Measurement of Angle and Length of the Eustachian Tube on Computed Tomography Using the Multiplanar Reconstruction Technique

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Objective: To compare the anatomic features of the eustachian tube (ET) between children with and without otitis media with effusion (OME) and with adults.

Methods: The angle and length of the ET in children with OME (54 ears, OME children) and without OME (50 ears, normal children), as well as those of normal adults (90 ears), were measured on computed tomography using the multiplanar reconstruction technique.

Results: The angles of ET in the OME children group, the normal children group, and the normal adult group were 20.4 ± 3.5° and 21.2 ± 4.8°, 19.9 ± 3.4° and 20.0 ± 3.6°, and 27.3 ± 2.7° and 27.3 ± 2.8° on the right and the left sides, respectively. There was no significant difference between the right and the left side in any group (P = .541, P = .952, P = .978). The lengths of ET in the OME children group, the normal children group, and the normal adult group were 37.2 ± 3.0 mm (mean ± SD) and 37.6 ± 3.2 mm, 37.5 ± 3.3 mm and 38.0 ± 3.2 mm, and 42.5 ± 2.8 mm and 42.9 ± 2.9 mm on the right and the left sides, respectively. There was no significant difference between the right and left sides in any group (P = .670, P = .597, and P = .545). Both the angles and lengths were significantly greater in the normal adult group than in either the OME children group or the normal children group (one-way analysis of variance and Fisher’s protected least significant difference tests, P < .05), but there was no significant difference in either the angle or length of the ET between the OME and normal children groups (P > .05). In the OME and normal children groups, the angle was observed to constantly increase with age, and the values were found to be within the range of the adult size in all the patients older than 7.5 years and 7.7 years in the OME children group and the normal children group, respectively. As well as the angle, the lengths were observed to constantly increase with age, but the increase appeared to be greater at a younger age (until approximately 3 to 4 years) than at an older age, and the values were found to be within the range of the adult size in all the patients older than 6.8 years and 7.7 years in the OME children group and the normal children group, respectively.

Conclusion: The angle and length of the ET are more horizontal and shorter in infants than in adults. However, there is no statistical difference between the angle and length of the ET in infants with and without OME. These results lead us to believe that a short and horizontal ET may not be a main etiologic factor related to high susceptibility to OME in infants and children.

Key Words: Eustachian tube, angle, length, otitis media effusion, infant, adult.


INTRODUCTION

It is known that the eustachian tube (ET) plays an important role in maintaining middle ear physiology and functions,1 and that the ET of an infant is short and located horizontally compared with that of an adult.2,3 These anatomic features are speculated to be related to high susceptibility to otitis media with effusion (OME) in infants and children. However, patients with OME have not been studied in reports describing this anatomic difference of the ET between infants and adults. Furthermore, there are only a few reports that precisely measure the angle and length of the ET against Reid’s standard plane in patients with OME.

Recent remarkable advances in the imaging technique of computed tomography (CT) are providing clearer and clearer imaging of the anatomic features of the ET. The multiplanar reconstruction (MPR) technique is one of the new imaging techniques for CT, with which any
arbitrarily reconstructed image can be obtained by changing the angle of the plane by 0.5° and by changing the place by 1 mm. We previously reported the anatomic features of the ET in patients with a patulous ET using this technique. The aim of this study is to clarify the precise anatomic features of the ET of infants and children with and without OME on CT using this MPR technique.

MATERIALS AND METHODS

All participants examined in this study were Japanese. The OME children group comprised 54 ears of 27 patients (15 males and 12 females; age range, 301 days to 8.9 yr [3,253 days]; mean age, 4.9 yr). Their OME was diagnosed with an otomicroscope showing fluid behind the eardrum, and tympanometry demonstrated type B or C. All were treated with tympanostomy tube at least once because the fluid was still present after 12 weeks despite treatment with internal medicine. All CT images of the OME children group showed soft tissue density in the middle ear cavity. The control group (normal children group) comprised 50 ears of 25 patients (9 males and 16 females; age range, 281 days to 8.2 yr [2,975 days]; mean age, 4 yr) without middle ear problems. All had sensorineural hearing loss without middle ear problems and showed normal otomicroscopic findings. All CT images of the normal children group showed no soft tissue density in the middle ear cavity and no inner or middle ear anomaly. There was no significant difference in the age distribution between these two groups (P = .8656). The adult control group (normal adult group) comprised 90 ears of 45 patients (24 males and 21 females; age range, 18–82 yr) without present or past history of any ear problems. All CT images of the normal adult group demonstrated normal findings in the inner or middle ear. All patients were informed of the purpose of the study, and their informed consent to participate in this study was obtained before CT examination.

The CT system used was a GE Hispeed Advantage (GE Medical Systems, Chalfont, UK), and imaging parameters were as follows: 1 mm slice thickness; 1:1 pitch; 0.5 mm reformat; field of view 9.6 cm; window width 4,000; window level 400. A total of 80 to 100 slices axial CT data of all patients covering the entire part of the ET including surrounding tissues were saved on each compact disk recorder. Using software (Virtual Place Liberty, Office Azemoto Ltd., Tokyo, Japan) on a personal computer, we reconstructed 1-mm thick, gapless, three-dimensional CT images from the CT data (Fig. 1).

In the present study, we defined each anatomic site of the ET as follows: 1) the pharyngeal orifice of the ET lumen, the point nearest the pharynx where a loop-shaped ET lumen appears; 2) the tympanic orifice, the nearest point in the ET before the external auditory canal appears on the cross-sectional image. Length of the ET was defined as the distance from the pharyngeal orifice to the tympanic orifice. Angle of the ET was defined as the angle of a straight line representing the length of the ET against Reid’s standard plane, which is defined as the plane connecting the right infraorbital margins and both upper margins of the external auditory meatus (Fig. 1).

To compare the angle and length of the ET between the right and left sides in each group, we statistically evaluated the data with the Student t test. To compare the angle and length of the ET among the three groups, we used one-way analysis of variance (ANOVA) and Fisher’s protected least significant difference (PLSD) tests (P < .05).

RESULTS

The mean values and standard deviations (SD) of the angles and lengths of the ET on the right and left sides of the three groups are given in Figure 2 and indicate no
significant difference between the right and left sides in any of the groups. Both the angles and lengths were significantly greater in the normal adult group than in either the OME children group or the normal children group (one-way ANOVA and Fisher’s PLSD tests, \( P < .01 \)), but there was no significant difference in either the angle or length of the ET between the OME group and the normal children group (\( P > .01 \)).

Figure 3 shows the distribution of the angle of the ET as a function of age in the OME and normal children groups. In both groups, the angle was observed to constantly increase with age, and the values were found to be within the range of the adult size (mean value \( \pm 2 \) SD) in all patients older than 7.5 years (2,737 days) and 7.7 years (2,818 days) in the OME children group and in the normal children group, respectively. In Figure 4, the distribution of the length of the ET of OME and normal children groups is shown as a function of age. In addition to the angle, the lengths were observed to constantly increase with the age, but the increase appeared to be greater at a younger age until approximately 3 to 4 than in the older ages, and the values were found to be within the range of the adult size in all patients older than 6.8 years (2,470 days) and 7.7 years (2,818 days) in the OME children group and in the normal children group, respectively.

**DISCUSSION**

The present study was the first report measuring the angle of the ET using CT images. The value of the angle of the ET in the present study was quite different from that in Proctor’s\(^2\) report, in which the angle of the ET to the horizontal plane was shown to be 45° in adults and 10° in infants. Because there has been no anatomic report about the angle of the ET in Japanese infants and children to date, this discrepancy might be related to racial differences. However, because Proctor’s measurements were probably made with the gross anatomic method, the results may lack accuracy. Also, in his report, it is not stated whether the angle of ET was measured against Reid’s standard plane. We think that it is extremely difficult to accurately measure the angle of the ET against Reid’s standard plane by the gross anatomic technique. We believe that the values of the angle and length of the ET in the present study are more accurate, because we can precisely measure the angle and the length of the organs on CT using the MPR technique.\(^4,5\)

Because the angle of the ET in OME patients was not stated in previous reports,\(^2,3\) the relation between the angle and the incidence of OME is unclear. In the present study, we demonstrated that the angle and length of the ET were more horizontal and shorter in children than in adults, and there was no significant difference between the angle and length of the ET in children with OME and those without OME. Furthermore, the values of the angle and length of the ET in 6 or 7 year olds or older are similar to those in adults, regardless of the presence or absence of OME. These results suggest that a short and horizontal ET is not a major etiologic factor of OME in infants and children. It is also interesting that the length of the ET was found to develop in early childhood, when OME is generally prevalent. This may be related to the high susceptibility of OME in early infancy.\(^6\)
O’Donoghue et al.\(^7\) reported that the development of the petrous and squamous portion of the temporal bone was at its greatest in the first 2 years of life. In the present study, we revealed that the values of the angle and length of the ET at 7 years of age were the same as in an adult. This means that the ET may become morphologically closer to that of an adult at approximately 7 years. Further investigation using an adequate amount of cases is necessary to discuss the development of the ET.

In the present study, we did not measure the length of the ET along its course but as the straight distance from the pharyngeal orifice to the tympanic orifice. Although Ishijima et al.\(^8\) reported that the ET curves in adults, Yoshida et al.\(^4\) reported that the whole air space in the ET in an adult patient with severe patulous ET is seen as almost a straight line in a plane on CT. Therefore, it does not appear to cause a serious problem to substitute the straight distance from the tympanic orifice to the pharyngeal orifice for the length of the ET.

**CONCLUSION**

The anatomic features of the ET related to susceptibility to OME in children were measured on CT using the multiplanar reconstruction technique. The angle and length of the ET are more horizontal and shorter in infants than in adults. There is no statistical difference between the angle and length of the ET in infants with and without OME. These results suggest that a short and horizontal ET may not be a main etiologic factor related to high susceptibility to OME in infants and children.

**BIBLIOGRAPHY**
