A Novel Functional Imaging Method of the Eustachian Tube

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ABSTRACT

Outcome Objectives: 1) Image the Eustachian tube (ET) lumen by CT scanning during ET function (ETF) testing; 2) Characterize the differences in image quality for different scanning protocols, and 3) Establish a novel research methodology for studying ET anatomy and physiology.

Methods: In a cadaver head without craniofacial or otologic abnormalities, the tympanic membrane was perforated and ETF test was done using the forced response test (FRT) in a CT scanner. Opening OP, steady (PS) and closing (CP) pressures were measured during forced air flow from the middle ear (ME) to the nasopharynx across the open ET. Temporal bone CT scans with 0.25 mm thickness were done at a low and standard radiation doses before and during the steady flow (SF) phase of the FRT, after instilling iodinated contrast into the ME and ET, and after the FRT cleared the contrast from the ET. Multipleplan reformats of the ET were created using post-processing software.

Results: The average OP, PS and CP values were 488±249, 376±101 and 211±52 daPa. While a distinct ET lumen could not be demonstrated during the FRT done with air at any radiation dose, CT with intra-luminal contrast clearly demonstrated the entire ET lumen. Post-contrast FRT demonstrated residual contrast outlining the lumen.

Conclusion: Standard temporal bone CT dose provided a slightly better signal-to-noise than low dose CT but neither provided adequate spatial resolution to demonstrate an air filled ET during FRT. ET lumen was easily visualized with iodinated water soluble contrast at all radiation doses. Combining ETF testing and CT imaging has potential research applications.

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INTRODUCTION

The Eustachian tube (ET) is a natural tube that connects the middle ear (ME) to the back of the nose (nasopharynx). The posterior 1/3 of the ET is a bony extension of the ME with a patent lumen while the anterior 2/3 is a membranous-cartilaginous structure that opens into the nasopharynx. The physiologic functions attributed to the ET are middle ear pressure regulation, clearance of secretions and protection from reflex of nasal secretions. The ET is usually closed due to the natural pressure of the surrounding tissue and is opened intermittently by the active contraction of the tensor veli palatini (mTVP) and levator veli palatini (mLVP) muscles, allowing equilibrium between the ambient and middle ear pressures.

Inefficient ET openings are associated with the progressive development of ME under pressure and set the basis for several middle ear diseases such as acute and chronic otitis media, otitis media with effusion (OME), retraction pockets, cholesteatoma, barotrauma and hearing loss.

The ET is located at the base of the skull and its complexity and difficult access resulted in frustrated attempts of imaging studies previously. Another challenge comes from the fact that the ET has a virtual lumen that only opens for a few hundred milliseconds during middle-ear and ambient pressure equalization (0.2 – 0.4 sec on average). An example of ET imaging is nasopharyngoscopy, a routine outpatient procedure in which a flexible or rigid endoscope is introduced through the nostrils allowing examination of the nasal cavity and the back of the nose. It requires expensive equipment, the use of topical anesthesia and decongestants, is uncomfortable and cannot be tolerated by many patients, especially young children. Although it is very useful for assessment of peribulbar diseases and nasal and pharyngeal infectious or inflammatory processes, it only allows the visualization of the opening of the tube and sometimes a few millimeters of the lumen.

Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) and imaging techniques largely used by the medical community to study biological tissues from all regions of the body. The development of high resolution three-dimensional (3-D) reconstruction software has broadened their use to explore the anatomy of small structures such as the ET. Initially, MRI seemed to be the technique of choice to study the nasal cavity and surrounding tissues along all ET dimensions (3-D) with excellent image quality. By using dedicated post-processing software (Virtex®; CoreVital Images, Minnetonka, MN), Axial oblique and coronal oblique 1 mm thick reconstructions with 1 mm increment parallel and perpendicular to the long axis of the ET were obtained.

RESULTS

Scanning of a cadaveric head was performed using a 64-channel multidetector CT scanner (GE LightSpeed VCT; GE Healthcare, Milwaukee, WI). Forced Response Test (FRT) was performed by running air with a pump from the external ear canal, through middle ear and into the ET as the nasopharynx. FRT standard speed was 23 cm/min and high speed was 60 cm/min. This was repeated after injection of water soluble iodinated contrast (IO) through the middle ear.

The sequence of CT protocols performed were as follows with example images provided in Figure 1: 1. A (localizer) - Low dose (100kVp, 180mA, pitch 0.969) 2. B (helical) - Low dose (100kVp, 200mA, pitch 0.531) with standard speed FRT 3. B CT technique with IC 4. B CT technique with IC and standard speed FRT 5. Standard dose Temporal bone CT (120kVp, 195 mA) with standard speed FRT 6. B CT technique with IC and high speed FRT 7. High dose CT (120Vp 320 MA) with IC and high speed FRT

Axial 0.625 mm bone and 1.25 mm soft tissue reconstructions were performed for all scans. An edge enhancing reconstruction kernel was used (Bone Plus; GE Healthcare, Milwaukee, WI). All protocols were performed by a CAQ certified neuroradiologist (T.J.R) using dedicated post-processing software (Virtex®; Core Vital Images, Minnetonka, MN). Axial oblique and coronal oblique 1 mm thick reconstructions with 1 mm increment parallel and perpendicular to the long axis of the ET were obtained.

A. 1.25 mm in soft tissue algorithm, soft tissue window (Window 145, Level -5). The patulous ET (black arrows) is seen similar in density to subcutaneous fat (while arrow) displayed as dark grey. No definite air density could be visualized in the eustachian tube when using air (white arrow) in the nasopharynx as a reference.

B. Displayed in thinner 0.625 mm bone algorithm with a lower level (Window 432, Level -200). Small loss of air (black arrows) were suspected in the eustachian tube using air (white arrow) in the nasopharynx as a reference.

C. When the window was narrowed and dichotomized (Window 432, Level -200) to show only air displayed as black, versus all other densities displayed as white, only 2 small loss of air (black arrow) could be seen, suggesting that air passing through the eustachian tube during the forced response test is not clearly detected by CT due to inadequate spatial resolution and partial volume averaging with adjacent paratubal fat.