Asymmetry of the anterior skull base at the level of frontal ostium, a radioanatomical study*

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Abstract

Background: Radioanatomical studies have shown that the ethmoid roof is asymmetric in 10 to 40% of individuals. The right ethmoid roof has been found on average to be lower compared to the left. The aim of this study was to extend existing results by assessing asymmetry between the right and left anterior skull base at the level of the frontal ostium.

Methodology: Curved multiplanar reconstruction was used to analyse 247 consecutive paranasal sinus CT scans. The corresponding left and right parasagittal profiles of the skull base marked from the anterior ethmoidal artery to the level of the orbital roof were superimposed and compared.

Results: Asymmetry greater than 1 mm was found in 87% of patients, greater than 2 mm in 40.5% of patients, and greater than 3 mm in 8% of patients. The prevalence of the patients with lower skull base on the right side was greater than those with lower skull base on the left side at a ratio of more than 2:1.

Conclusion: Skull base asymmetry in the region of the frontal ostium is observed in a large percentage of the population and may be a potential source of complications during endoscopic sinus surgery.

Key words: frontal sinus, frontal ostium, skull base, anatomy, computerized tomography

Introduction

Endoscopic surgery of the frontal sinus is often challenging due to the narrow curved drainage pathway. Recognition and understanding of the anatomy of the frontal recess and frontal sinus ostium is essential for safe surgery of this region [1-4]. It was found that the anterior ethmoid roof is lower on average on the right side compared to the left side [4-7]. Little is known about the asymmetry of the anterior skull base at the level of the frontal sinus recess and frontal ostium. Current advances in CT imaging and development of software used for images reconstruction allow for detailed comparison between the curvature of right and left anterior skull base.

The aim of this study is to assess asymmetry between the right and left anterior skull base at the level of the frontal ostium.

Patients and methods

The study was approved by the University Ethics Committee. Overall, 948 CT examinations performed to assess sinonasal complaints were retrospectively assessed. Examinations acquired with slice thickness greater than 1 mm, with a non-regular slice interval, gantry tilt, or performed using cone beam CT were eliminated.

CT images were analyzed with multiplanar reconstructions (MPR) in the bony window (window level - 300 ; window width – 1500). The patients with unilateral or bilateral frontal sinus agenesis or hypoplasia, after osteoplastic flap procedure, Draf IIb or III procedures, with frontal bone fractures, and those with neoplastic or expansile lesions of the frontal recess and sinus were excluded. The remaining 247 examinations of adult Cauca-

sians (126 females and 121 males) mean age 43 years (SD = 16, range 18-82 years) were evaluated further.

Examinations were evaluated using Osirix (Apple, CA, USA) software. The coronal, sagittal and horizontal planes were set using lateral aspect of orbits, the floor of the nasal cavity and crista galli. The profile of the skull base was marked from the anterior ethmoidal artery entry point up to the level of the orbital roof in the parasagittal plane crossing the midpoint between the lamina papyracea and lateral lamella of the cribriform plate. For the purpose of establishing the orbital roof level, the horizontal plane parallel to the floor of the nasal cavity was used. The profile of the right skull-base was superimposed over the corresponding profile of the left skull base using 3D curved MPR (Figure 1). Examinations were cross-checked by marking the left skull base and superimposing its profile over the right side. The maximum distance between the right and left contours of the skull base was noted for each subject (Figure 1). Two observers blinded to each other's findings evaluated each CT examination.

Statistical analyses

Interobserver agreement was analyzed using kappa statistics. The differences in the prevalence of skull base configurations were analyzed using Cochran's Q test.

Results

Three types of skull-base profile configurations were observed:

1. The profiles are positioned one above the other (Figures 1, 2).
2. The superimposed profiles cross, changing position with respect to each other from below to above or from above to below (Figure 3).
3. The profiles overlap.

Asymmetry greater than 1 mm between the sides was observed in 215 (87%) subjects, greater than 2 mm in 101 (40.8%), and greater than 3 mm in 20 (8%) patients. The interobserver agreement (K) was 95%. The results are summarized in Table 1.

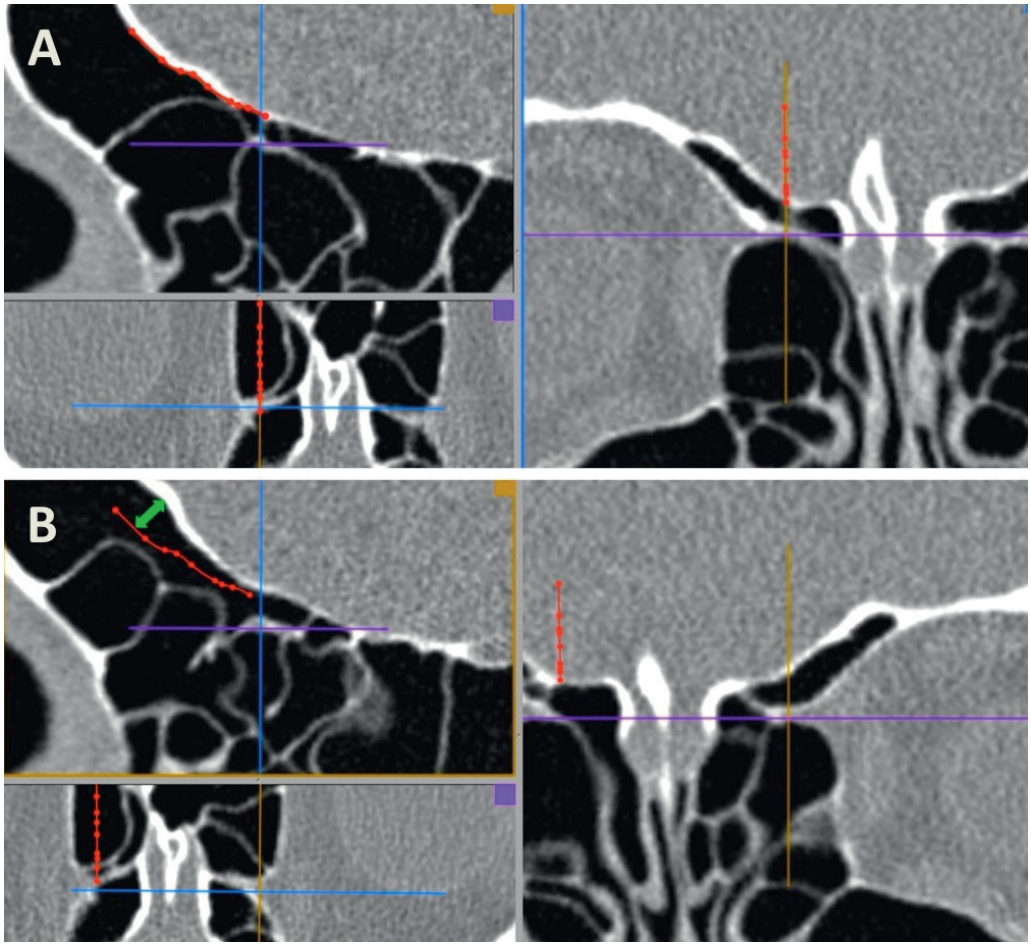

Figure 1. Measuring the distance between the right and left skull base contour using multiplanar CT reconstruction.
A – The right anterior ethmoidal artery is identified in three planes (shown by the intersection of reference lines). The anterior skull base is marked in parasagittal plane crossing half way between the lamina papyracea and lateral lamella of the cribriform plate from the level of the right anterior ethmoidal artery. B –The marked right skull-base segment (dotted red line visible in three planes) is superimposed over the corresponding left parasagittal profile. The maximum distance between the two profiles is measured (green arrow).

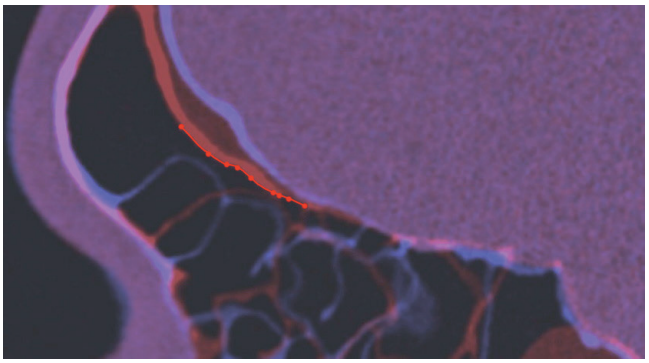

Figure 2. Superimposed corresponding right and left parasagittal sinus CT sections (coloured in red and blue, respectively). The evaluated segment of the skull base is marked with a red dotted line on the right side.

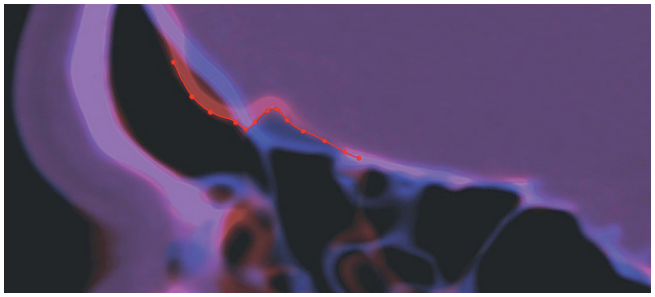

Figure 3. Superimposed corresponding right and left parasagittal sinus CT sections (coloured in red and blue, respectively). The evaluated segment of the skull base is marked with a red dotted line on the right side.

Table 1. Percentage of skull base asymmetry configurations.

Type of configuration	Difference > 1 mm	Difference > 2 mm	Difference > 3 mm
Right lower	118 (48%)*	67 (27%)*	14 (5.5%)*
Left lower	56 (22.5%)	25 (10%)	5 (2%)
Cross #	41 (16.5%)	9 (3.5%)	1 (0.4%)
Total (right, left, cross)	215 (87%)	101 (40.5%)	20 (8%)
Equal / no difference	32 (13%)	146 (59.5%)	227 (92%)

Cross - Superimposed profiles of the left and right skull-based crossed
* The difference between "right lower" and "left lower" was statistically significant ($p < 0.05$).

Discussion

Multiplanar reconstruction (MPR) of CT images gives the possibility to assess the architecture of the ethmoid labyrinth, and is a valuable tool for planning the surgery [2,8].

Several studies focused on asymmetry of the ethmoid roof posterior to the anterior ethmoidal artery and compared the position of left and right olfactory groove or fovea ethmoidalis [5-7,9,10]. Jones at al. did not find any differences in the height of the ethmoid roof in 151 patients [10]. Other authors reported asymmetry of the ethmoid roof in about 10 to 40% of subjects, which is less compared to the asymmetry of the skull base at the level of the frontal ostium found in our study [6,7,9]. In all of these studies the majority of asymmetric ethmoid roofs were lower on the right side. Analysis of consecutive 100 CT examinations performed by Zacharek et al. showed that there is no difference in the height of the ethmoid roof between the right and left sides in the region of the sphenoethmoid junction. In contrast, in the region of the anterior ethmoidal artery, the mean height of the right ethmoid roof was smaller compared to the left [5].

The frontal sinus is often variable in shape and size, asymmetric, occasionally absent on one or both sides, which is not that common in other paranasal sinuses [11]. This variability is very likely to be associated with the asymmetry of the skull base in the sagittal profile at the level of the frontal ostium. These data, together with the results of our study, suggest that the skull base of the anterior cranial fossa is symmetric in the posterior ethmoid region, tends to be asymmetric in the anterior ethmoid region, and becomes the most asymmetric in the region of the frontal ostium.

The studies on paranasal sinuses development using CT revealed that the left frontal sinuses reached bigger sizes compared to the right [11,12]. The authors did not find an explanation for this phenomenon. Unilateral frontal sinus aplasia, which can be related to anterior skull base asymmetry, was reported more frequently on the right side compared to the left in most of the studies [13-15].

A possible explanation of the above mentioned asymmetry is that lateralization of the brain influences skull-base development. The term "brain lateralization" can refer to both handedness, and to asymmetric language and also visuospacial functions of the hemispheres. Handedness and language specialization are not perfectly correlated [16].

Kizilkaya et al. studied asymmetry of the olfactory groove in relation to handedness. The authors found that in a majority of cases the olfactory groove was lower on the right side in right-handed persons, on the left side in left-handers, and was equal in ambidextrous subjects [9].

It is generally accepted that there is left hemispheric brain specialization for language abilities and right hemispheric specialization for visuospacial performance in most humans. This specialization results in macroscopic brain asymmetry known as Yakovlevian torque, which is the tendency of the brain to twist along the longitudinal axis with protrusion of the right frontal and left occipital poles beyond the corresponding left and right edges [17]. This brain asymmetry is reflected in the shape of the

inner skull surface as shown with the use of 3D MRI reconstruction [18].

Brain asymmetry is observed as early as in the fetal and newborn periods. However, left hemispheric brain specialization for language abilities was found to develop in early childhood during speech development at the time when the frontal sinus is yet not developed. In contrast, visuospacial performance related to the right hemisphere develops gradually between the ages of 6 and 16, thus simultaneously with the development of the frontal sinuses [19].

Although relatively small, the described differences in the level of the anterior skull base between right and left sides may affect the possibility to inspect the frontal sinus with an endoscope during sinus surgery, or even access it with surgical tools, as the frontal ostium is narrow and angulated. These differences may also influence surgical complication rates. Intracranial penetration during endoscopic sinus surgery was found to occur more frequently on the right side [20]. It was hypothesized that this can be due to poorer visualization of the right ethmoid cavity for the right-handed surgeon, and due to asymmetry of the ethmoid roof. The described asymmetry of the skull base at the level of the frontal ostium, which is more frequent on the right side, may be an additional factor.

Another potential consequence of the described asymmetry to be considered is its impact on rhinosinusitis. It can be hypothesized that ventilation and drainage of the frontal sinus can be impaired on the side with a lower skull-base. Anatomical variations such as concha bullosa, Haller's cell or septal deviation are known factors predisposing to recurrent acute sinusitis [21,22]. In chronic rhinosinusitis the contribution of these variations is questioned [22,23]; however, there are still not enough data on the role of a single type of variants. The frontal sinus drainage pathway is relatively long and dependent on several anatomical structures such as agger nasi cells, bulla lamella, frontal cells type I-IV, supraorbital ethmoid cell or frontal intersinus septal cell. Thus, it could be difficult to establish the role of single anatomical factor predisposing to acute or chronic frontal sinusitis. On the other hand, orbital complications of frontal sinusitis were observed more frequently on the left side, more commonly in males compared to females [24]. This may be related to the greater size of the frontal sinus on the left side in children and adults, the greater width and length of the frontal sinuses in males, together with more frequent aplasia of the frontal sinus in females compared to males [11]. Greater pneumatization is associated with the bigger area of the mucoperiostium covering the orbital wall, which potentially increases the risk of orbital complications.

Conclusion

Skull base asymmetry in the region of the frontal ostium is observed in a large percentage of the population and may be a potential source of complications during endoscopic sinus surgery.

Authorship contribution

TG: Research concept and design, collection and analysis of data, writing of the article; MK: data analysis; MHZ: data analysis; KN: critical revision of the article

Conflicts of Interest

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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