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Original Article

Frontal sinus asymmetry: Is it an effect of cranial asymmetry? X-ray analysis of 469 normal adult human frontal sinus

Ayhan Kanat, Ugur Yazar[1], Bulent Ozdemir, Zerrin O. Coskun[2], Ozlem Erdivanli[2]

Departments of Neurosurgery and [2]Otorhinolaryngology, Medical Faculty, Recep Tayyip Erdogan University, Rize, [1]Department of Neurosurgery, Medical Faculty, Karadeniz Technical University, Trabzon, Turkey

ABSTRACT

Background and Aims: There is no study in the literature that investigates an asymmetric morphological feature of the frontal sinus (FS). **Materials and Methods:** Four hundred and sixty-nine consecutive direct X-rays of FSs were analyzed for the asymmetry between the right and left sides. When an asymmetry in the height and contour of the FS existed, this difference was quantified. **Results:** Of the 469 patients, X-rays of 402 patients (85.7%), there was an asymmetry between right and left sides of the FS. Of these 235 (50.1%) were dominant on the left side, whereas 167 (35.6%) were dominant on the right, the sinuses of remaining 67 patients (14.3%) was symmetric. **Statistical Analysis:** The comparisons between parameters were performed using Wilkinson signed rank test. The relationship between handedness and sinus asymmetry was also examined by two proportions test. There is statistically significant difference between the dominance of left and right FS. **Conclusions:** Hemispheric dominance may have some effect (s) of on sinus asymmetry of the human cranium. Surgeons sometimes enter the cranium through the FS and knowledge of asymmetric FS is important to minimize surgical complications.

Key words: Asymmetry, frontal sinus, X-ray

Introduction

A biological variation allows for a unique craniofacial character and many asymmetries found in each individual.[1] The human skull is made up of 22 paired and unpaired ossicles, which are classified as viscerocranium and neurocranium. The neurocranial bones of variable size and shape are often encountered at the fontanelle or along the sutures.[2] In humans, the two brain hemispheres differ in their anatomy and function. Although a cursory examination of the gross features of the human brain fails to expose profound left-right differences, a careful examination of its structure reveals a variety of asymmetrical features. This is not a surprise because most biological systems show some degree of asymmetry. In addition, handedness has been shown to be associated with differences in the morphology and the structure of the corpus callosum, and cerebral anatomical lateralization, as well as functional lateralization both in behavioral and scanning studies.[3,4] The handedness may lead to misbalance of the human cranium, and some kind of asymmetry of frontal sinuses (FSs). Certain anatomical structures call for detailed study due to their functional importance.[5] The literature on laterality is large, but there are no published studies concerning the asymmetry in the human FS. The aim of this work was to analyze this subject.

Address for correspondence:
Dr. Ayhan Kanat, Ekrem Orhon Mahallesi, 2.Laleli Sok, Yilmaz Apt 14/3, 53100 Merkez-Rize, Turkey.
E-mail: ayhankanat@yahoo.com

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Materials and Methods

The local institutional review board approved the protocol for this study. Four hundred and sixty-nine patients with "Sinus headache (349 women, 120 men) patients aged between 10 and 94 years" were evaluated prospectively. Measurements included both lateral and superior extent of the FS in reference to a mid-pupillary line, and the superior extent of the FS from the nasion. Sometimes, the maximal extension of the FS was slightly oblique in the craniocaudal plane. In these cases, the height measurement was done in a slightly oblique direction. Consecutively, the maximal length was slightly oblique since it was measured perpendicularly to the height measurement. The class number was defined as follows: FS = −1 if the left sinus was superior to the right one, FS = +1 in the reverse case.

Handedness

It was asked the patient their preferred hands for writing, drawing, throwing, using various implements such as scissors, toothbrush, knife without fork, spoon, striking matches, and jar opening. Hand used to write and throw a ball was accepted as dominant hand. The categories were left hand (−1), right hand (+1), and both (0).

Data analysis

Data were analyzed with the statistical software package 16.0 SPSS for Windows (SPSS Inc., Chicago, IL, USA). The comparisons between parameters were performed using Wilkinson signed rank test. The relationship between handedness and sinus asymmetry was also examined by two proportions test, and $P < 0.05$ was regarded as significant.

Results

Of the 469 patients, the height and contour of the FS of 402 patients (85.7%) were asymmetric. In 235 (50.1%) of cases, the left sinus were dominant, whereas 167 (35.6%) were dominant on the right. It was symmetric remaining in 67 patients (14.3%). Table 1 shows the distribution of FS dominance between groups. Two proportions test performed and found that there is statistically significant difference between the dominance of left and right FS. Table 2 shows the percentage of hand dominance. The patient was analyzed according their sex, and each sex was divided to three groups. Group I was constituted from the patient with left FS, Group II from the patients with symmetric sinus, and Group III the patient with right FS dominant. Statistical analysis was made between groups. In males, handedness rate of males was statistically significantly different between Group I and II, between Group II and III ($P < 0.05$). The differences between groups were not statistically significant in females. In 175 (50.1%) of cases, the left sinus were dominant, whereas 124 (35.5%) were dominant on the right. Sinus frontalis on the remaining 50 patients (14.3%) was symmetric. Although there is difference left (50.1%) and right (35.5%), this difference was not found as statistically significant. However, there is statistically significantly difference of handedness rate between the patient with symmetric and left sinus dominant patients and right sinus dominant patient $P < 0.05$.

Table 1: The distribution of frontal sinus dominance between groups

	Frequency (%)
−1	235 (50.1)
0	67 (14.3)
1	167 (35.6)
Total	469 (100)

(−1) if the left sinus was superior to the right one, (+1) in the reverse case, 0 means bilateral symmetric sinus

Table 2: The percentage of hand preferences

	Frequency (%)
−1	36 (7.7)
0	9 (1.9)
1	424 (90.4)
Total	469 (100)

The categories were left hand (−1), right hand (+1), and both (0)

Discussion

It is well-known that the brain is asymmetric in structure and function. Like the brain, the cranium has frequently asymmetrical feature.[6] It is suggested that in the normal population, handedness and footedness are relevant factors in predicting cerebral dominance. Recent studies found in right-handed individuals' strong left hemispheric dominance while in left handers significant right hemispheric dominance was shown.[7] Most humans have a strong preference for using the right hand in unimanual tasks, a minority prefers the left hand, and very few people do not exhibit a hand preference. This question can be answered in different ways. For example, manual asymmetries can be related to asymmetries of the brain and FS. Lateralization and asymmetry secondary to cerebral dominance is also important for neurosurgical pathologies. Kim *et al*. reported that the anatomical asymmetry of the cranium influences the left predilection of chronic subdural hematoma.[6] The relationship between brain asymmetry and handedness has, for some time, sparked considerable interest and debate.[8] The hemispheric asymmetry implies the existence of developmental influences that

affect one hemisphere more than the other. However, the influence of this to FS asymmetry has not been studied previously. In this study, it was found that, in 85.7% of patients, there was an asymmetry of FS between on the right and left sides. Although 424 cases (90.4) are right-hander, but there was left FS dominance 63.4% in the left-hander, 66.7% ambidextrous patients, and 48.6% right-hander. As it can be seen the present study, asymmetry is a common phenomenon in the human body and for the skull as its part. The asymmetry of skull is directional, and appears as larger left occipital, sphenoid bone compared with right side while frontal, temporal, parietal bones show opposite difference, and the internal length of the skull is larger on the right side than on the left side. It has been hypothesized that human functional laterality that is, handedness, eyedness, footedness, is related to this anatomic laterality of brain, and for example right-handedness is associated with a larger left side of brain, whereas non-right-sidedness with increased symmetry of the head and body halves, and asymmetric development of brain region may be responsible for the development of symmetric facial regions. Similar to fingerprints, each FS is so distinctive and unique that the chances of two individuals having the same morphology of the FSs are extremely remote.[9] In addition, we showed in this study that left FSs dominance was 69.3% in left-hander, 66.9% in ambidextrous, in 48.6% in the right-hander. It is clear that analysis of fluctuating asymmetry in this study reveals the influence of cerebral dominance. All participant were referred for headaches, our finding the finding generalize to a healthy population sample. Figure 1 shows left FS dominance of a right-hander.

Why frontal sinuses were preferred in this study?

A precise knowledge of the anatomy of the paranasal sinuses is essential for the neurosurgeon. Increasingly, subtle bony anatomic variations and mucosal abnormalities of this region are being detected. This sinus comprises one of the most complex anatomic areas of the anterior cranial fossa. Its complexity is magnified by the frequency of anatomic variations and consequently very difficult to study; its anatomy possesses great complexity and is rather variable from person to person. They are the last paranasal sinuses to develop, and this sinus is present in approximately 90% of adults, are the only sinuses consistently absent at birth. We think that the patterns of asymmetry are fixed after adolescence. Their development is variable beginning the first year of years of life and completed in early adolescence. Its development seems parallel with laterality of brain. For that reason, we postulated that, during development, handedness can have some effect (s) of on sinus asymmetry of the human cranium. To support this statement, in this study, it was decided to investigate that correlation between a dominant FS and right-handedness and vice versa. Left FS dominance was seen in 69.3% in the left-hander, 66.9% in ambidextrous, in 48.6% in the right-hander. This is an interesting result. Because bone is a malleable tissue, it is highly responsive at both macroscopic and microscopic levels to its external, mechanical environment throughout the life course. It is well-established that skeletal morphology is mediated locally by its mechanical loading history against a systemic genetic and endocrinological/metabolic background. Directional bilateral asymmetries in human gross skeletal morphology are largely attributable to differential mechanical loading from handedness during endochondral bone growth. Hence, it should not be surprised then; asymmetry of FS inside of cranium may be a consequence of cerebral laterality.

Figure 1: Left frontal sinus dominance of a right-hander

Importance of this asymmetric anatomic knowledge

Over the past several decades, the instruments and techniques of endoscopic surgery have greatly improved. A precise knowledge of the anatomy of the paranasal sinuses is essential for the clinician.[10]

In this era, the recognition of the larger diameters of the left FS is important. The recognition of this fact is important. If indeed one is the first to report something and that something is of value.[11,12] In addition, the knowledge provided in the present study is useful and will widen the anthropometric knowledge of humanity. Preferred hand use has been observed even at embryonic and fetal stages in humans, long before language ability is developed. These results imply that anatomical and functional brain asymmetry precedes uptake of information from the environment and cognitive development.[13]

Limitation of this study

The quantification of hand preference is generally performed using specific questionnaires like the Annett Handedness Inventory,[14] but these questionnaires are not feasible to be filled in the hospital setting. We used to ask the patient their preferred hands for writing, drawing, throwing, using various implements such as scissors, toothbrush, knife without fork, spoon, striking matches, and jar opening. Hand used to write and throw a ball was accepted as dominant hand. The reliability of the present analyses was supported by replication, especially in findings for hand preferences for writing and throwing described by Gilbert and Wysocki.[15] In this study, we evaluated human FSs of 469 patients with headache, and compared right and left sinuses and noticed asymmetry of both sinuses. The "superiority of size" was depended simply upon the extent of both sinuses toward superior and lateral directions. The volumes of both sinuses were not calculated because we thought that such a calculation will not be loaded to additional data.

Conclusions

The challenge of studying brain asymmetry is that because the obvious anatomical and functional asymmetries have been identified largely in humans, we cannot carry out direct experiments.[13] This study suggests that the brain development can take a different course for different individuals, producing individual differences in lateralization. Lateralization seems a factor in human FS asymmetry. To understand the development origins of hemispheric specialization is an important part of understanding what it is to be human.

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Conflicts of interest

There are no conflicts of interest.

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