Measurement of Angle and Length of the Eustachian Tube on the CT Using Multiplanar Reconstruction Technique.

Kenji Takasaki, M. D. [1)], Ikue Miyamoto, M. D. [1)]
Kaori Enatsu, M. D. [1)], Tomomi Fukuda-Yamamoto, M. D. [1)],
Haruo Yoshida, M. D. [1)], Hidetaka Kumagami, M. D. [1)]
Haruo Takahashi, M. D. [1)]

1) Department of Otolaryngology, Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences

Address:
Department of Otolaryngology, Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences
1-7-1, Sakamoto, Nagasaki 852-8501, Japan

Correspondence / Reprint requests:
Kenji Takasaki, M. D.
Department of Otolaryngology, Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences
1-7-1, Sakamoto, Nagasaki 852-8501, Japan
Phone: +81-95-849-7349, Fax: +81-95-849-7352
E-mail:ktakasa@nagasaki-u.ac.jp

ABSTRACT

Objective: To obtain clues on the anatomical features of the eustachian tube (ET) related to the susceptibility to otitis media with effusion (OME) in children.

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

Results: The angles of ET in OME children group, normal children group, and normal adult group were 20.4±3.5 degree (°) and 21.2±4.8°, 19.9±3.4° and 20.0±3.6°, and 27.3±2.7° and 27.3±2.8° in the right and left sides, respectively. There was no significant difference between the right and left sides in any group (p=0.541, p=0.952, p=0.978). The lengths of the ET in the OME children group, normal children group, and normal adult group were 37.2±3.0 mm (mean±standard deviation) 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 in the right and the left side, respectively. There was no significant difference between in the right and left sides in any groups (p=0.670, p=0.597, and p=0.545). Both the angles and lengths were significantly greater in the normal adult group than in either the OME children group or normal children group (one-way ANOVA and Fisher's

PLSD tests, $p<0.05$), but there was no significant difference either in the angle or length of the ET between the OME group and normal children group ($p>0.05$). 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 cases older than 2737 days and 2818 days in the OME children group and in normal children group, respectively. In addition to the angle, the lengths were observed to constantly increase with age, but the increase appeared to be greater in younger age until around 1000 to 1500 days (3 to 4 year old) than in the older age, and the values were found to be within the range of the adult size in all the cases older than 2470 days and 2818 days in OME children group and in normal children group, respectively.

Conclusion: The angle and length of ET are more horizontal and shorter in infants than in adults. However, there is no statistical difference between the angle and length of ET in infants with and without OME. These results suggest that short and horizontal ET may be one of the predisposing factors related to the high susceptibility of OME in infants and children rather than etiological factors.

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 anatomical features are speculated to be related to high susceptibility to otitis media with effusion (OME) in infants and children. However, cases with OME have not been studied in such reports describing the anatomical difference of the ET between infants and adults mentioned above. Furthermore, there are only a few reports precisely measuring 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 realizing clearer and clearer imaging of the anatomical features of the ET on CT. The multiplanar reconstruction (MPR) technique is one of the new imaging techniques for CT, with which any arbitrarily reconstructed image desired can be obtained by changing the angle of the plane by 0.5 degrees and by changing the place of the plane by 1 millimeter. We previously reported the anatomical features of the ET in patients with patulous ET using this technique (4). The aim of this study is to clarify the precise anatomical features of the ET of infants and children with and without OME on CT using this MPR technique.

MATERIAL AND METHODS

All the participants examined in this study were Japanese. The OME children group comprised 54 ears of 27 patients (15 males and 12 females; age range from 301 days to 3253 days; mean age 1778 days). Their OME was diagnosed by pure-tone hearing test and/or tympanometry, and all of them were treated by tympanostomy tube at least once. The control group (normal children group) comprised 50 ears of 25 patients (9 males and 16 females;, age range from 281 days to 2975 days; mean age 1451 days) without middle ear problems. All of them had sensorineural hearing loss without inner or middle ear anomaly. There was no significant difference in the age distribution between these two groups (p=0.8656). The adult control group (normal adult group) comprised 90 ears of 45 patients (24 males and 21 females; age range from 18 years to 82 years) without any ear problems. All patients were informed of the purpose of the study, and their informed consents to participate in this study were obtained before CT examination.

The CT system used was a GE Hispeed Advantage (GE Medical Systems) 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 4000; window level 400. A total of 80-100 axial CT data of all patients covering the entire part of the ET including surrounding tissues were saved on each compact disk recorder. Using a software (Virtual Place Liberty, Office Azemoto Ltd., Japan) on a personal computer, we reconstructed 1-mm-thick gapless three-dimensional CT images from the CT data (Figure 1).

In the present study, we defined each anatomical site of the ET as follows (4): 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 the straight line representing the length of ET against Reid's standard plane (Figure 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 Student's t-test, and to compare the angle and length of the ET between the three groups, we used one-way ANOVA and Fisher's PLSD tests ($p < 0.05$).

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 described in the Table, indicating no significant difference between the right and left sides in any of the groups. Both the angles and lengths were significantly greater in normal adult group than in either OME children group or normal children group (one-way ANOVA and Fisher's PLSD tests, $p<0.01$), but there was no significant difference either in the angle or length of the ET between OME group and normal children group ($p>0.01$).

Figure 2 shows the distribution of the angle of the ET as a function of age in 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±2SD) in all the cases older than 2737 days and 2818 days (7 years old) in OME children group and in normal children group, respectively. In Figure 3, the distribution of the length of the ET of OME and normal children groups is shown as a function of the age. In addition to the angle, the lengths were observed to constantly increase with the age, but the increase appeared to be greater in younger age until around 1000 to 1500 days (3 to 4 years old) than in the older age, and the values were found to be within the range of the adult size in all the cases older than 2470 days (6 years old) and 2818 days (7years old) in OME children group and in normal children group, respectively.

DISCUSSION

The present study was the first report measuring the angle 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 report (2), in which the angle of the ET to the horizontal plane is 45 degrees in adults, and 10 degrees in infants. Since there has been no anatomical report about the angle of the ET in Japanese infants and children to date, a race difference might be related to this discrepancy. However, since Proctor's measurements were probably done by the gross anatomical method, the results may lack accuracy. Also in his report, it is not stated whether the angle of ET was measured against the "Reid's standard plane" or not. We think that it is extremely difficult to accurately measure the angle of the ET against the Reid's standard plane by the gross anatomical 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 the CT using the MPR technique (4, 5).

As the angle of the ET in OME cases 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 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 etiological factor but one of the predisposing factors 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. reported that the development of the petrous and squamous portion of the temporal bone was at its greatest in the first two years of life (7). In the present study, we revealed that the values of the angle and length of ET were the same value as an adult at 7 years old. This means that the ET may become morphologically closer to that of an adult around 7 years old. Further investigation using an adequate amount of cases is necessary to discuses the development of the ET.

In the present study, we did not measure the length of the ET along the 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 with an adult patient with severe patulous ET was depicted as almost a straight line in a plane on the 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 length of the ET.

CONCLUSION

The anatomical features of the ET related to the susceptibility to OME in children were measured on the CT using the multiplanar reconstruction technique.

The angle and length of ET are more horizontal and shorter in infants than in adults. There is no statistical difference between the angle and length of ET in infants with and without OME. These results suggest that short and horizontal ET may be one of the predisposing factors related to the high susceptibility of OME in infants and children rather than etiological factors.

REFERENCE

1. Sando I, Takahashi H, Matsune S, Aoki H. Localization of function in the eustachian tube: a hypothesis. Ann Otol Rhinol Laryngol. 103:311-314,1994.

2. Proctor B. Embryology and anatomy of the Eustachian tube. Arch Otolaryngol 86:503-514, 1967.

3. Blustone CD. Physiology of the Middle Ear and Eustachian Tube. In: Paparella MM, Shumrick DA, Gluckman JL, Meyerhoff WL, editors. Otolaryngology. 3rd ed. Philadelphia: W.B.Saunders Company: 1991. P163-197.

4. Yoshida H, Kobayashi T, Takasaki K, Takahashi H, Ishimaru H, Morikawa M, Hayashi K. Imaging of the patulous Eustachian tube: High-resolution CT evaluation with multiplanar reconstruction technique. Acta Otolaryngol 124:918-923; 2004.

5. Choi SC, Ann CH, Choi HM, Heo MS, Lee SS. Accuracy of reformatted CT image for measuring the pre-implant site: analysis of the image distortion related to the gantry angle change. Dentomaxillofac Radiol 31:273-277;2002.

6. Elbrond O, Birch L: Prospective epidemiological investigation of secretory otitis media in children attending day-care centers. Ed by Sade J, Acute And Secretory

Otitis Media, Kugler Publications, Amsterdam, The Netherlands, 1986, pp147-149.

7. O'Donoghue GM, Jackler RK, Jenkins WM, Schindler RA. Cochlear implantation in children: the problem of head growth. Otolaryngol Head Neck Surg. 94:78-81;1986

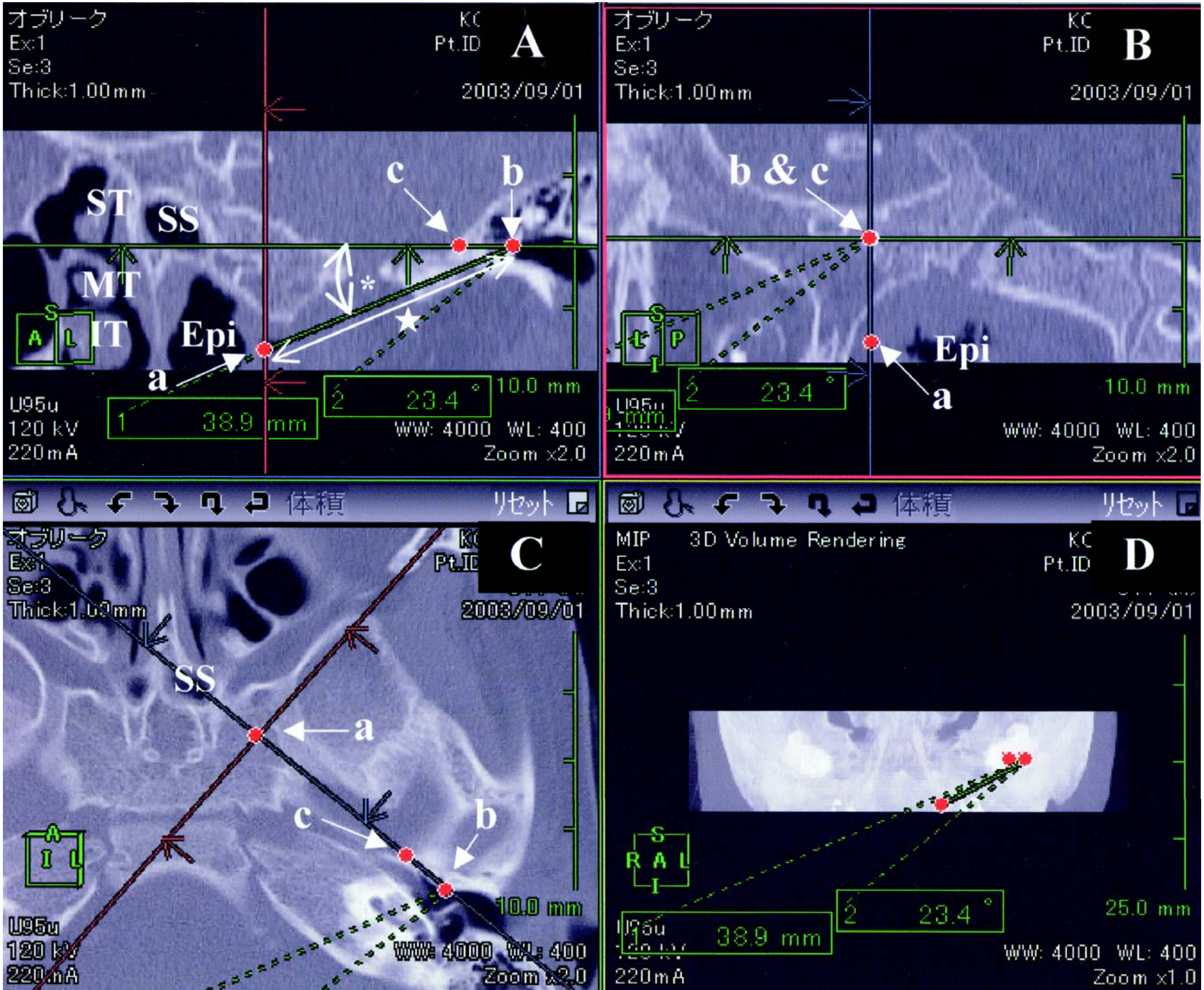
8. Ishijima K, Sando I, Balaban CD, Suzuki C, Takasaki K. Length of the Eustachian tube and its postnatal development: Computer-aided three-dimensional reconstruction and measurement study. Ann Otol Rhinol Laryngol 109:542-548; 2000.

LEGEND

Figure 1. Reconstructed CT images of the left-side eustachian tube (ET) and its surrounding tissues in a 4-year-old child without otitis media with effusion are demonstrated. “Plane A” is perpendicular to Reid’s standard plane, including the left pharyngeal orifice of ET (a) and tympanic (b) orifices of ET. “Point c” is the reference point on the reflected ET line in the plane parallel to Reid’s standard plane at the level of the left tympanic orifice of ET (b). “☆” and “*” indicate the length and angle of the ET in this case, respectively. “Plane B” is perpendicular to Reid’s standard plane and “plane A”, including the left pharyngeal orifice of ET (a). “Plane C” is horizontal plane at the level of the left tympanic orifice of ET (b) parallel to Reid’s standard plane, and perpendicular to “plane A” and “plane B”, including “Point c”. “Plane D” shows a three-dimensional volume rendering image of the patient. Epi:Epipharynx, IT:Inferior Turbinate, MT:Middle Turbinate, SS:Sphenoid Sinus, ST:Superior Turbinate.

Figure 2. The results of the angle of the eustachian tube (ET) as a function of age in the OME children group (A) and in normal children group (B) are shown. The area enclosed by the dotted line demonstrates normal range of adults calculated from the mean and 2SD of the normal adult group.

Figure 3. The results of the length of the eustachian tube (ET) as a function of age in OME children group (A) and in normal children group (B) are shown. The area enclosed by the dotted line demonstrates the normal range of adults calculated from the mean and 2SD of the normal adult group.


A
B
C
D
オブリーク
Ex:1
Se:3
Thick:1.00mm
2003/09/01
Pt.ID
ST
SS
MT
IT
Epi
a
b
c
b & c
38.9 mm
23.4 °
10.0 mm
25.0 mm
U95u
120 kV
220mA
WW: 4000 WL: 400
Zoom x2.0
Zoom x1.0
体積
リセット
MIP 3D Volume Rendering

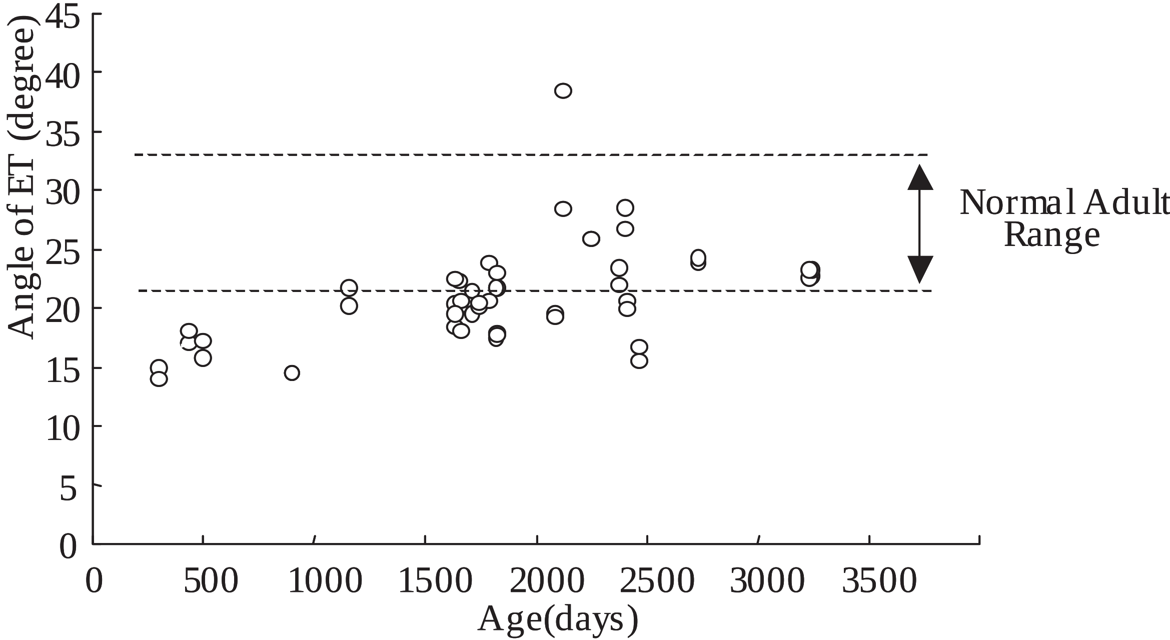
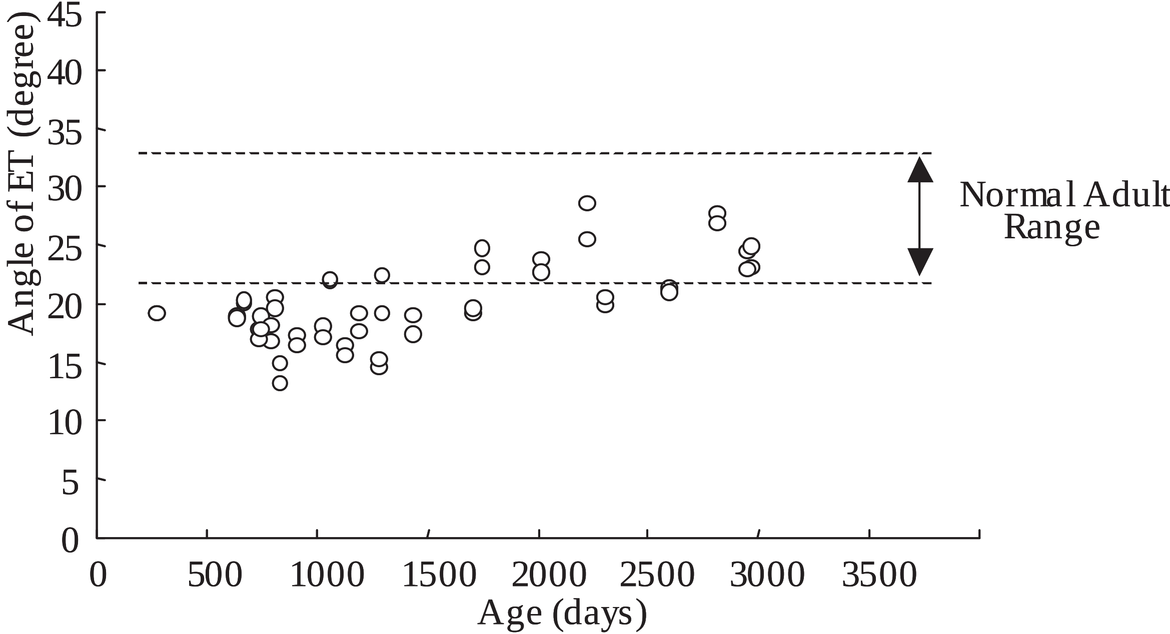
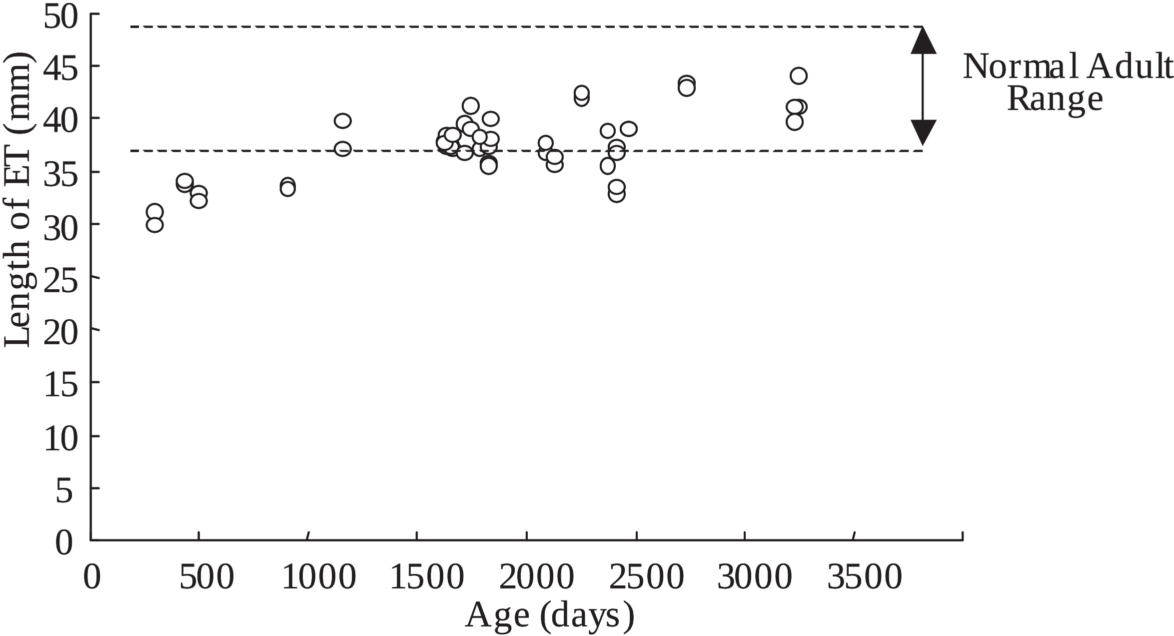

Angle of ET (degree)
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
Age(days)
Normal Adult
Range

Figure 2-A



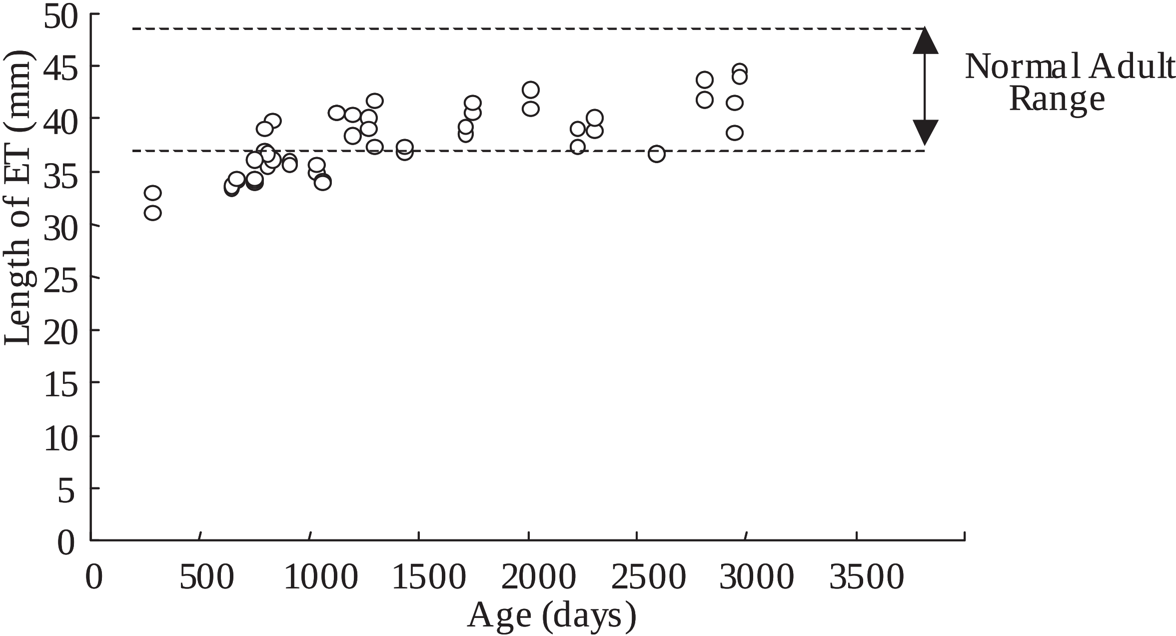
Angle of ET (degree)
45
40
35
30
25
20
15
10
5
0
Normal Adult
Range
0
500
1000
1500
2000
2500
3000
3500
Age (days)

Figure 2-B



Length of ET (mm)
50
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
Age (days)
Normal Adult Range

Figure 3-A



Length of ET (mm)
50
45
40
35
30
25
20
15
10
5
0
Normal Adult Range
0
500
1000
1500
2000
2500
3000
3500
Age (days)

Figure 3-B