Original article

Frontal sinus size on facial plain radiographs

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Abstract

Introduction: Plain radiographs are still routinely used for diagnosis in dentistry. They allow the assessment of anatomical structures and their variations, and the detection of abnormalities in the region assessed. The aim of this research was to determine the width and height distances of the frontal sinus on posteroanterior skull view of Brazilian subjects. Materials and methods: The sample was composed of 158 posteroanterior facial radiographs (Caldwell projection). It was measured the height and width of the frontal sinus, both sides, under a standardized protocol, using rules and a viewer box. The relationship between frontal sinus size and side of the face, and size and age were evaluated. Results: Thirteen radiographs were excluded (six of unilateral frontal sinus, two agenesies, and five showing totally individualized chambers). The final sample studied was of 145 subjects. The mean values obtained were a 68 mm for latero-lateral and 39 mm for superoinferior distances. In 39.3% cases both sides were approximately equal or had the left chamber larger than the right one. There was a significant correlation between width and height of frontal sinus (Spearman coefficient), however there was no significant difference among the age groups studied (Kruskal-Wallis, $p > 0,05$). Conclusion: There is a great anatomical variety of frontal sinus in this population. The left cavity of frontal sinus is larger or equal to the right one and the age group differences was not significant regarding the size of the frontal sinus.

Keywords: frontal sinus, radiography, anatomy, posteroanterior view, anatomical variation.

1 Introduction

Historically, shortly after the discovery of the X ray in 1895, the paranasal sinuses were frequently studied by plain film radiography. The posteroanterior projection described by Caldwell (1907) is designed to provide a clear view of the frontal and ethmoid sinuses without loss of definition by superimposition of portions of the sphenoid bone. The central X ray is aligned to exit between the orbits at the base of the nose, eliminating the superposition with the petrous ridge of the temporal bone. The frontal sinus alone has the clearest silhouette in this projection and presents the least chance for error in interpretation. Their vertical axes are parallel to the film in the Caldwell projection and there is no space between the frontal bone and the film cassette (NAMBIAR, NAIDU and SUBRAMANIAM, 1999).

The function of the paranasal sinuses are not well understood, but anatomical literature suggests that they lighten the skull, add more resonance to the voice (NAMBIAR, NAIDU and SUBRAMANIAM, 1999; YANAGISAWA and SMITH, 1968) or are vestigial (PROSSINGER and BOOKSTEIN, 2003).

The paranasal sinuses begin development early in fetal life. The frontal sinus develops as diverticula from the lateral nasal wall around the fourth fetal month following the development of the frontal recess. In the 26-week intrauterine life, the nasal mucosa of the middle meatus grows toward the developing frontal bone, forming the primordial frontal sinus. By 32 to 40 weeks, the primordial frontal sinus is still surrounded by a sleeve of cartilage that is part of the cartilaginous nasal capsule (WANG, JIANG and GU, 1994). By the sixth year, they can be demonstrated radiographically and grow larger in size by late adolescence (HARRIS, WOOD, NORTJÉ, 1987; WEIGLEIN, ANDERHUBER and WOLF, 1992). The definitive frontal sinuses are paired, irregular shaped, air-containing chambers, lined by mucoperiosteum and are located between the outer and inner tables of the frontal bone, posterior to the superciliary arches and at the roof of the nose (YANAGISAWA and SMITH, 1968).

Pneumatization of the frontal bone begins later in life at about the age of four (BARGHOUT, PRIOR, LEPORI et al., 2002). In the four-year-old child the upper ethmoidal cells begin to overstep the ethmoid bone. The most anterior cell excavates the frontal squama more and more, whereas the other cells stop growing when they reach the orbital part of the frontal bone. However, the pneumatization of the frontal squama is very variable (MARESH, 1940b) and may continue even after forty years (FINBY and KRAFT, 1972).

Some factors can modify the normal anatomy of the frontal sinus, such as fractures, neoplasias, severe infections and mucoceles. At the forensic field, it was reported that no two persons have identical frontal sinuses, including identical twins (NAMBIAR, NAIDU and SUBRAMANIAM, 1999; RIBEIRO, 2000).

A few authors have studied paranasal sinus growth and some proposed scales of sizes (BROWN, MOLLESON and

CHINN, 1984; FATU, PUISORU, ROTARU et al., 2006; MARESH, 1940a, b; ODITA, AKAMAGUNA, OGISI et al., 1986; QUATHREHOMME, FRONTY, SAPANET et al. 2003; SPAETH, KRÜGELSTEIN and SCHLÖNDORFF, 1997; WEIGLEIN, ANDERHUBER and WOLF, 1992; WOLF, ANDERHUBER and KUHN, 1993). It has been described left/right differences with the right frontal sinus being smaller than the left without objective explanation (BARGHOUT, PRIOR, LEPORI et al., 2002; SPAETH, KRÜGELSTEIN and SCHLÖNDORFF, 1997). However, Odita, Akamaguna, Ogisi et al. (1986) did not find significant differences in the mean left and right sinus widths of nigerian infants and children.

The frontal sinus is also often thought of as a more "symptomatic sinus" because of the difficulties encountered in frontal sinusitis and maintaining a patent frontal sinus ostium in patients with difficult to treat frontal rhinosinusitis. However, as indicated by the current data, many patients with a completely opacified frontal sinus are not necessarily more significantly negatively affected in terms of symptom scores by their frontal sinus disease. This may be caused by several factors such as patients adapting or accommodating to painful symptoms of frontal sinusitis, other symptoms such as rhinorrhea or nasal obstruction overshadowing the frontal sinus symptoms, or other factors yet to be elucidated. As an example, chronic rhinosinusitis may have symptom manifestation leading to headache, facial pain and facial discomfort. It would appear intuitively likely that patients with higher radiographic volumes of disease would manifest more severe symptom scores and greater disease volumes would carry with them potentially more deleterious effects on quality of life (BHATTACHARYYA, 2005).

Moreover, as the conventional plain-based film radiographies are the first one to be analyzed by the clinicians, so still important to know the anatomy, size and variants of the frontal sinus for specific populations. Paranasal sinuses are prone to a great diversity of anomalies. It is important for surgeons to be aware of variations that may predispose patients to increased risk of intraoperative complications and help avoid possible complications and improve success of management (HAKTANIS, ACAR, YUCEL, 2005). A better knowledge of normal pneumatization and development of paranasal sinuses is important to evaluate sinus disease and to propose an adequate treatment (FATU, PUISORU, ROTARU et al., 2006). Therefore, this work studied the size of frontal sinus in a Brazilian population to better understand how it develops through out life.

2 Material and methods

A retrospective research was performed in 158 good quality and standardized X ray images (Caldwell view) of the Maxillofacial Surgery Department (School of Dentistry, Federal University of Bahia, Brazil). The research protocol was approved by an Ethics Committee. It was excluded two agenesis and six unilateral cases. Five other cases showed two or more single independent chambers separated by a very tick bone wall, so they were excluded as well. Of the remaining 145 subjects, 116 (80%) were males and 29 (20%) females. All the X ray images had bilateral frontal sinuses measured by a ruler over a viewer box.

The age distribution was as follow: 17 (11.7%) subjects at the range of 14 to 20 years old; 35 (24.1%) from 21 to 30 years; 49 (33.8%) from 31 to 40 years; 22 (15.2%) from 41 to 50 years and 17 (11.7%) older than 51 years. The data were lost in 5 (3.5%) cases.

The measurements were done according to the sequence bellow (Figure 1):

a) The first step was to place the radiography on a viewer box and draw a line directly on it between both orbital cavities, at the nasofrontal suture;

b) The diameter of the frontal sinuses at the widest points – that was the distance between two projected lines that delineate the maximum lateral limits of the right and left sinuses (RIBEIRO, 2000);

c) The height was done by drawing a parallel line to the nasofrontal line at the highest superior point of the frontal sinuses; and

d) measure the distance between both.

The measurements were accomplished according to the parameters to follow (RIBEIRO, 2000): only air-containing cavities without any pathology or trauma; two equally high points, measure the one closer to the intersinus septum; when the highest point was located at a large-open curve lobulation, measure the point at the middle of the lobulation; when the highest point was located at a plateau lobulation measure the middle of the plateau.

3 Results

The mean age was 34 years old, and it was found a mean measurement of 68 mm to the width and 39 mm to the high. The intersinuses septum was present in all the 145 measured cases. The sizes of the cavities were different as: 31 (21.4%) cases had a larger right side; 57 (39.3%) had a larger left side and 57 (39.3%) showed almost the same size for both cavities. The highest point was located at the middle line in 113 (78%) cases, 19 (13.1%) at the left cavity and 13 (8.9%) at the right cavity.

Considering the initial 158 X ray, it was found an anatomical variety of 1.3% agenesies, 3.8% unilateral frontal

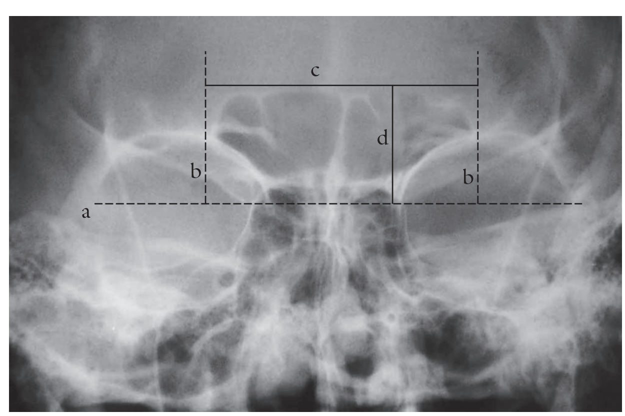

Figure 1. a) Line drawn on radiography between both orbital cavities, at the nasofrontal suture; b) The diameter of the frontal sinuses at the widest points – that was the distance between two projected lines that delineate the maximum lateral limits of the right and left sinuses; c) The height was done by drawing a parallel line to the nasofrontal line at the highest superior point of the frontal sinuses; and d) measure the distance between both.

sinus and 3.2% frontal sinus consisting of two or three small isolated cavities. These cases were excluded from the measurements.

There was a significant correlation between the width and height by the Spearman Test. However, there was no significant difference among the age groups (Kruskal-Wallis, $p > 0.05$) regarding the height and width of the frontal sinuses in this population.

4 Discussion

Establishing an average size of frontal sinuses for a population provides an evident improvement in sinus development knowledge. It permits better appreciation of the effect of frequent diseases such as sinusitis and other less frequent diseases on sinus development. Better knowledge of sinus development also provides guidance in planning sinus surgery since it may compromise sinus pneumatization and facial growth (KIM, FRIEDMAN, SULEK et al., 1997; KOSKO, HALL and TUNKEL, 1996; MAIR, BOLGER and BREISCH, 1995). In our institution, such values are considered as useful by the maxillofacial surgeons and other surgical categories in the preoperative staging the complex craniofacial malformations, bone dysplasia and various skull base and facial tumors.

The sinus measurements presented in this paper were similar to those published by other authors (DUERINCKS, HALL, WHYTE, 1991; MARESH, 1940a, b; ODITA, AKAMAGUNA, OGISI et al., 1986; SCUDERI, HARNSBERGER and BOYER, 1993; SPAETH, KRÜGELSTEIN and SCHLÖNDORFF, 1997; WEIGLEIN, ANDERHUBER and WOLF, 1992; WOLF, ANDERHUBER and KUHN, 1993) so these data contributed in the management of sinus disease and sinus surgery in our population. As well, Fatu, Puisoru, Rotaru et al. (2006) (2006) found, in a series of 60 patients from 4 to 83 year-old, that the frontal sinus pneumatization increases up to 19 years of age, synchronous to craniofacial growth. In the 15-16 year old patients the sinusal area has almost the same values as in adults. In 20-45 year-old adults, the individual variations in the sinusal area were most obvious. A significant variation in sinusal size and configuration has been observed in 46-60 year old patients. In patients older than 60 years, the osseous resorption has been suggested to be responsible for increasing the sinusal area. This process was more intense with age and was accompanied by a significant thinning of the cortical orbital plate.

In our study, the mean dimensions of frontal sinuses found for both genders from 14 to 20 years was 65 mm wide; 36 mm high; from 21 to 30 years was 65 mm wide; 38 mm high; from 31 to 40 years was 66 mm wide; 39 mm high; from 41 to 50 years was 70 mm wide; 39 high and finally above 51 years was 71 mm wide; 41 mm high. Considering all age ranges, the height was 55 to 59% smaller than the width. As has been showed (BARGHOUT, PRIOR, LEPORI et al., 2002; FATU, PUISORU, ROTARU et al., 2006; WEIGLEIN, ANDERHUBER and WOLF, 1992), our data also confirm that the size of the frontal sinuses is very varied. We measured width from 5 to 125 mm and height from 7 to 65 mm. In all cases the medium septum was seen. The frontal sinus is generally larger in males than in females (BARGHOUT, PRIOR, LEPORI et al., 2002; SPAETH, KRÜGELSTEIN and SCHLÖNDORFF, 1997). Prossinger and Bookstein (2003) found that the estimated maximum expansion rates for males occur 3.02 years later than of the females. The results showed that frontal sinus has a great individual variability. This variability is considered an useful tool in forensic identification (RIBEIRO, 2000).

The frontal sinuses may be a prime catalyst in the process of developing intracranial complications on the basis of it anatomical characteristics (GOLDBERG, OROSZLAN and ANDERSON, 2001; MORTIMORE and WORNALD, 1999). In a series of pediatric patients with acute sinusitis the prevalence of intracranial complications was significantly higher (30.4%) in patients with frontal sinusitis compared with those without frontal sinus involvement (2.12%) (EL-HAKIM, MALIK , ARONYK, 2006). Apart from its location (GOLDBERG, OROSZLAN and ANDERSON, 2001; MORTIMORE and WORNALD, 1999), the venous supply comes from the dura matter for the inner table, the periorbita for the orbital plate and the cranial periosteum for the outer table. Additionally, venous mucosal drainage is through the small diploic veins extending through the bony sinus wall. These in turn communicate with the venous plexuses of the three structures. This exceptional watershed between intra- and extra-cranial venous systems accounts logically for transmission of infection. The study of El-Hakim, Malik, Aronyk et al. (2006) provided evidence for the first time on a statistical basis for the strength of this association.

The pneumatization of the paranasal sinuses, especially the frontal sinuses vary greatly in size and shape, for reasons as yet unknown (FATU, PUISORU, ROTARU et al.,). During the fetal period, the frontal sinus and posterior ethmoidal cells are still rudimentary surrounded by cartilage. It is possible that earlier ossification of the cartilage will interfere with their further development, manifesting as a hypoplastic (WANG, JIANG and GU, 1994). Complete aplasia of frontal sinus is very rare but unilateral or hypoplasia was 7.2% in plain radiographies studies (BASSIOUNY, NEWLANDS, ALI, 1982). Similarly, in this work we found 1.3% of agenesies and 3.8% unilateral sinus, all together accomplished 5.1% from the initial population. If we add 3.2% representing the sinuses with small and isolated cavities (hypoplastic), the total percentage will represent 8.3%. Aplasia was seen more in females (18.2%) than in males (10%) (SPAETH, KRÜGELSTEIN and SCHLÖNDORFF, 1997). Unusual conditions include an unpartitioned central sinus (2.5% cases) (QUATHREHOMME et al., 1996), unilateral absence of a sinus (14.3% of males; 7.1% females) (YOSHINO, MIIYASAKA, SATO, 1987), agenesis (5%) (YOSHINO, MIIYASAKA, SATO, 1987).

The study of Fatu, Puisoru, Rotaru et al. (2006) showed that the frontal sinuses must be considered dynamic components of the fronto-ethmoidal complexes. In 5% of the adults we found a bilateral absence of the frontal sinus and in 1.6% it was unilaterally absent. The frontal sinus pneumatization increases up to 19 years of age synchronous to craniofacial growth. In the adult the individual and right-left variations in size are significant and may be caused by inflammatory factors. In this respect there were no major differences between males and females. In elderly patients, the osseous resorption leads to an enlargement of the sinusal cavity and can be responsible for orbital complications during surgery.

Spaeth, Krügelstein and Schlöndorff (1997) found frontal sinuses were visible only in 10.7% of four years old and in 50% of eight years old. Finally they found in more than 90% after the age of 15, using CT scans. The development of frontal sinuses was comparable between male and female patients. They also encountered that the development of the frontal sinuses is completed by age of eighteen. The right frontal sinus of both sexes was almost constantly found to be smaller than the left sinus (WOLF, ANDERHUBER and KUHN, 1993). In agreement, these work showed 57 (39.3%) cases where the left side was larger than the right. As the right and left frontal sinuses develop independently, at different rates osseous resorption, a significant asymmetry between both sides can arise in the same individual. Variability in size and aspect of the frontal sinuses is usually found in individuals of the same age (FATU, PUISORU, ROTARU et al., 2006).

The preoperative recognition of individual anatomic variations is a prerequisite for any successful surgical procedure performed on the frontal sinus (McLAUGHLIN, REHL and LANZA, 2001). The analysis of radiographs of the frontal sinuses is therefore an useful tool to identify its size and configuration and to minimize the risk factors for any sinusal or orbital operation (LANDSBERG and FRIEDMAN, 2001). In elderly patients, asymmetrical bone resorption might determine the enlargement of the sinusal cavity. The osseous laminae separating the ethmoidal labyrinth from the inferior and posterior walls of frontal sinus becomes thinner and may cause intracranial dissemination of sinusal inflammation (LANDSBERG and FRIEDMAN, 2001).

The frontal sinus had been singled out as a prime catalyst and a common denominator in the pathogenesis of intracaranial complications. This had been attributed to its unique anatomy (EL-HAKIM, MALIK , ARONYK, 2006; GOLDBERG, OROSZLAN and ANDERSON, 2001). Therefore, the knowledge of the extent of pneumatization and the development of different parts of the paranasal sinus system is an important condition for adequate treatment of its diseases and traumas. It is of special interest to determine developmental and size of the frontal sinuses.

5 Conclusion

According to the population studied, the frontal sinus had the left cavity larger or equal to the right one and the age group differences was not significant regarding the size of the frontal sinus.

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