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Volumetric analysis of the maxillary, sphenoid and frontal sinuses: A comparative computerized tomography based study☆

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ABSTRACT

Objective: To study volume characteristics of the maxillary, sphenoid and frontal sinuses among healthy Caucasians adults, using computed tomography (CT) scans.

Methods: A retrospective, case series study in a single academic center, CT scans of 201 consecutive adult subjects, performed between January and September 2014, were reviewed for the volume and dimensions of the paranasal sinuses. Patients with documented sinus pathology or lack of pneumatization were excluded.

The study population was subdivided by gender and age (50 men age 25–64; 51 men age ≥65; 50 women age 25–64, and 50 women age ≥65).

Results: The mean volume of maxillary, sphenoid and frontal sinuses in the four groups were 12.75 ± 4.38 cc; 4.00 ± 1.99 cc and 2.92 ± 2.57 cc, respectively. In both genders, older patients demonstrated a significantly lower volume of the maxillary and sphenoid sinuses (14.81 ± 3.96 cc vs. 11.82 ± 4.28 cc and 4.84 ± 1.97 vs. 3.84 ± 1.89 cc respectively; $p < 0.001$). No age related difference was found in the frontal sinus. Males had significantly larger sinus volumes than females ($p < 0.001$): maxillary 14.38±(4.64) vs. 12.23 ± (3.82) cc, sphenoid 4.74 ± (2.06) vs. 3.55 ± (1.73) cc, frontal 3.74 ± (2.97) vs. 3.21 ± (2.79) cc. No synergistic effect of age and gender was found.

Conclusion: Volumes of the paranasal sinuses correlates with age and gender. Age related volume degeneration is expected in the maxillary and sphenoid sinuses. This volume reduction may influence future surgical and therapeutic approaches in the geriatric population.

1. Introduction

CT scans of the paranasal sinuses have become a cornerstone in the evaluation and management of patients with sinus disease [1]. It had expanded our knowledge of anatomical features and variations of the sinus system [2], and allowed a better assessment of the pneumatization of the paranasal sinuses [3].

CT based volumetric measurements of the sinuses have replaced earlier methods such as cadaveric studies and plain radiography [4]. Some CT studies have estimated the sinuses' volume based on 2 dimensional scans, using different formulas [5–8], while others used different 3 dimensional (3D) models to better estimate the volume of the paranasal sinuses and other anatomical relations in the system [3,9,10]. Moreover, 3D CT volume-based scoring of the paranasal sinuses exhibited better

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degree of correlation to quality of life improvement after medical treatment for chronic rhinosinusitis than Lund–Mackay scoring [11].

Despite several investigations in the past, there is still lack of consensus regarding the affect of gender and age on paranasal sinuses. Age related volume degeneration of the paranasal sinuses has been studied and shown in the maxillary and sphenoid sinuses [6,7,10]. The effect of gender on sinus volume in previous studies is inconsistent. Studies of the maxillary sinus have shown conflicting results [5–7,10,12]. Differences were found in the frontal sinuses [6,9] but not in the sphenoid sinus [7]. The increasing interest in 3D CT models has stressed the need for better understanding of normal volume values of the general populations, and the impact of different factors on these values, both physiologic (i.e. age and gender) and pathologic factors (e.g. chronic sinusitis). Establishment of such baseline values may contribute to further studies investigating the connection between the sinuses' volume and pathologies of the sinuses' system.

Our study was designed to establish the normal volume of the maxillary, sphenoid and frontal sinuses, and to evaluate the impact of age and gender on sinus volume. This may have future implications regarding perioperative assessment of the sinuses, dental implant planning [8] and future surgical and therapeutic approaches to the paranasal sinuses.

2. Patients and methods

This is a retrospective, case series study of patients who underwent head CT scan at our institutional emergency department (ED) between January and September 2014. The study was approved by the Institutional Ethics Committee.

Patients were assigned to the study consecutively. Twenty-five years old was defined as minimum age, assuring full development of the paranasal sinuses [3,4]. Patients with known paranasal sinus pathology or patients whose CT scans were of poor technical quality were excluded. CT scans which demonstrated agenesis (complete lack of development) of a sinus or sinuses in which air content was limited by opacification were excluded as well.

Sixty five years and older were defined as elderly population, according to the definition of the World Health Organization (WHO) [13]. The study population was divided by gender and age into four groups as follows:

(1) Men younger than the age of 65 years—younger men (YM) group.
(2) Men at or over the age of 65 years—older men (OM) grou.
(3) Women younger than 65 years—younger women (YW) group.
(4) Women at or over the age of 65 years—older women (OW) group.

Beginning with January 1st 2014, the first fifty consecutive patients that fulfilled the requirements for each group were assigned to the study.

CT scans of the brain and/or paranasal sinuses were performed on a 64-slice MDCT scanner (Brilliance 64, Philips Healthcare, Cleveland, Ohio, USA). Helical scans were acquired at 0.625 mm slice collimation, 2 mm slice thickness, 120 kVp and tube current of 50–250 mAS. For each patient, the volume of the specific sinus was measured using commercial interactive volumetric-assist software (Volume Tracing in Advanced Vessel Analysis, Philips Healthcare, Cleveland, Ohio, USA) on a viewing work station (Extended Brilliance Workspace, Philips Healthcare, Cleveland, Ohio, USA). Each sinus was measured manually by marking the lumen of the sinus in each of the axial plane slices. The lumen of a sinus was defined as the space within the bony walls of the sinus in all three planes (axial, coronal and sagittal). After completion of the marking process, a 3D image of the sinus was automatically created by the software aforementioned, as demonstrated in Fig. 1. The volume of the marked lumen was calculated by the software (Volume Tracing in Advanced Vessel Analysis, Philips Healthcare, Cleveland, Ohio, USA). In order to avoid inter-observer and intra-observer variations, CT selection and volumetric evaluation were conducted by the same two observers (MF, MA). All measurements were approved by the expert radiologist observer (MA). As several measurements of the ethmoid sinuses varied between the observers (MF, MA), without a feasible standardized method of measurement using our software, those sinuses were not included in the study.

Statistical analyses were performed with Statistical Package for the Social Sciences package version 20.0 (SPSS Inc, Chicago, IL). The numeric variables were presented as total numbers, percentages, and mean ± standard deviation (SD) values. Normally distributed volumes are represented by mean and standard deviation (SD). Abnormally distributed volumes are represented by median and 5th–95th percentiles range. Paired T test was used to compare non-categorical continuous variables in both sides of the same sinus. Categorical variables were compared using Fisher exact test or Chi-square test, as appropriate. Two-tailed p value <0.05 was considered

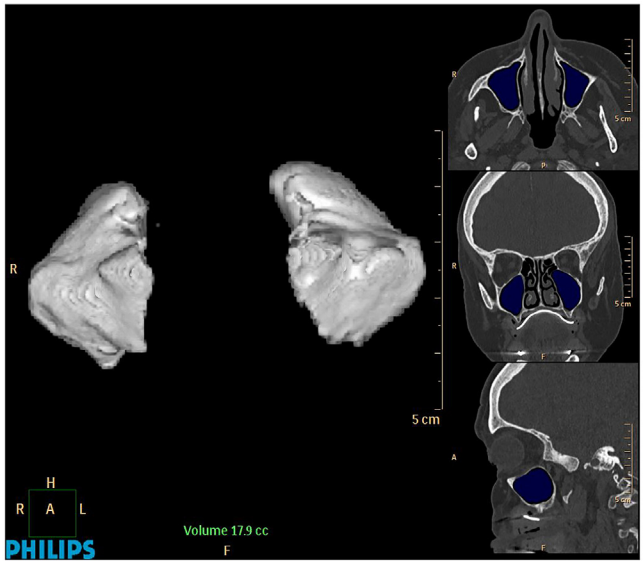

Fig. 1. Example of volumetric measuring of maxillary sinus.
Fig. 1 displays a 3-dimentional recreation of the maxillary sinus based on the volumes measures by painting all plains of the scan (top).

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