Spatial Anatomy of the Nasofrontal Recess on the CT Using Multiplanar Reconstruction Technique

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ABSTRACT

Objective: To clarify the spatial orientation relevant to the endoscopic sinus surgery (ESS) for the frontal sinus.

Methods: Various dimensions of structures around the frontal recess were measured on 256 CT images of 128 Japanese patients using the multiplanar reconstruction technique. Measurements done in this study were: The distance from the nostril to the narrowest point of the frontal recess (D1), and the distance from the narrowest point of the frontal recess to the bony wall of the anterior skull base on an extension of the same line (D2). The smallest anterior-posterior (D3) and right-left (D4) diameters of the "route to the frontal sinus," a site containing the narrowest airspace in the frontal recess, being surrounded by the posterior edge of maxillary bone anteriorly, by the bony wall of the anterior skull base posteriorly, by the middle turbinate medially, and by the medial orbital bony wall laterally, respectively, on the parasagittal and coronal planes. The angle between the line connecting the nostril to the lowest portion of the frontal process of the maxilla and frontal bone, and the line connecting the lowest portion of the frontal process to the narrowest portion of the frontal recess (A1).

Results: The mean values D1 to D4 were 55.9, 9.4, 6.9 and 8.2 mm. In 154 of 256 sides, A1 ranged from 129.5 to 175.7 degrees.

Conclusion: The present study provides important information about the spatial anatomy of the nasofrontal recess, which is essential for avoiding complications of an ESS for the frontal sinus.

Introduction

Endoscopic sinus surgery (ESS) is currently in widespread use for treating frontal sinus diseases (1, 2). Several anatomical reports using computed tomography (CT) have dealt with the frontal recess, sinus, and their surrounding structures to date (3-5). However, they did not state the spatial anatomic relationship from the nostril to the frontal recess like a surgeon's viewpoint.

Recently, as CT with the multiplanar reconstruction (MPR) technique has advanced, it has become possible to observe and measure anatomical structures on the CT images three-dimensionally in a way that meets surgeons' needs (6-8). The aim of the present study was to clarify the spatial orientation relevant to the ESS for the frontal sinus and recess from a surgeon's viewpoint.

Materials and Methods

All the participants examined in this study were Japanese adult patients. Two hundred fifty-six (256) CT images of the paranasal sinus of 128 participants (67 males and 61 females) were reviewed. The patients' ages ranged from

15 years to 85 years, with a mean of 52.5 years. Cases with a benign or malignant tumor and chronic sinusitis in the frontal, ethomoid and maxillary sinuses, a massive nasal polyposis, or a previous history of nasal surgery or trauma were excluded. High-resolution coronal CT images were taken at 0.5 mm or 1 mm thickness and were saved on a compact disk recorder. Using 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. Measurements were done on the CT images under the bone window (window width 4000; window level 400).

In the present study, we first defined the exact location of the narrowest point of the frontal recess, which was indicated as the narrowest area of the frontal recess on the horizontal plane, by viewing CT images from the three directions on the horizontal, coronal and parasagittal planes using the software mentioned above, on a personal computer by first author (KT, Figure 1). We also defined the “narrowest route to the frontal sinus” as a site containing the narrowest airspace in the frontal recess, being surrounded by the posterior edge of maxillary bone anteriorly, by the bony wall of the anterior skull base posteriorly, by the middle turbinate medially, and by the medial

orbital bony wall laterally.

Measurements performed in this study were: 1. The distance from the nostril to the narrowest point of the frontal recess (D1), and the distance from the narrowest point of the frontal recess to the bony wall of the anterior skull base on an extension of the same line (D2, Figure 2). 2. The smallest anterior–posterior (D3) and right-left (D4) diameters of the narrowest route to the frontal sinus on the parasagittal and coronal planes, respectively (Figure 3). 3. In the cases in which the frontal process of the maxilla and frontal bone, so-called the frontal “beak” (9), were observed to cross the line connecting the nostril to the narrowest point of the frontal recess on the parasagittal plane (Figure 4), we measured the angle between the line connecting the nostril to the lowest portion of the frontal “beak”, and the line connecting the lowest portion of the frontal “beak” to the narrowest point of the frontal recess (A1). The protocol was approved by our hospital’s institutional review board.

Results

All the results observed in the present study were summarized in the

Table. D1 was 56 mm on average with a standard deviation (SD) of 4.7 mm, which was less than 10% of the mean value, indicating that the distance is quite consistent with the small variations among individuals. While the value of D2 ranged from 3.3 mm to 21 mm with an SD of more than 35% of the mean value. The value of D3 was also found to vary considerably, with an SD of more than 35% of the mean value. D4 did not show so large variation as those of D2 or D3, but its range (4.0 to 13.4 mm) seemed wide enough to call an attention to surgeons.

In 102 of 256 sides (approximately 40 %), the line connecting the nostril to the narrowest point of the frontal recess did not cross the frontal “beak”. In the remaining 154 sides, in which the line crossed the frontal “beak”, A1 ranged from 129.5 to 175.7 degrees (mean±SD, 159.9±9.9).

Discussion

In the hands of expert surgeons, ESS is now a successful procedure. However, the frontal recess remains the most difficult area to operate endoscopically. Because of the large variations in the size and shape of the frontal sinus and recess, it is

very important for surgeons to know in detail about the three-dimensional anatomical features of the frontal sinus and its surrounding structures in order to safely perform an ESS. Although there have been several exhaustive reports about the anatomical features of the frontal sinus and its surrounding structures (3-5), they focused only on the frontal sinus and its surrounding structures without examining the spatial surgical orientation from the nostril to the frontal recess. As it is important to clarify such spatial anatomical orientation for the safe performance of an ESS for the frontal sinus, we measured several dimensions that seemed important from a surgeon's viewpoint in the present study. D1 was found almost consistent, while the value of D2 varied considerably with its minimum distance of only 3.3 mm. From these findings, we learned that we should operate very carefully at the posterior portion of the frontal recess to avoid a cerebrospinal fluid leak caused by surgically injuring the anterior skull base.

The use of angled endoscopes has the advantage of better visualization of areas with difficult access such as the frontal recess (1, 2). However, Kang et al. (10) reported that use of a 70 degree-angled endoscope in frontal recess

surgery appeared risky as it caused visual distortion more than a straight endoscope. To avoid complications, Wormald (9, 11) advocated the axillary flap approach for endoscopic frontal sinus surgery. He reported that 96% of surgeries for the frontal recess can be performed using a 0° endoscope with the axillary flap approach, and that this gives the surgeon the advantage of not having to work around the corner with angled telescopes and instruments, and that this technique was easy and safe in the frontal recess. In the present study, the line connecting the nostril to the narrowest portion of the frontal recess was found to cross the frontal process of the maxilla and frontal bone, which was constituted by rigid bone, in approximately 60 % of the images. This may indicate that we should remove not only the agger nasi cell but also the inferior portion of the frontal “beak” in 60 % of Japanese adult cases when we operate with the axillary flap approach in the frontal recess with a 0° endoscope. Otherwise, in those cases, we can use the less-angled telescopes and instruments, because Kang et al (10) reported that the risk using less-angled endoscopes (30 and 45°) in frontal recess surgery is as low as that using the 0 degree.

In the present study, the smallest anterior–posterior and right-left

diameters of the narrowest route to the frontal sinus were similar to those reported by Landsberg (3). They assumed, as did many others, that the frontal ostium is a narrow opening and that its exposure, especially while infected, necessitates “drill-out” or aggressive curettage. And they also stated that a wide and roughly elliptical opening to the frontal sinus was exposed in most cases if the precise removal of a high terminal recess, an agger nasi cell, or a frontal cell was completed. Consequently, based on their surgical experience, they obtained a conclusion that an indication for drill-out or curettage, i.e., Draf II or Draf III surgery (12), or modified Lothrop procedure (13) seldom exists. However, in our present study, the smallest anterior–posterior diameter of the narrowest route to the frontal sinus was found to vary considerably, with an SD of more than 35% of the mean value, and the smallest value of the anterior–posterior and right-left diameters of the route to the frontal sinus among 256 sides were 2.2 and 4.0 mm respectively. Therefore we thought that the drill-out, curettage, or obliteration (14) surgery for the frontal sinus was necessary in some cases with the narrow frontal recess.

Since there was, to our knowledge, no report on the anatomic

variation about the frontal sinus and its surrounding structures among races using the CT except a report about the other sinuses (15), we could not know whether the data in the present study applied to the other races or not. However the present report is, to our best knowledge, the first report describing the fine three-dimensional surgical orientation from the nostril to the frontal recess from a surgeon's viewpoint using MPR technique. We hope that this information will be of great help, especially to young surgeons who are learning how to perform an ESS for the frontal sinus.

The MPR technique has recently developed as a new imaging technique in the field of CT. With this technique, any arbitrarily reconstructed image desired can be obtained by changing the angle of the plane by 0.5 degrees and by changing the target location by 1 mm. We previously reported new findings that we obtained by using this method regarding the spatial anatomy and dimensions of the eustachian tube (7) and sphenoid sinus (8). Although the navigation operation system is now widely used in the field of nasal surgery, preoperative understandings of spatial anatomy on the CT images using this MPR technique can help promote safe performance of ESS for the frontal sinus. This method provides us with fine and

precise digital information about the anatomy of the frontal sinus and important structures surrounding it.

Conclusion

The present study provides important information about the spatial anatomy of the nasofrontal recess and surrounding structures in Japanese adults, which is essential for avoiding complications in performing an ESS for the frontal sinus.

References

1. Stammberger H. Functional Endoscopic Sinus Surgery: The Messerklinger Technique. Philadelphia: BC Decker, 1991: 60–87.

2. Friedman M, Landsberg R, Schults RA, Tanyeri H, Caldarelli DD. Frontal sinus surgery: endoscopic technique and preliminary results. Am J Rhinol. 2000;14:393-403.

3. Landsberg R, Friedman M. A computer-assisted anatomical study of the nasofrontal region. Laryngoscope. 2001;111:2125-2130.

4. Zhang L, Han D, Ge W, Xian J, Zhou B, Fan E, Liu Z, He F. Anatomical and computed tomographic analysis of the interaction between the uncinate process and the agger nasi cell. Acta Otolaryngol. 2006;126:845-852.

5. Leunig A, Sommer B, Betz CS, Sommer F. Surgical anatomy of the frontal recess--is there a benefit in multiplanar CT-reconstruction? Rhinology. 2008;46:188-194.

6. Kew J, Rees GL, Close D, Sdralis T, Sebben RA, Wormald PJ. Multiplanar reconstructed computed tomography images improves depiction and understanding of

the anatomy of the frontal sinus and recess. Am J Rhinol. 2002;16:119-123.

7. Takasaki K, Takahashi H, Miyamoto I, Yoshida H, Yamamoto-Fukuda T, Enatsu K, Kumagami H. Measurement of angle and length of the eustachian tube on computed tomography using the multiplanar reconstruction technique. Laryngoscope. 2007;117:1251-1254.

8. Enatsu K, Takasaki K, Kase K, Jinnouchi S, Kumagami H, Nakamura T, Takahashi H. Surgical anatomy of the sphenoid sinus on the CT using multiplanar reconstruction technique. Otolaryngol Head Neck Surg. 2008;138:182-186.

9. Wormald PJ. The axillary flap approach to the frontal recess. Laryngoscope. 2002;112:494-499.

10. Kang SK, White PS, Lee MS, Ram B, Ogston S. A randomized control trial of surgical task performance in frontal recess surgery: zero degree versus angled telescopes. Am J Rhinol. 2002;16:33-36

11. Wormald PJ. Approach to the frontal sinus and frontal recess. In Endoscopic Sinus Surgery: Anatomy, Three-dimensional Reconstruction, and Surgical Technique, New York, NY: Thieme Medical Publishers Inc. 2005;55-57.

12. Draf W. Endonasal micro-endoscopic frontal sinus surgery: the Fulda concept. Operative Techn Otolaryngol Head Neck Surg 1991;2:234–240.

13. Gross W, Gross C, Becker D, Moore D, Phillips D. Modified transnasal endoscopic Lothrop procedure as alternative to frontal sinus obliteration. Otolaryngol Head Neck Surg 1995;113:427–434.

14. Kaieda S, Takano A, Hatachi K, Takahashi H. Sinus obliteration with bone pate and hydroxyapatite in treatmenting recurrent frontal sinus mucocele. (in Japanese) Jpn J Rhinol. 2004;43:206-211.

15. Badia L, Lund VJ, Wei W, Ho WK. Ethnic variation in sinonasal anatomy on CT-scanning. Rhinology 2005;43:210-214.

Legend

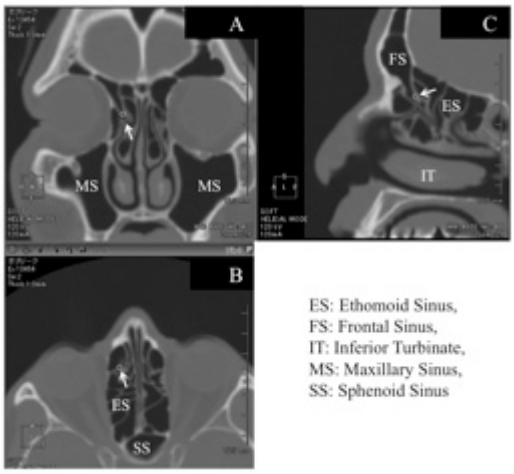
Figure 1. Reconstructed CT images of the paranasal cavity in a 42-year-old man without sinusitis are demonstrated. Plane A, B, and C are coronal, horizontal and parasagittal planes, respectively. Arrows demonstrate the narrowest point of the frontal recess in each plane.

Figure 2. The narrowest point of the frontal recess (solid circle) on the reconstructed parasagittal image was demonstrated. D1 and D2 showed the distance from the nostril to the narrowest point of the frontal recess, and the distance from the narrowest point of the frontal recess to the bony wall of the anterior skull base on the extension of the line 1, respectively

Figure 3. Parasagittal (A) and coronal (B) planes showing the frontal recess and its surrounding structures were demonstrated. D3 and D4 showed the shortest anterior–posterior and right-left diameters of the narrowest route to the frontal sinus, respectively. Solid circle: the narrowest point of the frontal recess.

Figure 4. In case “A”, the line connecting the nostril to the narrowest point of the frontal recess (solid circle) did not cross the frontal process of the maxilla and frontal

bone, so-called the frontal “beak” (arrow), but it crossed in case “B.” The angle between the line connecting the nostril to the lowest portion of the frontal “beak,” and the line connecting the lowest portion of the frontal “beak” to the narrowest point of the frontal recess was measured (★).


A
C
FS
ES
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MS
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B
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ES: Ethomoid Sinus,
FS: Frontal Sinus,
IT: Inferior Turbinate,
MS: Maxillary Sinus,
SS: Sphenoid Sinus

Fig. 1

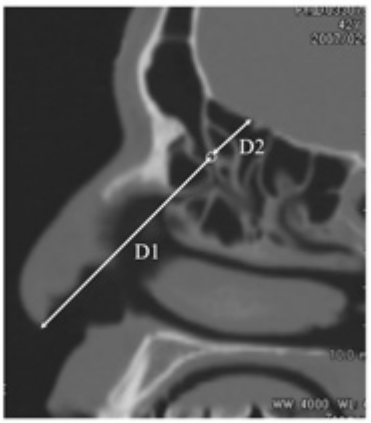
D2
D1

Fig. 2

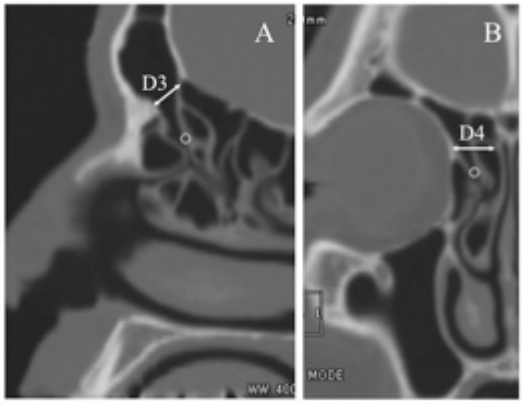

Fig. 3

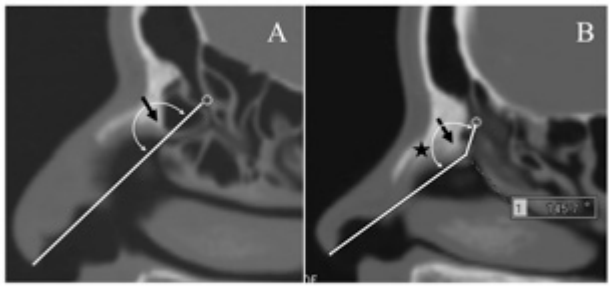

Fig. 4

Table. Dimensions Measured in This Study

Distance from Nostril to FR (D1)	55.9±4.7 mm Min:43.9, Max:68.1
Distance from FR to ASB (D2)	9.4±3.7mm Min:3.3, Max:21.0
Smallest Anterior–Posterior Diameter of RFS (D3)	6.9±2.5mm Min:2.2, Max:22.4
Smallest right-left Diameter of RFS (D4)	8.2±1.5mm Min:4.0, Max:13.4
Angle between the line connecting the nostril to FP and the line connecting FP to FR (A1)	159.9±9.9degree Min:129.5, Max:175.7 N=154

ASB: Anterior Skull Base, FP: Lowest Portion of the Frontal Process of the Maxilla and Frontal Bone,
FR: Narrowest Portion of Frontal Recess, Max: Maximum, Min: Minimum, RFS: Route to the Frontal Sinus