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Morphometry of the external auditory canal: Radiological study

Dış kulak yolunun morfometrisi: Radyoloji çalışması

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Abstract

Aim: Morphometry of the external auditory canal was not previously studied among the normal population in the literature. In this study we aimed to indicate normal values and age, gender, and side related changes of the external auditory canal of healthy individuals.

Methods: Computed Tomography (CT) images of 379 patients were evaluated in this cross-sectional study. Two diameters at three points were measured on sagittal images for each side: First point was at the level of the tympanic membrane where chorda tympani leaves the bony canal. The height (1a) and width (1b) were measured from the ground where the cylindrical view of EAC was most prominent. The second point was at isthmus level, where height (2a) and width (2b) were measured. The third point was the most lateral site of external auditory canal (EAC) at the level of the tympanomastoid suture where height (3a) and width (3b) were measured. Age, gender, and side related changes for each measurement were statistically analyzed.

Results: The diameter of each point in each direction was similar between the left and right sides. The median diameter of left 1a was 9.4 mm in males and 9.2 mm in females, which was significantly different. The "a" diameter of each point was higher in males than females for both sides. There was no significant difference between males and females in terms of b diameters. Diameter 1b was higher on the left side compared to the right side for females, while left-right side comparisons for other measurements were similar. None of the diameters differed between the left and right sides for males.

Conclusion: Normal measurements of EAC diameters and its age, sex and side related changes are important for surgeons, radiologists, and anatomists. Proper evaluation of EAC is critical for transcanal endoscopic ear surgery and early diagnosis of a pathology impairing the anatomy of EAC on radiologic images.

Keywords: External auditory canal, Temporal bone, Morphometry, Computed tomography

Öz

Amaç: Literatürde dış kulak yolu morfometrisi normal popülasyonda daha önce incelenmemiştir. Bu çalışmada, sağlıklı bireylerde dış kulak yolunun normal ölçümleri ve bu değerlerin yaş, cinsiyet ve taraflar arasında gösterdiği farklılıkları değerlendirmeyi amaçladık.

Yöntemler: Bu kesitsel çalışmada 379 hastanın bilgisayarlı tomografi (BT) görüntüleri incelendi. Her iki taraf için sagital görüntülerde üç noktada iki çap ölçüldü. 1.nokta, timpanik membran seviyesinde chorda tympani'nin kemik kanalından çıktığı noktaydı . Bu noktada dış kulak yolunun (DKY) silindirik görünümünün en belirgin olduğu yerden yükseklik (1a) ve genişlik (1b) ölçümleri alındı. 2.nokta isthmus seviyesindeydi ve bu noktadan yükseklik (2a) ve genişlik (2b) ölçümleri yapıldı. 3.nokta timpanomastoid sutur düzeyinde DKY'nun en lateral bölgesiydi. Bu noktadan da yükseklik (3a) ve genişlik (3b) ölçümleri yapıldı. Her ölçüm için yaş, cinsiyet ve tarafla ilişkili değişiklikler istatistiksel olarak analiz edildi.

Bulgular: Her bir nokta için her yönde yapılan ölçümler sol ve sağ taraflar arasında benzerdi. Erkeklerde sol 1a'nın ortalama uzunluğu 9,4 mm, kadınlarda 9,2 mm idi. Her noktanın 'a' uzunlukları erkeklerde her iki taraf için kadınlardan daha yüksekti. Erkekler ve kadınlar arasında 'b' uzunlukları açısından anlamlı bir fark yoktu. Kadınlarda 1b ölçümü sol tarafta sağ tarafa göre daha yüksekti, diğer ölçümler için sol-sağ taraf karşılaştırmaları anlamlı değildi. Ölçümlerin hiçbiri erkekler için sol ve sağ taraf arasında farklılık göstermemektedir.

Sonuç: DKY çaplarının normal ölçümleri ve bu ölçümlerin yaş, cinsiyet ve taraflar arasındaki farklılıkları cerrahlar, radyologlar ve anatomistler açısından önemlidir. Endoskopik kulak cerrahisi açısından ve radyolojik görüntülerde DKY anatomisini bozan bir patolojinin erken tanısı için DKY'nin doğru değerlendirilmesi önemlidir.

Anahtar kelimeler: Dış kulak yolu, Temporal kemik, Morfometri, Bilgisayarlı tomografi

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Introduction

External auditory canal (EAC) extends from the concha to the tympanic membrane. S-shaped EAC has a cartilaginous lateral part (one third) and medial bony part (two thirds), the lengths of which are 8mm and 16mm, respectively. Total length of EAC is around 2-3 cm. EAC narrows near the medial end of cartilaginous part and at the isthmus, which is 2 cm from the concha [1,2].

We encountered in vivo and in vitro measurements of EAC in the literature, for which the researchers used tympanometry, ear mold injections, computed assisted tomography (CAT), water injection and high-resolution computed tomography. EAC volume measured before canaloplasty operation is a predictor for post operation volume. It may also reveal efficacy of topical ear wax treatments [3-7].

EAC width, as well as its length and volume, are clinically important. Acquired or congenital stenosis of EAC leads to conductive or mixed hearing loss. Chronic otitis externa, cholesteatoma, exostoses are common reasons of acquired stenosis [8,9]. Bony ear canal opening equal or less than 2mm leads to cholesteatoma formation, which is a slow-growing destructive pathology [10]. It may develop in the middle ear cavity and communicate with EAC through a perforation on tympanic membrane or may individually develop in EAC [11]. Canaloplasty which consists of cholesteatoma removal and EAC enlargement is a common surgical procedure. Restenosis after canaloplasty is another cause of acquired EAC narrowing [7].

Proper understanding of EAC anatomy is essential for transcanal endoscopic ear surgery. Ayache et al. [12] reported that 89% of the patients had EAC narrowing in their study including 5000 patients.

An anatomical canal which has a tortuous path such as EAC should be analyzed on more than one point. In this study we aimed to present the detailed objective measurements and reveal normal morphometry of EAC diameters and its age, gender, and side-related changes. These measurements have both clinical and research applications.

Materials and methods

Ethics committee approval was received from Ankara Yıldırım Beyazıt University Yenimahalle Research and Training Hospital Clinical Research Ethics Committee. (Decision number: 2019/09 -90).

Computed Tomography (CT) images of 379 patients obtained for head and neck pathologies between February-September 2019 were evaluated in the radiology department. Patients with pathologies in the external auditory canal (atresia, fracture, foreign body, cholesteatoma, tumor, keratosis obturans, osteoma, exostoses, medial canal fibrosis, necrotizing external otitis) were not enrolled in this study. CT imaging was performed with the General Electric Revolution EVO CT device. Axial images were reformatted using high-resolution multiplanar reconstruction (MPR). Two dimensions at three points were measured on sagittal images for each side by the same radiologist, certified with 25 years' experience at head and neck imaging. The age, gender and side related changes for each measure were statistically analyzed.

Measurements were obtained from three points:

1st point: The level of the tympanic membrane where chorda tympani leaves the bony canal. The height (1a) and width (1b) were measured from the ground where the cylindrical view of EAC was most prominent (Figure 1A, Figure 1B).

2nd point: Height (2a) and width (2b) were measured at isthmus level (Figure 2A, Figure 2B).

3rd point: The height (3a) and width (3b) were measured from the most lateral site of EAC at the level of tympanomastoid suture. (Figure 3A, Figure 3B).

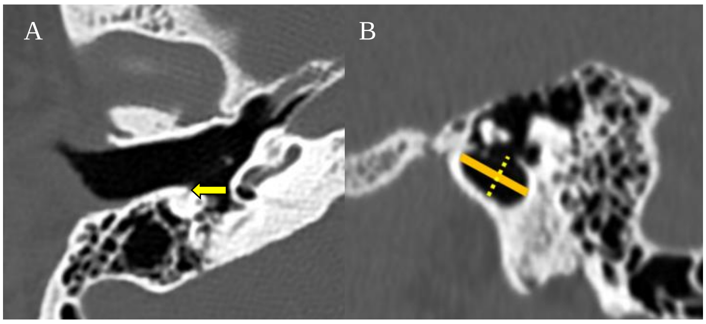

Figure 1A: Axial CT image of temporal bone. 1st measurement point is at the level of the tympanic membrane where chorda tympani leaves the bony canal (yellow arrow), 1B: Sagittal CT image of temporal bone diameters at the level of the tympanic membrane where chorda tympani leaves the bony canal (1a: non-interrupted line, 1b: interrupted line)

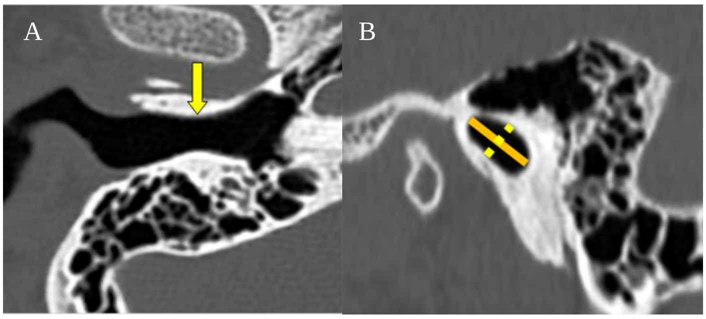

Figure 2A: Axial CT image of temporal bone. 2nd measurement point is at the level of isthmus (yellow arrow), 2B: Sagittal CT image of the temporal bone. Diameters at the level of the isthmus (2a: non-interrupted line, 2b: interrupted line)

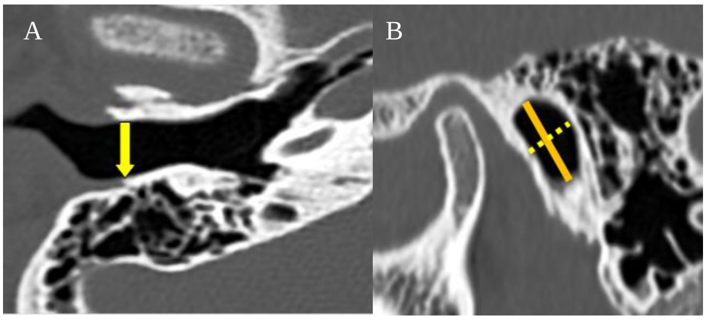

Figure 3A: Axial CT images of the temporal bone. 3rd measurement point is at the level of the tympanomastoid suture (yellow arrow), 3B: Sagittal CT image of the temporal bone. Diameters at the level of the tympanomastoid suture (3a: non-interrupted line, 3b: interrupted line)

Statistical analysis

Power analysis performed by G* Power (ver 3.1) revealed that the achieved power of this study was 98.4% (Cohen's d=0.423) with a Type 1 error rate of 0.05 and a sample size of 379 patients.

The distributions of the measurements were examined by the Shapiro-Wilk's test and the normality plots. Median (min-max) was reported for all metric variables, and gender was presented with frequency (%).

The left- and right-side measurements were compared by Wilcoxon signed-rank test within the whole sample. The Mann-Whitney U test was used to compare males and females with respect to the diameter measurements. A *P*-value<0.05 was considered as statistically significant.

All statistical analyses and computations were performed via IBM SPSS Statistics 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

Results

Three-hundred seventy-nine individuals were examined, out of which 46.4% (n=176) were male. The overall median age was 40 years (min-max:20-76). The median ages of males and females were both 40 years with a range of 20-75 years for males and 20-76 years for females. There was no significant difference between males and females with respect to age.

The median diameter of 1a was 9.3 mm (min-max:7.5-12.0) on the left and 9.3 mm (min-max:7.7-12.0) on the right (Table 1). The diameter of each point in each direction was similar between the left and right sides.

The median diameter of left 1a was 9.4 mm (min-max: 8.0-12.0) in males and 9.2 mm (min-max: 7.5-11.2) in females, resulting in a significant difference (Table 2). The "a" diameter of each point was higher in males than females for both sides. There was no significant difference between males and females in terms of "b" diameters.

Diameter 1b was higher on the left side compared to the right side for females, while left-right side comparisons for other measurements were similar (Table 2). All diameters were similar between the left and right side for males.

Table 1: The comparison of diameters between left and right ears

Diameters (mm)	Left Median (min-max)	Right Median (min-max)	*P*-value
1a	9.3 (7.5-12.0)	9.3 (7.7-12.0)	0.275
1b	6.1 (4.0-7.7)	6.0 (4.2-7.3)	0.348
2a	9.0 (6.9-12.1)	9.0 (6.8-12.1)	0.889
2b	5.4 (3.7-6.8)	5.3 (3.7-9.4)	0.308
3a	10.1 (7.8-13.5)	10.2 (7.4-13.9)	0.209
3b	6.3 (4.2-8.3)	6.3 (4.6-7.9)	0.550

1st point at the level of the tympanic membrane where chorda tympani leaves the bony canal. 1a: Height measured at 1st point, 1b: Width measured at 1st point, 2nd point at the level of isthmus, 2a: Height measured at the 2nd point, 2b: Width measured at 2nd point, 3rd point at the most lateral site of external auditory canal (EAC) at the level of tympanomastoid suture, 3a: Height measured at 3rd point, 3b: Width measured at the 3rd point.

Table 2: The comparison of measurements between males and females

Diameters (mm)	Males Median (min-max)	Females Median (min-max)	*P*-value
Left1a	9.4 (8.0-12.0)	9.2 (7.5-11.2)	0.009
1b	6.1 (4.1-7.7)	6.1 (4.0-7.7)*	0.695
2a	9.2 (7.0-12.1)	9.0 (6.9-11.7)	0.004
2b	5.5 (3.7-6.8)	5.3 (4.0-6.6)	0.155
3a	10.2 (7.9-13.5)	10.0 (7.8-12.7)	0.007
3b	6.4 (4.7-8.3)	6.3 (4.2-8.2)	0.137
Right1a	9.4 (7.9-12.0)	9.1 (7.7-12.0)	<0.001
1b	6.1 (4.6-7.3)	6.0 (4.2-7.3)*	0.216
2a	9.2 (6.9-12.1)	9.0 (6.8-11.8)	0.020
2b	5.4 (4.1-6.6)	5.3 (3.7-9.4)	0.355
3a	10.3 (7.4-13.9)	10 (7.5-13.5)	0.028
3b	6.3 (4.7-7.9)	6.2 (4.6-7.7)	0.251

**P*=0.019 for the comparison of left and right 1b in females. P>0.05 for other within-gender comparisons of left and right-sided measurements.

Discussion

Morphometric studies executed normal populations are valuable to distinguish abnormalities from normal ones. Knowledge of normal morphometry provides physicians a more constant ground when evaluating patients. An anatomical canal which has a tortuous path such as EAC should be analyzed on more than one point. Each of the points measured in the present study were revealed in detail on CT images.

Tsung et al. [13] created a three-dimensional ear canal model using CT on 40 individuals. They aimed to present proper data to ear plug producers and to protect workers from noise damage which leads to hearing loss. Studies analyzing the geometry of the ear canal among different populations may contribute to preventing workplace-related hearing problems which is a common health care issue worldwide. In our opinion these studies must be conducted with larger sample sizes. We included 379 patients in the present study.

Zemplenyi et al. [14] used an optical method to measure the ear canal length, and their results ranged from 2.2cm to 3cm. Djupesland et al. [15] also studied the length of the canal and found a mean value of 23mm. Due to bending of the ear canal, two dimensional radiologic images are insufficient to indicate accurate length. Experimental studies of Zempleyni et al. [14] and Djupesland et al. [15] contributed valuable data to literature but did not measure the diameters of the canal. Yu et al. [7] used high resolution computed tomography (HRCT), water injection and tympanometry on 9 male volunteers for EAC volume measurement. They created 3D images on HRCT images. In our opinion, it is not a practical method in routine radiology practice. As a contribution to the missing points of the mentioned studies diameters of ear canal were measured in our study. These measurements inform physicians about the narrowing of the canal, which are critical in approach to middle ear and eardrum. We measured the narrowest value at the transverse diameter of the isthmus (left:5.4mm and right 5.3mm).

Per-meatal, end-aural and post-auricular approaches are viable options for surgical access to eardrum and middle ear cavity in operations such as myringoplasty, tympanoplasty and stapedectomy. Each approach has limitations. A narrow EAC is a limitation for per-meatal approach [1,16]. Preoperative assessment of EAC is often underestimated. We believe that this study reveals sufficient anatomical data for surgeons in terms of per-meatal approach. End-aural and post auricular access are other alternatives if the EAC is not wide enough to allow per-meatal approach [1]. The post auricular approach has disadvantages in visualization of the posterior margin of tympanic membrane and end-aural approach limits the view of the anterior margin of tympanic membrane. [16].

Zhao et al. [17] declared that individuals with EAC less than 4 mm are considered to have congenital aural stenosis. They conducted their research on 10 children with a mean age of 12 years. Cole et al. [10] declared that patients with EAC less than 2mm were prone to developing cholesteatoma and should undergo surgery in late childhood before irreversible damage occurs. Because of the slow gradually growing pattern of cholesteatoma, most of the patients present with late complications such as discharge, hearing loss, facial paralysis, and intracranial complications in adulthood [18]. If undiagnosed, cholesteatoma may destroy EAC, skull base and temporal bone [19]. Randomly detected EAC narrowings in radiologic images may be valuable for differential diagnosis of such pathologies. We need scientific data on the normal values in the society to talk about narrowing. Clearly defined measurements based on large series are superior to subjective views. To the best of our knowledge, this study is the first to reveal measurements of EAC on clearly defined points in a large adult series. Individuals included in this study had no history of ear problems. From this point of view, our study presents valuable data to the scientific literature.

Limitations

A study with a larger sample size would have been more significant. A comparative study between patient groups with normal morphology and EAC pathologies will contribute valuable data to literature. Comparative studies between imaging techniques and endoscopic techniques visualizing EAC will enlighten radiologists and otologists.

Conclusion

This study provides proper data to surgeons, radiologists and anatomists dealing with EAC. Thorough evaluation of EAC is critical for transcanal endoscopic ear surgery and helps radiologists in early diagnosis of a pathology impairing the anatomy of EAC.

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