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CT Imaging of the Eustachian Tube: Review Article

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ABSTRACT

Background: Over the past century, numerous methods have been used to image the Eustachian tube, but none of them have gained widespread acceptance. Patients with persistent Eustachian tube dysfunction now have an increased need to have their Eustachian tubes examined, thanks to the discovery of balloon Eustachian tuboplasty (BET). Prior to BET, a lot of facilities perform temporal bone and epipharynx computed tomography (CT) scans.

Aim: The aim of our study was to review measures of patency of ET and delineate its interior luminal anatomy in patients with tympanic membrane perforation subjected for myringoplasty in an objective radiologic way by injecting a radiopaque dye into tympanic orifice of ET through TM perforation and tracing it with high resolution computerized tomography scan.

Conclusion: It is possible and safe to visualize the ET lumen in people using intratympanic contrast media, and doing so during a preoperative CT scan does not cover up other important image data.

Keywords: Ear, nose and throat, Eustachian tube, computed tomography, contrast agents, Eustachian tube dysfunction.

INTRODUCTION

A tube called the eustachian tube (ET) connects the nasopharynx to the middle ear cavity (ME). It is roughly 36mm long in adults and has a downward and forward pointing tip. Its medial two thirds are cartilaginous and open about a centimeter below the inferior turbinate's posterior end in the supero-lateral wall of the nasopharynx. Its bony lateral third opens in the front wall of ME [(1)]. When the body is at rest, the tube is usually closed. The tensor palati and, to a lesser extent, the levator palati actively open the tube during swallowing and yawning. The major purposes of the ET are to allow fluids from the ME to drain and to equalize air pressure on both sides of the tympanic membrane [(2)].

Gas transfer, nasopharynx-to-ME pressure equalization, ME mucus clearing, and nasopharynx sound or fluid reflux prevention are actually its three major functions [(3)]. A lack of dilatory function that causes secondary ear pathology and is referred to as "eustachian tube dysfunction" might be caused by mechanical, functional, or obstructional factors. Aberrant ET function is one of several factors that contribute to ME pathology and is essential for the emergence of ME diseases [(4)]. Auditory tube dysfunction raises the negative pressure within the ME, which causes intravascular fluid to migrate into interstitial spaces and then to the lumen of the tympanic cavity, causing the eardrum to retract and increasing the risk of chronic ME problems. As a result, the pathogenesis of chronic otitis media is influenced [(5)]. The function of the ET with an intact and perforated tympanic membrane was assessed using a number of tests, including the valsalva test, the politzer test, the toynbee test, catheterization, the saccharine or methylene blue test, sonotubometry, and tympanometry (TM). The aim of our study was to review measures of patency of ET and delineate its interior luminal anatomy in patients with tympanic membrane perforation subjected for myringoplasty in an objective radiologic way by injecting a radiopaque dye into tympanic orifice of ET through TM perforation and tracing it with high resolution computerized tomography scan.

Adult anatomy of Eustachian tube

The ET in adults is about 36 mm long and forms a 45-degree angle with the horizontal as it travels downward, forward, and medially from its tympanic end. It is divided into two sections: fibro cartilaginous, which is anteromedial and constitutes two-thirds of the length, and bony, which is posterolateral and makes up one-third (12mm) of the entire length (24mm). The isthmus, the tube's narrowest section, is where the two segments come together [(6)]. The usual range of the adult ET's reported length is 31 to 38mm, despite measurements as short as 30mm and as large as 40mm. beginning in the adult's nasopharynx, the ET passes through the petrous temporal bone and continues laterally and posteriorly. Instead of moving straight from the nasopharynx to the middle ear, the tube takes a gradually curving inverted S course [(7)].

Histologically, goblet cells that release mucus are scattered throughout the pseudo-stratified ciliated columnar epithelium that makes up the mucosa. The submucosa contains a lot of seromucinous glands, notably in the cartilaginous part of the tube. By beating in that direction, the cilia help to drain fluid and secretions from the middle ear into the nasopharynx. There were numerous ciliated cells, glands, and goblet cells in the floor's mucosa. These results prompted ***Orita et al.*** to hypothesize that the cartilaginous component of the tube's superior lumen is probably connected to the tube's ventilation (pressure regulation) function, while the lower lumen is linked to the tube's clearance function. The first 20 years of life saw a gradual disappearance of these mucosal folds [(8)]. The blood arteries that supply ET are the ascending palatine artery, ascending pharyngeal artery, middle meningeal artery,

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artery of the pterygoid canal, and veins emptying into the pterygoid venous plexus [(9)].

Eustachian Tube Functions

Ventilation and the resulting control of ME pressure: It is crucial for normal hearing that the pressure on the tympanic membrane's two sides be equal. Hearing is impacted by the positive or negative pressure in the middle ear. Therefore, ET should open occasionally to allow the middle ear's air pressure to equalize with the surrounding atmosphere defending action [(10)]: If the tube is open, abnormally high sound pressures from the nasopharynx may be conveyed to the middle ear, impairing normal hearing. The ET normally closes and shields the middle ear from these noises. The mucous membrane of the ET and anterior portion of the middle ear is lined by ciliated columnar cells, which are used to remove middle ear secretions. The cilia were beating toward the nasopharynx. This aids in moving dirt and secretions from the middle ear towards the nasopharynx. Active opening and closing of the tube enhances the clearance function even further [(11)].

Radiologic imaging of the Eustachian tube

Only one year after the invention of the x-ray, contrast media's initial application in radiology was described in 1896. Dr. Spielberg first described seeing the ET in 1927 by pumping an iodinated solution into a silk catheter that was placed via the nose. His 22 radiographs show healthy middle ears with iodine coating and a patient with chronic otitis media without iodine in the middle ear [(12)]. The non-toxic properties of paraaminohippuric acid, which could bind three iodine atoms per molecule, were discovered by chemist Wallingford in 1933. It was from this that modern contrast media was born. The following contrast substances were uncomfortable, but secure due to their viscosity and ionic composition. More water-soluble contrast media were developed in the 1950s and 1960s. There are water soluble contrast media with high and low osmolalities [(13)].

CT imaging tissues are assigned a particular shade of gray based on the Hounsfield scale's evaluation of the permeability of tissues to x-rays. The CT scan creates a beautiful image of the temporal bone structures with excellent spatial resolution since the two main components of the temporal bone, bone and air, are on opposite ends of the scale. Because of this, CT is widely used to diagnose temporal bone issues, and the majority of scans are performed without the use of intravenous or targeted contrast agents. A CT scan can assist in identifying conditions that may make balloon eustachian tuboplasty (BET) more challenging, such as cholesteatomas, or that may directly contribute to OME, such as epipharyngeal masses. The CT images will also display the anatomical conditions, which may vary from patient to patient [(14)].

The creation of a multi detector CT (MDCT) led to an increase in image resolution, a decrease in scan time, and an improvement in image quality (which equates to the amount of time the patient must remain still). If there is no air inside the cartilaginous ET lumen, a standard CT scan won't reveal it. In MDCT, detectors are positioned across from the source and an x-ray beam is formed like a fan. They rotate concurrently along the patient's axis, each rotation capturing a 2D slice or volume. After the scan is recorded in a helical form with some overlap, slices are stacked to capture an intact volume of the scanned area. Compared to maxillofacial imaging, metal artifacts in the temporal bone are less frequent; however they can still be observed in patients who have ossicular metal prostheses and hearing aids, such as cochlear implants and BAHAs. Artifacts reduction in CT is essential since the MRI device might be defective or dangerous. Due to the advancement of the multi detector technique and an increase in the number of detector rows, a sizable number of picture slices can be captured in a single rotation. This suggests that a single spin can provide the whole field of vision needed for a temporal bone assessment. Because of the quick scan time, MDCT is less prone to movement artifacts [(15)]. The two clinical requirements for radiological evaluation of the ET are accurate anatomical imaging of the ET and its surrounding structures for surgical planning and valid ET function testing. Research on novel drugs has been hampered and patient selection for new therapies has grown more difficult as a result of the absence of valid outcome indicators for ETD. To evaluate ET function, imaging may be a helpful, non-invasive method. Surgery in this region can be risky due to the ET's close proximity to the internal carotid artery and other skull base structures, as well as inter-patient anatomical variation. Surgeons are increasingly using imaging in the preoperative planning stage for challenging procedures like skull base surgery, ET excision in malignancy, and cutting-edge treatments for ETD like balloon dilatation tuboplasty**.** Because it fills in the knowledge gaps left by cadaveric dissection and in vivo endoscopy, imaging has been crucial in assisting us in understanding the structure and dynamic activity of the ET. This, together with the changing clinical demand. It's possible that other imaging techniques will improve our understanding of ETD [(16)].

ET Function Tests

1- Valsalva test: The goal of both this test and politzerization is to create a positive pressure in the nasopharynx, which will allow air to enter the ET. The patient tries to blow air into his ears while closing his mouth, taking a deep breath, and pinching his nose between his thumb and index finger. The tympanic membrane will migrate outward if air enters the middle ear, which can be seen with an otoscope or a microscope. A hissing or crackling sound is created when the tympanic membrane is perforated, depending on whether the middle ear discharge is also present [(17)].

2- Politzer test: Children who are unable to perform the valsalva test are subjected to this test. This test involves inserting the olive-shaped tip of the politzer bag into the patient's nostril on the side that will have its tubal function evaluated. The patient swallows while the other nostril is blocked and the bag is compressed [18].

3- Catheterization: A Eustachian tube catheter with a bent tip runs along the floor of the nose until it reaches the nasopharynx in this test. First, the nose is lignocaine topical sprayed to anaesthetize it. Here, it turns 90 degrees to the middle and slowly dragged back until it engages with the nasal septum's posterior edge. Then it turns 180 degrees laterally so the tip is up against the tubal hole.

4- Toynbee's test: The Toynbee maneuver results in negative pressure, as opposed to the positive pressure used in the previous three tests. It involves more bodily functions. The procedure involves pinching the patient's nose and requesting them to swallow. This causes the tympanic membrane to migrate inward and sucks air from the middle ear into the nasopharynx, which the examiner can see through otoscopy or under a microscope [19].

5. Tympanometry: (also known as the inflation-deflation test, or IDT) is a procedure that uses changes in air pressure in the ear canal to assess the health of the ME as well as the mobility of the ear drum and the conduction bones. Additionally, it's used to determine whether an ET function is intact or perforated. Tympanometry can be carried out in a hearing specialist's or a physician's clinic. First, the doctor will insert an otoscope into your ear to visually examine your ear canal and ear drum.

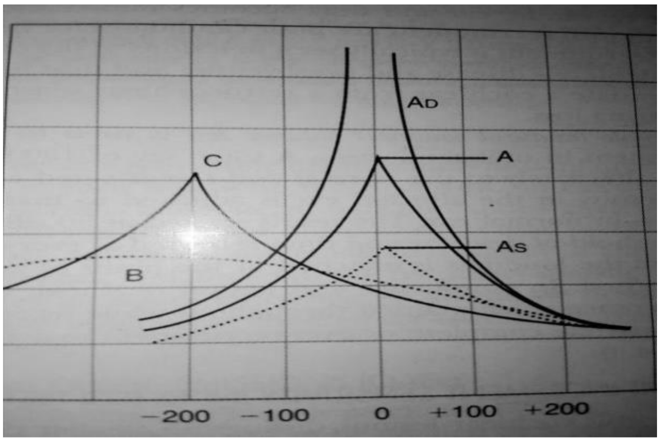

Figure 1: Types of tympanogram.

6- Radiological test: The tube and any obstruction should be visible on x-rays after hypaque or lipoidal dye is injected into the middle ear through a pre-existing puncture. The amount of time it takes the dye to reach the nasopharynx also reveals how well it clears. This test is no longer widely used nowadays [20].

7- Saccharine or methylene blue test: Through a pre-existing puncture, a saccharine solution is injected into the middle ear. Another indicator of clearing function is how long it takes for a sweet taste to be imparted in the pharynx. The time it takes for methylene blue dye to stain pharyngeal secretions can also be measured after being injected into the middle ear [21].

8- Sonotubometry: The external canal is used to record the tone that is delivered to the nose. When the tube is patent, the tone is audible louder. Additionally, it provides the time frame during which the tube is open. It offers details on active tubal opening and is a non-invasive procedure. When swallowing, the nasopharynx produces additional sounds that could affect the test's outcome [22].

9- Endoscopy: The goal of the first endoscopic exams of the Eustachian tube was to validate its patency. Techniques for looking into the tube using the transtympanic and transnasal approaches were described**.** Slow motion video endoscopy has lately been used to visually evaluate ET function. Tympanometric evaluations of ET function and the tubal appearance during swallowing have been found to be correlated, and efforts have been made to quantify dilatory motions at the ET orifice in healthy and ETD groups [23]**.**

Middle ear disease and Eustachian tube dysfunction

Albeit widely considered and talked about, the mechanics of ME pressure evening out are still just to some extent figured out**.** It is imagined that the two principal factors impacting typical ME pressure are the kickoff of the ET and resulting development of an air bolus to or from the center ear. It is exhibited that inside a 24-hour observing period, greater and quicker pressure changes are interesting [24]**.**

The physiology and pathophysiology of intratympanic pressure should be perceived, yet we right now have hardly any familiarity with how typical ear gas pressure is controlled. The gas strain inside the ME is impacted by various elements, including the gas' structure, dissemination into and out of the mucosa, equilibration with the nasopharynx through opening the ET, and dynamic expansion or departure, (for example, by sniffing, cleaning out one's nose, or playing out the Valsalva move). Chemoreceptive reflexes might have the option to direct ME pressure, as indicated by some exploration [25]**.**

The systems behind ET brokenness are hazy, and the causes are confounded.The center ear's waste and ventilation are the most often impacted capabilities.Blockages that influence these capabilities primarily or practically may think twice about. Tympanic layer withdrawal and negative strain in the center ear are likewise side effects of ETD. Tympanic film withdrawals can prompt different following illnesses, including atelectasis, glue otitis, hole, and, in the most pessimistic scenarios, cholesteatoma, an uncommon yet possibly unsafe and harming outcome to ET capability [26]. The pathophysiology of the tubal framework can be summarized as follows:

The cylinder won't open; it's excessively firm, short, or shut; excessively floppy, solid, or shut; or there's a strange strain at one or the flip side of the ET; or the framework is excessively shut or open at one or the flip side of the cylinder. The pathophysiology can be additionally partitioned into the accompanying classes: breakdown in pressure guideline, loss of the defensive capability, and brokenness in freedom [27].

Impairment of pressure regulation:

Allergies or viral or bacterial infection-related inflammation might restrict the lumen or the periluminal tissues (intrinsic obstruction). Congenital or acquired tube stenosis has been observed in adults, while being uncommon in children. The cartilaginous portion of the tube may become peritubal (extramural) occluded due to compression brought on by a tumor or an adenoid mass [28]**.** The tubal cartilage may continue to collapse because infants have less cartilage than older children and adults, which could prevent the tube from opening. With an ageing cartilage cell density, the stiffness of the tubal cartilage in newborns and young children can vary [29].

Comparing older children, teenagers, and adults with otitis media to healthy individuals while testing the tube's functionality demonstrated paradoxical constriction of the Eustachian Tube after eating. The exact cause of the ET's constriction during swallowing is currently unknown, however abnormalities in the muscles that support the tubal cartilage, such as the levator palatini and tensor veli palatine, may be responsible [30].

Loss of protective function:

In the limit, the ET's lumen is generally open, in any event, when it is very still. It is excessively open; this is alluded to as a strangely patent or patulous tube. Less extreme instances of deviant patency lead to semipatulous tubes, which are shut when very still however have lower lumen stream opposition than a typical cylinder. Expanded tube patency might be welcomed on by sporadic tubal calculation, a drop in peritubal pressure, which can happen following weight decrease, or periluminal causes [29]**.**

The center ear pressure is effectively constrained by a patulous ET, which is excessively open and commonly permits gas to pass from the nasopharynx into the center ear without any problem.

In any case, when the cylinder is unreasonably patent, unwanted emissions from the nasopharynx can all the more effectively enter (reflux or be insufflated) to the center ear [31]**.** Furthermore, whenever strong positive nasopharyngeal tensions form at the proximal end of the ET framework, the cylinder's defensive job might be compromised. At the point when this unnecessarily high strain happens, for example, when somebody cleans out their nose, a newborn child cries, or there is a nasal or nasopharyngeal deterrent, nasopharyngeal emissions might insufflate into the center ear [32]**.**

Impairment of Clearance Function:

The inability of the cylinder to open has also been linked to injuries to the nasogastric and nasal endotracheal tubes (i.e., the cylinder is excessively shut); the sense of taste; the pterygoid bone; the tensor veli palatini muscle (i.e., the cylinder won't open); and the mandibular portion of the facial nerve (i.e., the cylinder won't open or. Another reason had been accounted for as of late by **Unlu *et al.*** [33] who found impermanent tubal brokenness and aural completion following adenoidectomy in youngsters without otitis media.

An intriguing ongoing report by Park and partners **Park *et al.*** [34] found that patients with internal ear issues had ET brokenness**.**

The initial component of the cylinder may likewise glitch, bringing about otitis media, assuming harmless or dangerous neoplastic sickness influences the sense of taste, pterygoid bone, or tensor veli palatini muscle [35].

CONCLUSION

The eustachian tube has a significant impact on the middle ears' health. It is not the only critical element in the pathophysiology of CSOM, despite the fact that its function or inflammation increases the risk of the disease. Numerous E.T. function tests exist. E.T function testing using tympanometry and CT contrast delineation is one of them.. The Eustachian tube is a mysterious structure that its function can never be predicted accurately by any mean. As some of such cases proved to be obstructed objectively on CT delineation, yet, with successful outcome. Others, proved to be patent, yet with poor outcome, the explanation is vague

DECLARATIONS

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