Eustachian Tube: Computed Tomography Analysis

Mohammad Waheed El-Anwar, MD, Diaa Bakry Eldib, MD,† Ahmed Abdel Fattah Nofal, MD,* and Alaa Omar Khazbak, MD**

Background: Eustachian tube has a major role in ventilation, drainage, and protection of the middle ear. High resolution computed tomography magnifies the role of preoperative imaging for detailed inner and middle ear anatomical information. The aim of this study was to find an applicable way by computed tomography imaging for assessment of Eustachian tube. The goal was to provide improved understanding of the Eustachian tube measurements and the relationship with middle ear in Egyptian population. Computed tomography measurements for Eustachian tube were done including; length of the bony and cartilaginous portions, Total length of Eustachian tube, as well as the width and height of the tympanic orifice of the Eustachian tube. Also, tubotympanic and Reid plane-Eustachian tube angles were measured.

Results: Within 200 studied ears in 100 subjects, the mean total Eustachian tube length was 40.19 ± 3.05 mm, mean length of the bony Eustachian tube was 11.69 ± 1.8 mm with significant longer Eustachian tube on left side, The mean length of the cartilaginous Eustachian tube was 28.5 ± 2.95 mm with significantly longer cartilaginous and total length in male ($P < 0.0001$). The mean width and height of the tympanic orifice of the Eustachian tube was 5.4 ± 0.79 and 4.85 ± 0.75 mm, respectively. The mean tubotympanic angle of the Eustachian tube was $148.11 \pm 2.82^\circ$. The mean Reid plane- Eustachian tube angle was $27.69 \pm 2.08^\circ$ with significantly wider angle in males ($P < 0.022$).

Conclusion: The Eustachian tube measurements can easily be obtained on computed tomography images, and are representative for the Eustachian tube anatomy. There is importance of extending computed tomography examinations beyond the middle ear cavity and the mastoids to the Eustachian tube in order to have more data on its condition and relations with different pathological conditions. Computed tomography provides improved understanding of the Eustachian tube measurements and relationship with middle ear structures.

Key Words: Bony portion of Eustachian tube, cartilaginous portion of Eustachian tube, computed tomography, Eustachian tube

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Eustachian tube dysfunction is considered the most common reason for middle ear ventilation problems and Eustachian tube (ET) has a major role in ventilation, drainage and protection of the middle ear.[1] So, ET anatomy continues to be a focus of research. The ET is composed of a cartilaginous portion and a bony portion with the narrowest point connecting the 2 parts is the isthmus that is considered as surgical limiting point.[2]

There is little focus on the importance of cartilaginous ET length, which is recently the target of balloon dilatation procedures. It is well known that the length varies greatly. If the surgeon knows these measurements in advance, it will help to choose the length of the balloon and offer data on how far-away the catheter needs to be inserted to reach ET isthmus. Preoperative measurement can facilitate improved catheter placement and contribute to a safe procedure.[3]

In addition, identification of the length of the osseous part may carry some importance in dealing with the bony part through the tympanic membrane using the otoendoscope. Surgeons increasingly need imaging in preoperative preparation for new interventions for ET disorders such as balloon dilation tuboplasty. The proximity of the ET to major important structures such as the internal carotid artery and other skull base structures, together with anatomical variations, represent challenges and risks in this area.[4]

Previous studies have been conducted on the anatomy of the ET and its variance either on radiological studies such as computed tomography (CT)[5,6] and magnetic resonance[7] or even on human cadaveric temporal bone.[8,9] However, our search of the literature revealed that there are no studies in the Arab population. So, in the current study, we focus on the anatomical evaluation, measurements and angles of the ET on Arab population (Fig. 2).

PATIENTS AND METHODS

We retrospectively studied randomly selected CT images of non-pathologic temporal bones belonging to 100 subjects (200 sides) from January 2017 to January 2019. The study was approved by the research ethical committee. As our study was retrospective study, informed consent was not required.

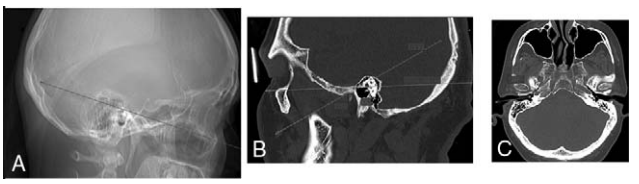

FIGURE 1. (A) CT scanogram showing Reid horizontal plane, the plane passing through the inferior orbital wall (1) and superior wall of the external auditory canal (2). (B) Sagittal oblique CT image showing measurement of Reid plane-ET angle, the angle between the Reid horizontal plane and plane of ET. (C) Axial CT image showing measurement of Right tubotympanic angle, the angle between the line extending through the tympanic orifice of the ET and the longitudinal axis the bony external auditory canal. CT, computed tomography; ET, Eustachian tube.

From the *Otorhinolaryngology-Head and Neck Surgery Department, Zagazig University, Zagazig; and †Radio Diagnosis Department, Benha University, Benha, Egypt.

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Address correspondence and reprint requests to Mohammad Waheed El-Anwar, MD, Otorhinolaryngology, Head and Neck Surgery Department, Faculty of Medicine, Zagazig University, Egypt;
E-mail: mwenteg@yahoo.com

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Exclusion criteria included patients aged below 18 years, history of surgery or trauma in ear and/or skull base, congenital anomalies of the face or paranasal sinus malignancies.

Data Acquisition and Post-Processing

All CT examinations for paranasal sinuses and skull base done using multi-detector row CT a 64 multislice CT scan (Light speed volume VCT; GE medical system, Milwaukee, WI) in helical mode. The raw data was exported by a dedicated post-processing workstation (Advantage Workstation 4.5, GE Medical System) and the images were generated for the temporal region following temporal bone imaging protocol. Scans parameters include: Tube voltage of 120.0 kV and a current of 180.0 mA. Images were reconstructed using 0.5-mm-thick sections at 0.5-increments; using a 512×512 matrix of 0.43 mm pixel size and a field of view of 22×22 cm. Images were displayed using a window center of 700 HU and a window width of 4000 HU.

The multiplanar reconstruction technique was used to reconstruct the CT images of ET, the axial plane was then tilted anteroinferiorly along the course of the ET between the superior point of the tympanic and pharyngeal orifices to produce oblique axial images until the whole length of the ET was visualized.

To achieve uniformity throughout this cranio-metric study and to resolve the asymmetry associated with patient positioning, the Reid horizontal plane was taken to be the standard horizontal plane (Fig. 1). Reid horizontal plane is defined as the plane connecting bilateral inferior orbital walls and superior walls of the bilateral external auditory canals. This plane is considered to be the neutral anatomical position of the head.[10,11]

Measurements

In our study, we defined each anatomic landmark of the ET and ET measurements following the methods used in previous studies[12–16] as described in Supplementary Digital Content, Table 1, http://links.lww.com/SCS/B403.

Statistics

All data were shown as means and standard deviation. Two-tailed, unpaired Student *t* tests were used to determine statistical significance when comparing right and left sides as well as the male and female subjects. All statistical data were analyzed with the SPSS program version 25 (Chicago, IL). The significance level was set at $P < 0.05$.

RESULTS

Two hundred ears of 100 subjects were included; 50 (50%) females and 50 (50%) males. Their age ranged from 18 years to 76 years (mean = 38 ± 13.29 years).

FIGURE 2. (A) Oblique axial CT image showing The ET on both sides, (1) The bony potion of ET, (2) The isthmus of ET, (3) The cartilaginous potion of ET, and (4) The pharyngeal orifice of ET, (5) Measurement of the bony potion of ET, (6) Measurement of the cartilaginous potion of ET. (B) Sagittal CT image showing measurement of the width and height of Tympanic orifice of ET. Arrow points to the supratubal recess, a landmark for tympanic orifice of ET. CT, computed tomography; ET, Eustachian tube.

The mean length of the bony ET (BonyET-L) was 11.69 ± 1.8 mm (11.36 ± 1.72 mm at right ears and 12.02 ± 1.85 mm at left ears). While the mean BonyET-L in male was 11.81 ± 1.61 mm and in female was 11.55 ± 2.02. Significant differences were found in length of the bony ET (BonyET-L) between right and left ears ($P < 0.0004$). No significant difference was observed between male and female subjects ($P < 0.31$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

The mean length of the cartilaginous ET (CartiET-L) was 28.5 ± 2.95 mm (28.15 ± 3.88 mm at right ears and 28.45 ± 3.86 mm at left ears). While the mean CartiET-L was 29.33 ± 3.74 mm in male and was 27.09 ± 3.66 in female. Highly significant differences were found in CartiET-L between male and female subjects ($P < 0.0001$). No significant difference was observed between right and left ears ($P < 0.5842$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

The mean total length of the ET (ET-TL) was 40.19 ± 3.05 mm (39.51 ± 3.87 mm at right ears and 40.47 ± 3.97 mm at left ears). While the mean ET-TL in male was 41.14 ± 3.83 mm and in female was 38.64 ± 3.65. Highly significant differences were found in ET-TL between male and female subjects ($P < 0.0001$). No significant difference was observed between right and left ears ($P < 0.$ 0.08) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.-com/SCS/B403).

The mean width of the ET tympanic orifice (ET-TO-W) was 5.4 ± 0.79 mm (5.36 ± 0.78 mm at right ears and 5.45 ± 0.81 mm at left ears). While the mean ET-TO-W in male was 5.38 ± 0.76 mm and in female was 5.43 ± 0.84. No significant difference was observed in ET-TO-W between right and left ears ($P < 0.42$) or between male and female subjects ($P < 0.66$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

The mean height of the ET tympanic orifice (ET-TO-H) was 4.85 ± 0.75 mm (4.88 ± 0.89 mm at right ears and 4.82 ± 0.59 mm at left ears). While the mean ET-TO-H in male was 4.85 ± 0.74 mm and in female was 4.86 ± 0.77. No significant difference was observed in the ET-TO-H between right and left ears ($P < 0.57$) or between male and female subjects ($P < 0.92$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

The mean tubotympanic angle of the ET was 148.11 ± 2.82 (148.33 ± 2.94 at right ears and 147.88 ± 2.68 at left ears). While the mean angle was 148.15 ± 2.7 in males and was 148.06 ± 2.96 in females. No significant difference was observed in the angle between right and left ears ($P < 0.26$) or between male and female subjects ($P < 0.83$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

The mean Reid plane-ET angle was $27.69 \pm 2.08^\circ$ ($27.86 \pm 2.1^\circ$ at right ears and $27.52 \pm 2.06^\circ$ at left ears). While the mean angle was $28 \pm 2.13^\circ$ in males and $27.33 \pm 1.97^\circ$ in females. Significant difference was observed between male and female subjects ($P < 0.02$) while no significant difference was observed between right and left ears ($P < 0.25$) (Supplementary Digital Content, Tables 2 and 3, http://links.lww.com/SCS/B403).

DISCUSSION

A normally functioning ET is necessary for preserving a healthy middle ear and normal hearing. Detailed anatomy, functions and imaging options of the ET are still areas that are poorly understood by the otolaryngologists and radiologists. With recent advances in the surgical management of ET disorders and with the introduction of ET balloon dilatation, it is the time to review what imaging can add to our understanding and diagnosis of ET pathological conditions.[17]

The angles, length, and diameter of the ET can be precisely measured using CT with the multiplanar reconstruction technique. Sudo et al[18] measured the length of the cartilaginous portion of ET

using computer reconstructions of cadaver specimens. But, both Dinc et al[13] and Takasaki et al[19] measured the ET as one unit without isolating the bony and cartilaginous portions. While the cartilaginous part represents the treatment target. Thus, in our study, we measured the whole length of ET as well as the length of the cartilaginous and the bony portions of the ET in living subjects.

In our study, the mean length of the cartilaginous ET (CartiET-L) was 28.5 ± 2.95 mm. Falkenberg-Jensen et al[20] studied 29 adult patients with ET dysfunction and found that CartiET-L (measured by CT) was 26.7 ± 2.1 mm without significant difference between left and right side. But we registered that females had significantly shorter CartiET-L than males ($P < 0.0001$) in line with results of Falkenberg-Jensen et al study.[20]

The present study demonstrated that the mean total length of the ET (ET-TL) was 40.19 ± 3.05 mm with non-significant difference between right and left sides. While, the ET-TL was significantly shorter in female than in male. Similar findings were detected by Dinc et al[13] (mean ET length = 40 mm). On the other hands, Takasaki et al[19] registered that the mean ET length was 42.56 ± 2.8 mm for the right ear and 42.96 ± 2.9 mm for the left ear and Ishijima et al[21] reported that the mean ET length was 37 mm. In our study, the mean ET-OT-W and ET-OT-H were reported to be 5.4 ± 0.79 and 4.85 ± 0.75, respectively, which in line with Hong et al[14] measurements.

In our study, the Reid plane-ET angle measurement in normal individuals was $27.69 \pm 2.08^\circ$ that seems to be close to these measurements of Takasaki et al ($27.3^\circ \pm 2^\circ$)[19] and Nemade et al[16] ($28.84^\circ \pm 3.97^\circ$). While in Dinc et al study,[13] the mean ET angle in normal ears was $23.6 \pm 2.4^\circ$ and in Masita et al study,[22] it was $33.61 \pm 3.83^\circ$. These differences may be related to the used measurement methods and/or the racial differences.

The tubotympanic angle is an angle more recently associated with chronic otitis media and cholesteatoma.[15] In our study, the mean tubotympanic angle was $148.11 \pm 2.82^\circ$, which is in line with Aksoy et al[15] results ($147.13 \pm 6.38^\circ$) and slightly differs from Nemade et al[16] results ($145.14 \pm 4.34^\circ$).

Balloon dilation of the ET is a recent treatment procedure for obstructive ET dysfunction. The balloon is positioned in the cartilaginous portion of ET. Thus, preoperative measuring the length and diameters of the cartilaginous portion in the CT of each patient will assist the surgeon in choosing of catheter length and also in properly placing the balloon.[20] So, there is an increasing need to know the length of the ET to improve treatment outcomes of its balloon dilatation. Moreover, a significantly shorter balloon is expected to be prepared for female than for male because as we detected in the current study, females had significantly shorter CartiET-L. In addition, females were found to have less Reid plane-ET angle than males. Thus, adding these measurements to the CT check list before balloon dilatation is critically important.

It is important to extend the CT examinations beyond the middle ear cavity and the mastoids to the ET in order to have more data on its condition and the relations of ET measurements with the different middle ear pathological conditions. The current study collects almost all the measurements of the ET that could be measured on the CT to increase familiarity and orientation of these measurements between surgeons and radiologists. This is demanded with growing use of balloon tuboplasty and ET endoscopy. Moreover, the study puts the base of ET lengths, diameters and angles in Arab peoples.

CONCLUSION

Computed tomography is helpful in showing the whole length of ET, the bony and cartilaginous portions, and the tympanic and nasopharyngeal orifices. The ET measurements can easily be obtained on CT images, and are representative for the ET. CT provides improved understanding of the ET measurements and relationship with middle ear structures.

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