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Morphological characteristics of external auditory canal in congenital aural stenosis patients

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ABSTRACT

Objective
To investigate characteristics of congenital aural stenosis (CAS) patients' external auditory canal (EAC) (position, length, orientation, etc.) and compare them with normal EAC.
Methods: CT images of normal people and CAS patient were utilized. We obtained coordinates of EAC landmarks. Then the Matlab program could calculate some anatomic parameters about EAC, including distances from central point of tympanic annulus (CA), central point of osseous EAC opening (CO), central point of cartilaginous EAC inside opening (CCi), central point of cartilaginous EAC outside opening (CCo) to the Frankfurt horizontal plane (Pfrkt), the median sagittal plane (Psag), the coronal plane (Pcor); orientations of EAC bendings; straight and arc lengths of EAC.
Results: Distances from CA, CO, CCi and CCo to Pfrkt were all shorter in CAS group than control group ($p < 0.05$). The straight and arc lengths of cartilaginous EAC in CAS group were shorter than control group ($p < 0.05$). Straight and arc lengths of EAC in CAS group were shorter than those in control group ($p < 0.05$). The proportion of one bending in cartilaginous EAC in control group was significantly lower than CAS group ($p < 0.05$). Orientations of EAC bendings in CAS group differed from those in control group ($p < 0.05$).
Conclusion: In addition to smaller diameters, compared with normal EAC, the position of CAS patients' osseous EAC was higher compared with the normal. The majority of CAS patients have a bending and downward slanting cartilaginous EAC. Orientations of EAC bending in CAS patients were different from normal. Besides, the length of CAS patients' cartilaginous EAC was shorter. However, there were no significant differences between CAS patients and normal people in length of osseous EAC. These differences in anatomic parameters could provide the basis for optimizing the meatoplasty.

Abbreviations: EAC, external auditory canal; CT, computed tomography; MRI, magnetic resonance imaging; CAS, congenital aural stenosis; PA, tympanic annulus; PO, osseous EAC opening; PCi, cartilaginous EAC inside opening; PCo, cartilaginous EAC outside opening; OEB-A, osseous EAC bending A; OEB-B, osseous EAC bending B; CEB-A, cartilaginous EAC bending A; CEB-B, cartilaginous EAC bending B; OEB-Ar, the radius of the OEB-A; OEB-Ac, the curvature of the OEB-A; OEB-Aa, the angle of the OEB-A; OEB-Al, the arc length of the OEB-A; Pfrkt, Frankfurt horizontal plane; FS, foramen spinosums; Psag, the median sagittal plane; Pcor, the coronal plane; CA, central point of the tympanic annulus; CA-Pfrkt, distance from the central point of CA to the Frankfurt horizontal plane; CA-Psag, distance from the central point of CA to the median sagittal plane; CA-Pcor, distance from the central point of CA to the coronal plane; CO, central point of osseous EAC opening; CO-Pfrkt, distance from the central point of CO to the Frankfurt horizontal plane; CO-Psag, distance from the central point of CO to the median sagittal plane; CO-Pcor, distance from the central point of CO to the coronal plane; CCi, central point of cartilaginous EAC inside opening; CCi-Pfrkt, distance from the central point of CCi to the Frankfurt horizontal plane; CCi-Psag, distance from the central point of CCi to the median sagittal plane; CCi-Pcor, distance from the central point of CCi to the coronal plane; CCo, central point of cartilaginous EAC outside opening; CCo-Pfrkt, distance from the central point of CCo to the Frankfurt horizontal plane; CCo-Psag, distance from the central point of CCo to the median sagittal plane; CCo-Pcor, distance from the central point of CCo to the coronal plane; ALO, the arc length of osseous EAC; SLO, the straight length of osseous EAC; ALC, the straight length of osseous EAC; SLC, the straight length of cartilaginous EAC; ALE, the arc length of EAC; SLE, the straight length of EAC.

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1. Introduction

Congenital malformation of external and middle ear is one of common birth defects in ontological clinic and the incidence rate may range from 0.05‰ to 0.1‰ [1]. Typical presentations include microtia, varying degrees of malformation of the external auditory canal (EAC) ranging from complete absence to mild stenosis and malformation of the middle ear. In addition, 11% to 47% of patients also associate inner ear malformations [2]. The diagnosis and preoperative assessment of congenital malformations of external and middle ear are based on clinical and functional examinations and radiological investigations, such as computed tomography (CT) and magnetic resonance imaging (MRI) [3]. For the classification of EAC dysplasia, it is mostly used Altmann [4] and Weerda [5] classifications, which divided into three categories according to the degree of EAC deformity: EAC stenosis with a small tympanic membrane, EAC stenosis with an atresia plate (no tympanic membrane) and EAC atresia. However, specific morphological characteristics of EAC stenosis are not well described in both above classifications. Congenital aural stenosis (CAS) cases with a functional ossicular chain, original tympanic membrane, and normal EAC epithelial structures could achieve and maintain excellent long-term results. Indeed, most of these cases reestablished serviceable hearing [6]. Therefore, it is crucial for otologists to comprehend morphological characteristics of EAC in CAS patients.

The aim of our study was to measure anatomic parameters of EAC among CAS patients. We investigated characteristics of EAC stenosis (shape, position, length, orientation, etc.) and compared them with normal EAC, which would provide the basis for optimizing the meatoplasty.

2. Materials and methods

2.1. Subjects

We retrospectively studied CT images of patients with the diagnosis of microtia in our hospital from March 2009 to February 2015. We selected randomly from a pool of patients with a radiological temporal bone CT scans. Inclusion criteria: patients with the diagnosis of CAS; complete radiological temporal bone CT scans; no history of the otitis media or other middle ear diseases; no history of the external and middle ear surgery. CAS was defined by Cole and Jahrsdoerfer as an EAC with a diameter of <4 mm [7]. The CAS patients can be with EAC cholesteatomas. But if EAC cholesteatomas involved the tympanic cavity or walls of EAC were not intact due to trauma, destruction of EAC cholesteatoma, other reasons, these patients were excluded.

The CAS group had a total of 27 subjects (30 ears), including 24 with single-sided aural stenosis, 3 with bilateral aural stenosis; 11 males, 16 females, age range 4–20 years. The control group had a total of 36 subjects (38 ears), including 2 normal subjects, 9 single-sided aural stenosis patients' healthy side ears, 25 single-sided aural atresia patients' healthy side ears; 20 males, 14 females, age range 6–24 years. Then, the normal group and CAS group were divided into two subgroups according to the age respectively, i.e. 0–12 years old subjects in the control group as Group A (19 ears), 13–25 years old subjects in the control group Group B (19 ears); 0–12 years old subjects in the CAS group as Group C (15 ears), 13–25 years old subjects in the CAS group as Group D (15 ears). The institutional review board approved our retrospective study, and written informed consent was waived for the use of patients' medical and imaging data. All of the patients' information was anonymized prior to the analysis.

2.2. Scanning method

All axial images were taken with multi-detector row CT (Sensation 16; Siemens Medical Systems, Forchheim, Germany) in helical mode. Our scanning procedure followed the standard temporal bone imaging protocol. Scans were acquired with a tube voltage of 120.0 kV and a current of 180.0 mA. The images were reconstructed with 0.75-mm-thick sections, 0.5-mm increment, 512 × 512 matrix, 0.43 mm pixel size, and display field of view (DFOV) of 22.0 × 22.0 cm. Images were displayed at a window center of 700 Hounsfield units (HU) and a window width of 4000 HU.

2.3. Post-processing

Digital imaging and communication in medicine images contain positioning data that defines spatial coordinate in the superior-inferior, anterior-posterior, and left-right directions. The CT digital imaging and communication in medicine data sets were imported into Mimics 10.0 software (Materialize, Belgium) for image processing in our study. This software allows users to view CT datasets simultaneously using a set of two-dimensional images and a three-dimensional rendered image for each dataset. Observation was performed with a contrast

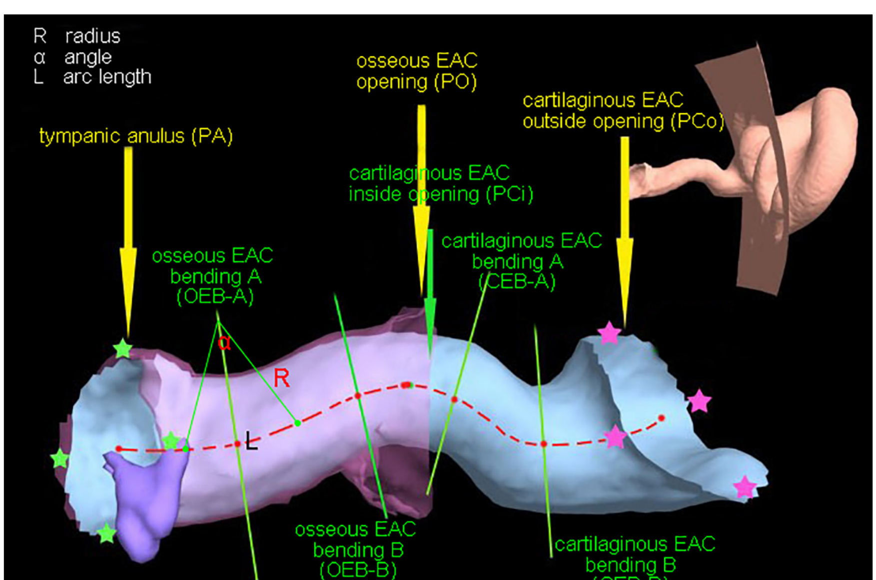

Fig. 1. Schematic diagram of the left normal external auditory canal (EAC) (superior view). Bendings of EAC were called the osseous EAC bending A (OEB-A), the osseous EAC bending B (OEB-B), the cartilaginous EAC bending A (CEB-A), the cartilaginous EAC bending B (CEB-B) successively from the inside to outside.

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