base of the pterygoid process laterally (see Fig. 7.10).

The medial part of the fascia of Tröltsch is anchored superiorly to the inferior curvature of the lateral lamina of the tubal cartilage. The region between the fascia and ET mucosa is occupied by a glandular tissue anteriorly and adipose tissue posteriorly. Thus, it is presumed that the forces developed by the TVP would pass to the lateral lamina of the cartilage rather than to the submucosa of the lumen to insure the opening of the tube.

7.2.3.3 Ostmann's Fat Pad

Ostmann's fat pad is a lympho-adipose body, situated around the pharyngeal end in the inferolateral aspect of the anterior part of the ET. It occupies the space between the ET proper and the TVP muscle (Fig. 7.11).

It is thought to represent an important contributing factor in closing the tube. It contributes to the protection of the ET and the middle ear from reflux of nasopharyngeal secretions. In malnourished persons this pad of fat is lost causing patulous ET.

Ostmann's fat pad increases in volume during childhood, being most voluminous in adults, and regresses in the elderly.

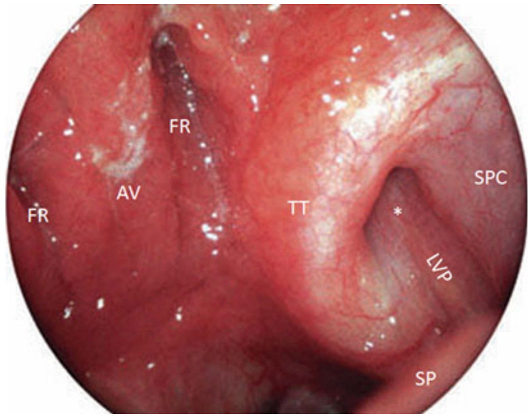

Fig. 7.12 Endoscopic view of left pharyngeal orifice. *FR* fossa of Rosenmuller, *AV* adenoid vegetation, *TT* torus tubari, *SPC*, salpingopalatine crease containing levator veli palatini muscle, *LVP* levator veli palatini muscle in the floor of the Eustachian tube, *SP* soft palate, * Eustachian tube lumen

7.2.4 The Pharyngeal End

The pharyngeal end of the ET passes above the superior constrictor muscle through the sinus of Morgani to lay under the mucosa of the nasopharynx. The pharyngeal orifice lies approximately at the posterior level of the vomer, about 1.25 cm behind the posterior end of the inferior turbinate and approximately 2 cm above the plane of the hard palate [9].

The pharyngeal orifice is triangular in shape with an inferior base; it measures 8–10 mm in height and 3–5 mm in width (Figs. 7.6 and 7.12). The pharyngeal orifice is closed at rest and becomes elliptical or triangular with a superior apex during opening.

Its anterolateral border is a vertical prominent crease, called the salpingopalatine crease. It corresponds to the lateral plate of the tubal cartilage and the TVP muscle. The posteromedial border is prominent and corresponds to the medial lamella of the tubal cartilage pressing against the nasopharyngeal mucosa; this prominent surelevation of the mucosa is called the *torus tubari* (Fig. 7.12). The torus tubari thickness is of 10–15 mm [15]. The mucosa of the torus tubari is rich in glands and lymphoid tissue forming the *tonsil of Gerlach.* The inferior border of the pharyngeal orifice is bounded by the levator veli palatini muscle.

Just medial and behind the torus tubari there is a recess called the *fossa of Rosenmüller*, which is a triangular recess of about 1.5 cm deep. Its apex is in close relationship with the carotid canal, and its base is closely related to the skull base with the foramen lacerum lying medially. Adenoid tissues usually extend into this recess giving soft tissue support to the ET (Fig. 7.12).

7.2.5 Muscles of the Eustachian Tube

Four muscles are associated with the ET: the tensor veli palatini (TVP), the levator veli palatini (LVP), the salpingopharyngeus, and the tensor tympani muscle.

ET is closed at rest and opens during swallowing or yawning. Active opening of the ET is induced by TVP muscle contraction [20–22]. Closure of the tube is a passive phenomenon and is not the result of a muscular contraction. It takes place secondarily to the passive reapproximation of the tubal walls by extrinsic forces exerted by the surrounding deformed tissues and also by the recoil of elastic fibers of the hinge portion [15].

7.2.5.1 Tensor Veli Palatini (TVP) Muscle

The TVP muscle is composed of two distinct bundles of muscle fibers: the lateral (superficial) and the medial (deep) bundle that are separated by a fibroelastic layer (Fig. 7.13).

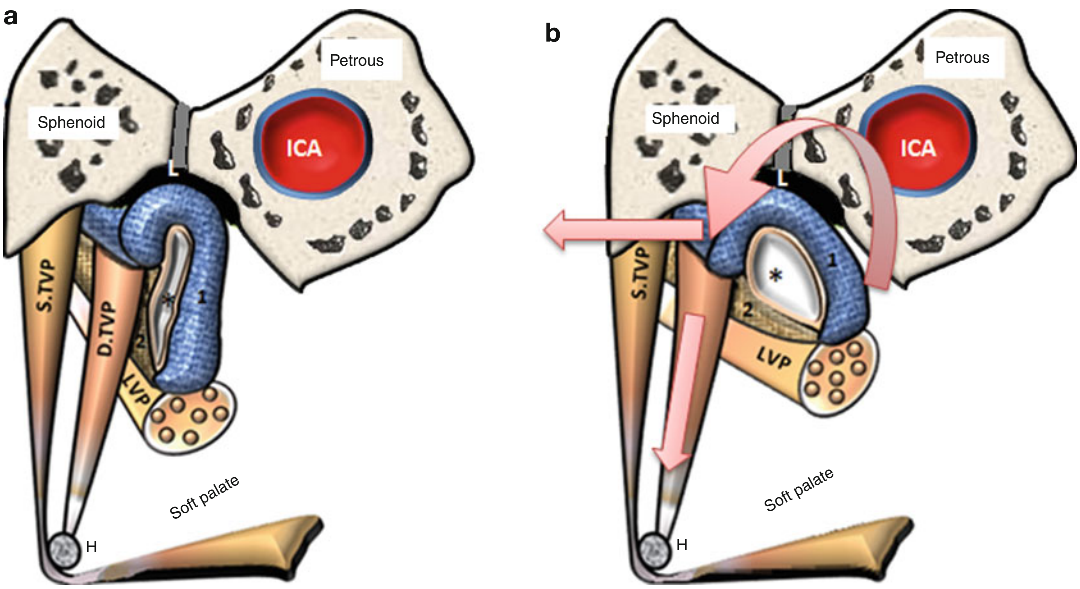

Fig. 7.13 Schematic representation of paratubal muscles and the action of tensor veli patine muscle. (**a**) During relaxation; (**b**) during contraction. *S.TVP* superficial bundle of tensor veli palatine muscle, medial bundle of *DTVP* deep bundle of tensor veli palatine muscle, *LVP* levator veli palatine muscle, *L* tubal ligament, *1* tubal cartilage, *2* tubal fibrous membrane, * tubal lumen, *H* hammulus, *ICA* internal carotid artery

The Lateral Bundle

The lateral bundle is not related to the ET function. It has an inverted triangular shape with a superior base and an inferior apex. It starts superiorly at the scaphoid fossa of the sphenoid bone lateral to the ET cartilage. Then, it descends anteriorly, laterally, and inferiorly to converge in a tendon that rounds the hamular process of the medial pterygoid lamina. From the hamular process it progresses to insert into the posterior border of the hard palate and into the palatine aponeurosis [15].

The lateral bundle of the TVP muscle ensures the tension of the soft palate.

The Medial Bundle

The medial bundle, also called the dilator tube muscle, has its superior origin in the posterior half of the lateral lamina of the cartilaginous ET. Its fibers descend sharply and converge in a tendon that inserts on the hamular process of the medial pterygoid plate.

The medial bundle is responsible for the active dilatation of the fibrocartilaginous tube by inferolateral displacement of its membranous wall [23–25].

Secondary attachments of the medial bundle are present sometimes at the maxillary tuberosity and the palatoglossal arch. These insertions suggest that even if the hamulus is in-fractured during cleft palate surgery, the TVP function could be maintained by preserving its maxillary insertion [26].

Both bundles are innervated by the mandibular nerve (V3).

7.2.5.2 The Levator Veli Palatini (LVP) Muscle (Fig. 7.13)

The LVP muscle arises from the inferior aspect of the petrous apex of the temporal bone. Its rounded body passes inferomedially, paralleling and lying beneath the floor of the fibrocartilaginous tube lumen. The fibers of this muscle insert by fanning out and blending with the dorsal surface of the soft palate [9, 17].

The LVP muscle is related to the tube only by a loose connective tissue [20, 27].

It is essentially a muscle serving the soft palate, but it could also support the ET function by elevating the medial lamina of the cartilage at the pharyngeal orifice [19, 28]. In addition, being located inferolaterally to the ET and with its large cross-sectional area in this portion, the LVP may be related to the pumping clearance (drainage) function of the tube in such a way that the distal end of the tube closes first followed progressively towards the pharyngeal orifice, thus pumping out the middle ear secretions [29].

The levator veli palatini is innervated by the glossopharyngeal nerve (IX).

7.2.5.3 The Salpingopharyngeal Muscle

The salpingopharyngeal muscle arises from the medial and inferior borders of the tubal cartilage via slips of muscular and tendinous fibers. Then the muscle courses inferoposteriorly to blend with the mass of the palatopharyngeal muscle. The salpingopharyngeal muscle is not involved in the function of the ET. It is innervated by the glossopharyngeal nerve IX [9, 27].

7.2.5.4 The Tensor Tympani Muscle

The tensor tympani muscle arises from the superior surface of the cartilaginous part of the auditory tube, the greater wing of the sphenoid, and the petrous part of the temporal bone. The muscle passes posterolaterally and always superiorly to the ET in its bony semicanal to the cochleariform process on the medial wall of the middle ear. Its tendon hooks around the cochleariform process to run laterally and insert into the medial aspect of the neck of the malleus. Contraction of the tensor tympani pulls the eardrum medially and restricts its mobility. Thus, sound transmission through the middle ear is attenuated when the tensor tympani is contracted. It is innervated by a branch of the mandibular nerve V3.

7.2.6 Eustachian Tube Mucosa

At the tympanic orifice of the ET, the lumen is of 2 mm in height and 5 mm in width. From the isthmus downwards, the lumen expands continuously to become about 8–10 mm in height and 1–2 mm in width at its pharyngeal orifice.

The lumen is lined by a pseudostratified, columnar epithelium of a ciliated type, which sweeps material from the middle ear to the nasopharynx. The mucosa is continuous with the lining of the tympanic cavity at its distal end, as it is with the nasopharynx at its proximal end. Associated with these ciliated epithelial cells are the goblet cells figuring about 20 % of the cell population [30, 31].

The floor mucosa of the tube contains numerous goblet cells, copious ciliated cells, and glands [31, 32]. The roof mucosa of the tube has sparse goblet cells and cuboidal ciliated cells without seromucous glands.

Therefore, we can recognize two different morpho-functional corridors in the ET lumen:

1. Superior corridor: the roof for the ventilation function
2. Inferior corridor: the floor with its mucociliary clearance function

7.2.7 Eustachian Tube Blood Vessels

The arterial blood supply of the ET is derived from the ascending pharyngeal and middle meningeal arteries. The venous drainage is carried to the pharyngeal and pterygoid plexus of veins. The lymphatic chains drain into the retropharyngeal lymph nodes.

7.2.8 Eustachian Tube Nerves

The ostium and the cartilagenous portion of the ET are innervated by the pharyngeal branch of the sphenopalatine ganglion deriving from the maxillary nerve (V2).

The bony portion of the ET is innervated by the tympanic plexus deriving from the glossopharyngeal nerve (IX).

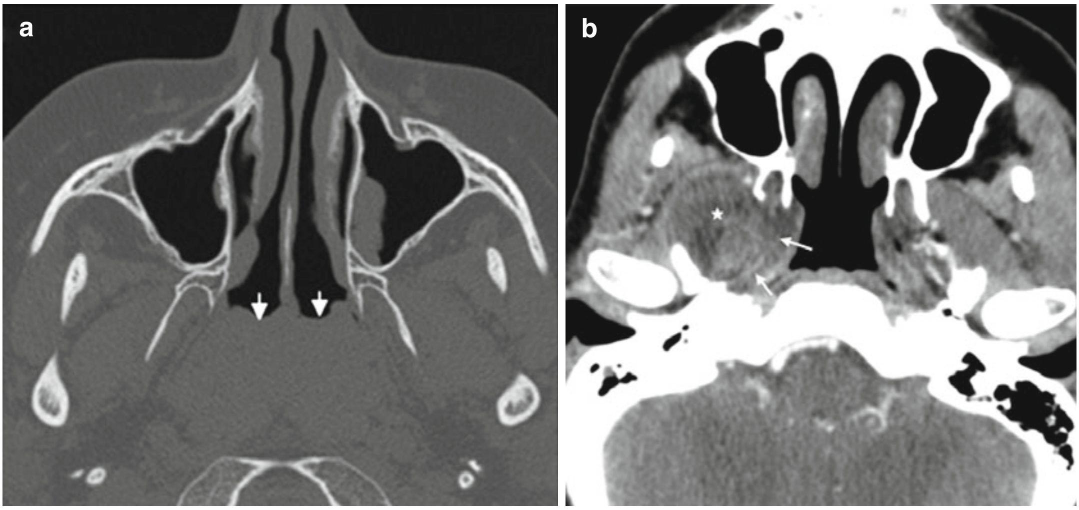

Fig. 7.14 (**a**) Transversal computed tomography of a 15-year-old boy with bilateral adhesive otitis media. Huge adenoid hypertrophy (*white arrows*) in the nasopharynx. (**b**) Transversal injected computed tomography of an adult showing a well-encapsulated globulous lesion (schwannoma) of the right infratemporal fossa (*), with a mass effect (*white arrows*) on the Eustachian tube

Clinical Application

Eustachian Tube Function

Although the osseous portion of the ET remains patent and is not dynamic, the cartilaginous portion of the ET is normally closed and opens only for brief periods of time. This situation blocks the nasopharyngeal secretions or a gastric reflux from entering into the middle ear as well as it prevents autophonia.

Brief intermittent periods of ET opening occur in normal individuals to insure middle ear ventilation. The ET opens 1.5 times every minute. Every opening lasts about 0.5 seconds [33]. These openings are the result of the contractions of TVP muscle.

In addition, the ET insures the function of the middle ear mucociliary clearance. The ciliated epithelial cells of the lumen floor provide a mucociliary "elevator" to push debris and secretions downwards from the ET into the nasopharynx.

Impairment of the tubal function can be divided into two main categories: *Eustachian tube dysfunction* when the tube does not open properly or *patulous Eustachian tube* when the tube remains inappropriately patent.

Eustachian Tube Dysfunction

ET dysfunction could be the result of mucosal inflammation with edema and obstruction, or anatomical extrinsic obstruction, or failure of dilatation from muscular problems causing dilatory dynamic dysfunction.

Dilatatory dynamic dysfunction of the ET is a strong contributor for ET disorders in infants [34, 35].

Anatomical extrinsic obstruction must always be ruled out. In children and adolescent, anatomical obstruction could be frequently due to adenoid hypertrophy. In adults presenting unilateral ET dysfunction, nasopharyngeal or infratemporal fossa tumors must be ruled out (Fig. 7.14).

Intrinsic blockage of the ET is more common than anatomical extrinsic obstruction. It is often the result of mucosal inflammation (mucosal disease), possibly due to allergies or laryngopharyngeal reflux. Tobacco use results in a loss of the

Table 7.1 Anatomical differences of the Eustachian tube between infants and adults

	Infant	Adult
Length (mm)	Approximately 15	Approximately 30
Cartilaginous portion	Less than 2/3 of the tube	2/3 of the tube
Bony portion	Relatively larger and wider than the adult	Relatively smaller
Pharyngeal orifice	About ½ that of the adult but similar width	Height 8 mm, width 2 mm
Angulation with respect to base of skull (°)	10	45
Tensor veli palatini muscle action	Less efficient	More efficient
Ostmann's pad fat	Less prominent	Prominent

normal ciliary clearance of the mucosa and causes frequently ET dysfunction.

Patulous Eustachian Tube

Patulous ET occurs when the ET tube remains patent for long periods of time beyond the normal brief interval of opening. This condition could be related to Ostmann's fat pad atrophy that may develop after substantial weight loss or post-pregnancy.

Patients with patulous ET typically complain of autophonia and aural fullness. When patients lie down, the symptoms usually abate due to venous engorgement of ET mucosa.

Infantile Eustachian Tube

The differences in the anatomy of the ET between infants and adults explain the functional differences that play an important role in the inflammatory pathology of the middle ear and their complications.

Dilatory dynamic dysfunction of the ET is a strong contributor for ET dysfunction in infants. In infants, the shallow tubal angle affects adversely the muscle vector of the TVP, which in addition to the highly compliant tubal cartilage leads to a failure of active opening of ET by TVP muscle contraction [34, 35].

Changes in the tubal angle and the cartilage strength until adulthood are responsible for more efficient active opening of the ET, improved protective role and an improved clearance function (Fig. 7.5 and Table 7.1).

References

1. Proctor B. Embryology and anatomy of the Eustachian tube. Arch Otolaryngol. 1967;86:503–26.
2. Swarts JD, Rood SR, Doyle WJ. Fetal development of the auditory tube and paratubal musculature. Cleft Palate J. 1986;23:289–311.
3. Wolff D. The microscopic anatomy of the Eustachian tube. Ann Otol Rhinol Laryngol. 1934;43:483.
4. Tos M. Growth of the fetal Eustachian tube and its dimensions. Arch Klin Exp Ohren Nasen Kehlkopfheilkd. 1971;198:177–86.
5. Sadler-Kimes D, Siegel MI, Todhunter JS. Age-related morphologic differences in the components of the Eustachian tube/middle-ear system. Ann Otol Rhinol Laryngol. 1989;98:854–8.
6. Siegel MI, Cantekin EI, Todhunter JS, Sadler-Kimes D. Aspect ratio as a descriptor of Eustachian tube cartilage shape. Ann Otol Rhinol Laryngol. 1988;97 Suppl 133:16–7.
7. Siegel MI, Sadler-Kimes D, Todhunter JS. ET cartilage shape as a factor in the epidemiology of otitis media. In: Lim DJ, Bluestone CD, Klein JO, Nelson JD, editors. Recent advances in otitis media: proceedings of the Fourth International Symposium. Burlington: BC Decker; 1988. p. 114–7.
8. Ishijima K, Sando I, Balaban C, Suzuki C, Takasaki K. Length of the Eustachian tube and its postnatal development: computer-aided three dimensional reconstruction and measurement study. Ann Otol Rhinol Laryngol. 2000;109:542–8.
9. Graves GO, Edwards LF. The Eustachian tube: review of its descriptive, microscopic, topographic, and clinical anatomy. Arch Otolaryngol. 1944;39:359–97.
10. Matsune S, Sando I, Takahashi H. Comparative study of elastic at the hinge portion of Eustachian tube cartilage in normal and cleft palate individuals. In: Lim DJ, Bluestone CD, Klein JO, et al., editors. Recent advances in otitis media: proceedings of the Fifth International Symposium. Burlington: BC Decker; 1993. p. 4–6.
11. Suzuki C, Balaban CD, Sando I, et al. Postnatal development of Eustachian tube: a computer-aided 3-D reconstruction and measurement study. Acta Otolaryngol (Stockh). 1998;118:837–43.

12. Orita Y, Sando I, Hasebe S, Miura M. Postnatal change on the location of Ostmann's fatty tissue in the region lateral to Eustachian tube. Int J Pediatr Otorhinolaryngol. 2003;67:1105–12.
13. Prades JM, Dumollard JM, Calloc'h F, Merzougui N, Veyret C, Martin C. Descriptive anatomy of the human auditory tube. Surg Radiol Anat. 1998;20(5):335–40.
14. Sudo M, Sando I, Ikui A, Suzuki C. Narrowest (isthmus) portion of Eustachian tube: a computer-aided three-dimensional reconstruction and measurement study. Ann Otol Rhinol Laryngol. 1997;106:583–8.
15. Bluestone CD, Bluestone MB, Coulter J. Eustachian tube: structure, function, role in otitis media. Hamilton/Lewiston: BC Decker; 2005. p. 25–50.
16. Jen A, Sanelli PC, Banthia V, et al. Relationship of petrous temporal bone pneumatization to the Eustachian tube lumen. Laryngoscope. 2004;114:656–60.
17. Bryant WS. The Eustachian tube: its anatomy and its movement: with a description of the cartilages, muscles, fasciae, and the fossa of Rosenmüller. Med Rec. 1907;71:931.
18. Rood SR, Doyle WJ. The nasopharyngeal orifice of the auditory tube: implications for tubal dynamics anatomy. Cleft Palate J. 1982;19:119–28.
19. Swarts JD, Rood SR. The morphometry and three-dimensional structure of the adult Eustachian tube: implications for function. Cleft Palate J. 1990;27:374–81.
20. Rich AR. A physiological study of the Eustachian tube and its related muscles. Bull Johns Hopkins Hosp. 1920;31:3005–10.
21. Cantekin EI, Doyle WJ, Reichert TJ, et al. Dilation of the Eustachian tube by electrical stimulation of the mandibular nerve. Ann Otol Rhinol Laryngol. 1979;88:40–51.
22. Honjo I, Okazaki N, Kumazawa T. Experimental study of the Eustachian tube function with regard to its related muscles. Acta Otolaryngol (Stockh). 1979;87:84–9.
23. Simkins C. Functional anatomy of the Eustachian tube. Arch Otolaryngol. 1943;38:476.
24. Goss C, editor. Gray's anatomy of the human body. Philadelphia: Lea & Febiger; 1967.
25. Canalis RF. Valsalva's contribution to otology. Am J Otolaryngol. 1990;11:420–7.
26. Abe M, Murakami G, Noguchi M, et al. Variations in the tensor veli palatine muscle with special reference to its origin and insertion. Cleft Palate Craniofac J. 2004;41:474–84.
27. McMyn JK. The anatomy of the salpingopharyngeus muscle. J Laryngol Otol. 1940;55:1–22.
28. Sudo M, Sando I, Suzuki C. Three dimensional reconstruction and measurement of human Eustachian tube structures: a hypothesis of Eustachian tube function. Ann Otol Rhinol Laryngol. 1998;107:547–54.
29. Ishijima K, Sando I, Miura M, et al. Postnatal development of static volume of the Eustachian tube lumen. Ann Otol Rhinol Laryngol. 2002;111:832–5.
30. Lim DJ. Functional morphology of the tubotympanum. Acta Otolaryngol (Stockh). 1984;98 Suppl 414:13–8.
31. Tos M, Bak-Pedersen K. Goblet cell population in the normal middle ear and Eustachian tube of children and adults. Ann Otol Rhinol Laryngol. 1976;85 Suppl 25:44–50.
32. Sando I, Takahashi H, Matsune S, Aoki H. Localization of function in the Eustachian tube: a hypothesis. Ann Otol Rhinol Laryngol. 1993;103:311–4.
33. Mondain M, Vidal D, Bouhanna S. Uziel, Monitoring Eustachian tube opening: Preliminary results in normal subjects. Laryngoscope. 1997;107:1414–9.
34. Bylander A, Tjernstrom O, Ivarsson A. Pressure opening and closing functions of the Eustachian tube by inflation and deflation in children and adults with normal ears. Acta Otolaryngol (Stockh). 1983;96:255–68.
35. Bylander A, Tjernstrom O. Changes in Eustachian tube function with age in children with normal ears: a longitudinal study. Acta Otolaryngol (Stockh). 1983;96:467–77.