Original Article
https://doi.org/10.5115/acb.21.051
pISSN 2093-3665 eISSN 2093-3673
Anatomy & Cell Biology

Volumetric growth analysis of maxillary sinus using computed tomography scan segmentation: a pilot study of Indonesian population

Erli Sarilita[1], Yurika Ambar Lita[2], Harry Galuh Nugraha[3], Nani Murniati[1], Harmas Yazid Yusuf[4]
[1]Department of Oral Biology (Anatomy Laboratory), Faculty of Dentistry, Universitas Padjadjaran, West Java, [2]Department of Oral Maxillofacial Radiology, Faculty of Dentistry, Universitas Padjadjaran, West Java, [3]Department of Radiology, Faculty of Medicine, Universitas Padjadjaran, West Java, [4]Department of Oral Maxillofacial Surgery, Faculty of Dentistry, Universitas Padjadjaran, West Java, Indonesia

Abstract: The aim of this study is to investigate the volumetric measurements of the maxillary sinus among Indonesian population through computed tomography (CT) scan semi-automated segmentation. This project collected 802 retrospective head CT scan archives from Department of Radiology, Hasan Sadikin Hospital, Bandung, Indonesia between 2019–2020. Patients with craniofacial anomalies/pathology fracture in proximity of the maxillary sinuses, and mediocre image quality were excluded from this study resulting only 97 CT scan archives (194 maxillary sinuses; 52 males; 45 females; age range 0–25 years old). Three-dimensional craniofacial structures were reconstructed and volumetric measurements of the maxillary sinus were computed through semi-automated segmentation using ITK-SNAP. This study recorded the initial phase of maxillary sinus pneumatization during infancy. The maxillary sinus developed until reaching the maximum of average maxillary sinus volume at 13,278.73 mm^3 in 16 to 20 years old group in which afterwards fell to 12,325.21 mm^3. There was no difference found between right and left maxillary sinus volume. This study revealed that the pneumatization of maxillary sinus begin during infancy and climb until reaching the second decade of life, in which after that slowly decrease. Moreover, no difference between right and left maxillary sinus volume was detected. The volumetric dimension of maxillary sinus presented in this study may serve as the basis knowledge surgical intervention of maxillary sinus and its related structures.

Key words: Volumetric computed tomography, Maxillary sinus

Received March 7, 2021; Revised June 23, 2021; Accepted June 25, 2021

Introduction

Paranasal sinuses are complex anatomical structured consist of aired area ethmoid, frontal, maxillary and sphenoid sinuses with significant variation of shape, morphology and size [1, 2]. Evaluation of paranasal sinus abnormalities using computed tomography (CT) radiograph can be based on segmentation of the volume of the paranasal sinus cavities, including mucosal thickening which considered as an objective diagnostic criterion for chronic sinusitis [3]. The volume of paranasal sinuses have been found in correlation with each other indicating harmonious growth [4].

Maxillary sinus volume (MSV) has been explored in otolaryngology, dentistry, oral maxillofacial surgery, and forensic fields. These attentions are due to the proximity of the

Corresponding author:
Erli Sarilita
Department of Oral Biology (Anatomy Laboratory), Faculty of Dentistry, Universitas Padjadjaran, Jatinangor 45363, West Java, Indonesia
E-mail: erli.sarilita@fkg.unpad.ac.id

maxillary sinus to the neighboring structures and the vital function in respiratory system. As a result, plethora of maxillary sinus quantitative research have been conducted using cadaveric dissection, conventional radiographs, CT, cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) scans. Nowadays, three-dimensional (3D) rendering allowed comprehensive morphometric analysis of the maxillary sinus [5].

CT is gold standard in paranasal sinuses imaging as it can capture the morphology, dimensions and abnormality of paranasal sinuses [6-8]. Volumetric calculation of paranasal sinuses can be performed manually, semi-automated [9], or automated [10-12]. Previous studies performed sinus volumetric measurements using CT Scan using different methods: axial CT [13] and 3D reconstruction data CT with V-works 4.0 software (CyberMed Inc., Seoul, Korea) in which the volume was automatically calculated [14]. Volumetric measurements in 3D reconstruction is enabled by the grayscale intensity differences of voxel segmented tissue in sinus.

The objectives of this study were to perform volumetric analysis of maxillary sinus obtained with semi-automatically segmentation the CT data and compare the results of the measurements relative to age and gender in Indonesian population.

Materials and Methods

Patients selection

This study collected 802 retrospective CT images of patients referred for various reasons from the archive of Department of Radiology, Hasan Sadikin Hospital between 2019–2020. The protocol of this study was approved by the

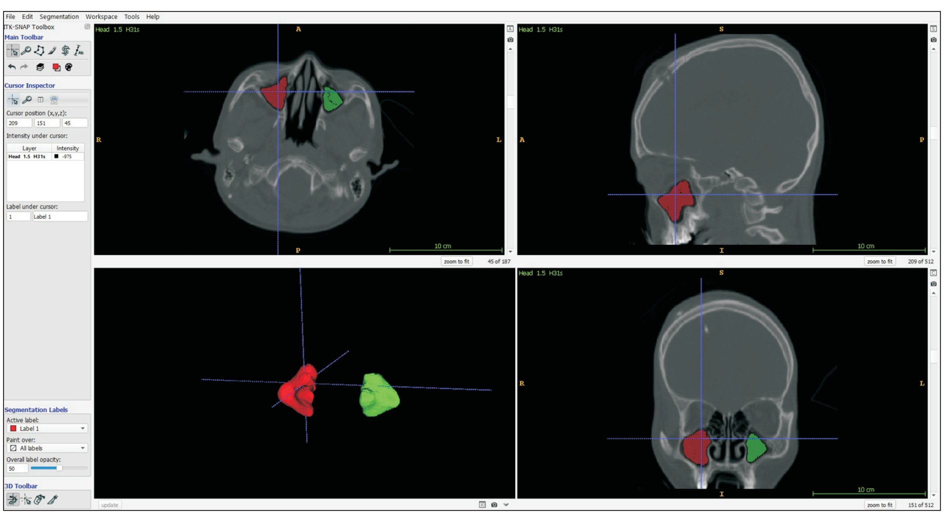

Fig. 1. Segmentation procedure of maxillary sinus using ITK-SNAP.

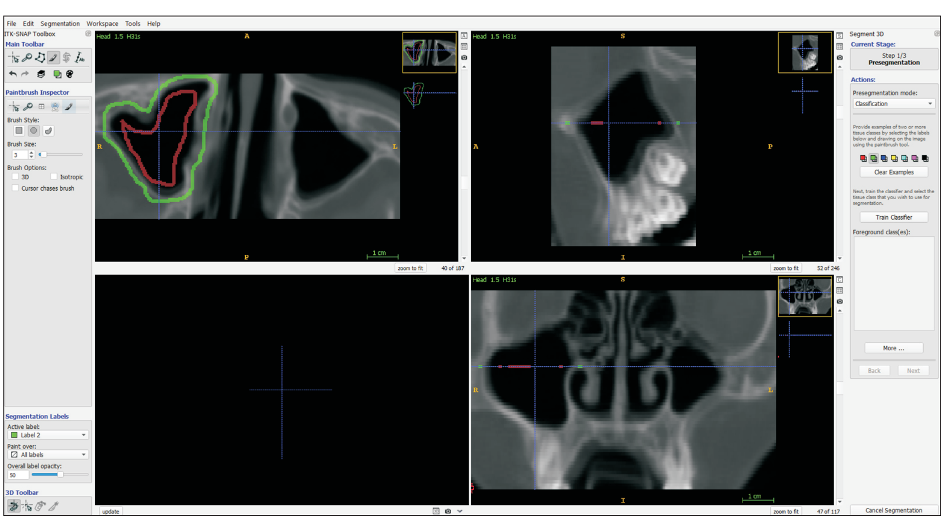

Fig. 2. Maxillary sinus classification of image regions.

Research Ethics Committee, Universitas Padjadjaran (477/UN6.KEP/EC/2020). These images were taken using SOMATOM Definition DS dual source 128 (Siemens, Erlangen, Germany).

Inclusion and exclusion criteria

CT data sets were selected based on strict inclusion and exclusion criteria from patient of age 0 to 25 years old. Only data set with field of view of paranasal sinus included. CT images with craniofacial pathology written on the data; fracture involving paranasal sinuses; and inadequate image quality; were excluded from this study. After carefully filtered by the criterion, 97 samples were selected for final evaluation.

Slice thickness 1.0–1.5 mm of the CT images were used. Digital Imaging and Communications in Medicine files were reconstructed and MSV were extracted using ITK-SNAP 3.0 software (Cognitica, Philadelphia, PA, USA) (https://www.itksnap.org) [15]. Region of Interest (ROI) volume was created using active contour segmentation to selected sinus area ROI from slice axial, coronal and sagittal for semi-automatic segmentation (Fig. 1).

The aired mask was drawn using train classifier: red label for sinus cavity and green label for bone. Then, paint brush mode was used to add manual label for any actives label or erase the excess of anatomy including the airway and the surrounding environment (Fig. 2). Next, the image was placed to initialize the contour of cavity.

The contours evolution was executed. The object rendered was export into 3D STL file. Open segmentation window was opened and volumetric measurement was chosen to export volume data into a spreadsheet. ITK-SNAP software were used to measure MSV as the method of choice in this CT imaging data study, because semi-automatically approach was suggested to be more accurate than automatic segmentation [15].

Statistical analysis

The data were analyzed using IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). The age of the subjects were grouped into 5 cohorts: 0–5, 6–10, 11–15, 16–20, and 20–25 years. The descriptive statistics were displayed using frequencies of sex and age, including average and standard deviation of the volumetric measurements. The symmetry of the right and left side MSV were noted, including the difference between genders.

Results

A total of 194 maxillary sinus were examined. Descriptive statistics were displayed in Table 1. The lowest average of MSV were shown between 0–5 years old group (1,361.12 mm^3) and the largest MSV were noticed at the 16–20 years old group (13,278.73 mm^3). After that, the MSV fell in 20–25 years old group to 12,325.21 mm^3. The trend of MSV average value was increasing beginning the first year of life until reaching the 16–20 years old cohort, in which it began to decrease (Fig. 3). There was no significant difference between right and left MSV (Table 2). Moreover, no sexual dimorphism were detected in 16–20 years cohort (male=16, female=14; P=0.608) and 20–25 years old (male=14, female=24; P=0.654) cohort. The earliest pneumatization was observed on a baby boy at 28 days of life at 23.97 mm^3. The largest MSV was recorded

Table 1. Distribution of patients and volume of maxillary sinuses pooled by age groups

Age group (yr)	Number	Mean (mm^3)	SD (mm^3)	Minimum (mm^3)	Maximum (mm^3)
0–5	56	1,361.12	1,876.76	0.00	7,396.00
6–10	36	6,031.04	1,888.06	1,756.31	9,273.55
11–15	32	9,172.59	4,616.69	2,233.00	21,310.00
16–20	30	13,278.73	4,666.84	3,253.00	21,210.00
20–25	40	12,325.21	4,863.62	2,570.02	26,450.00
Total	194	7,619.76	5,910.08	0.00	26,450.00

SD, standard deviation.

Table 2. Distribution of maxillary sinus volume

Side	Number	Mean (mm^3)	SD (mm^3)	SEM	Significance
Right	97	7,284.09	5,718.45	580.62	0.430
Left	97	7,955.43	6,106.84	620.06	

SD, standard deviation; SEM, standard error of mean.

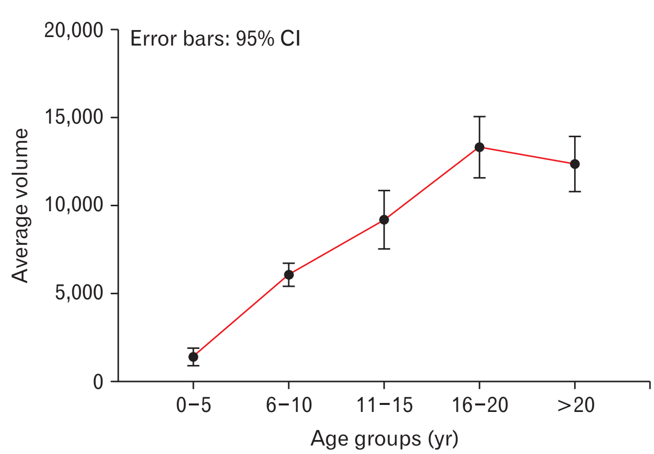

Fig. 3. Distribution of mean maxillary sinus volume by age groups (mm^3). CI, confidence interval.

https://doi.org/10.5115/acb.21.051

on a female patient aged 21 years old at 26.450 mm^3.

Discussion

The paranasal sinuses volumetric study is well explored in the East Asian population [14, 16-18]. However, specifically for Indonesian population there is a lack of published paper in the indexed literature. Due to the vast distance between the eastern and western border of Indonesia geographical region, the population reside within this country varied, in which East Asian ancestry group dominated the majority of the population [19].

This study pooled the subjects into 5 chronological age cohorts. The maxillary sinus pneumatization began since the first year of life which support previous findings [5, 20] and peak at the 16–20 years old cohort. Then the average MSV declined at the 20–25 years old group. This growth pattern of maxillary sinus appeared to agree with the previous East Asian studies [16, 17, 21]. This study also demonstrated that there was no difference detected between the MSV right and left side which support the previous studies [4, 16, 18, 20].

The current project served as the pilot study of paranasal sinuses volumetric quantification in Indonesian population. Ideally, MSV growth study should be performed on healthy subjects longitudinally, by following the maxillary sinus as the age progresses. Nevertheless, this approach will expose healthy population to unnecessary radiation exposure. Therefore, although deviate from the ideal, this type of project using the existing archive of CT images is considered optimal as the tool of exploring the paranasal sinuses volume characteristics as age progressing.

Previous published paper described the linear measurements of maxillary sinus using CBCT in Indonesian population [22]. Up to this date, this study was the first in analyzing the volumetric aspect of maxillary sinus in Indonesian population and may have served as an initial database for clinicians. Further research should aim at the accuracy of paranasal sinuses volumetric assessment for age and sex estimation; and also for clinical evaluation; using automated method to accommodate larger sample size with equal contribution within each age and gender. In addition, this paper provided morphological knowledge for otolaryngology surgeons and dental implant practitioners as the foundation for sinus pathology assessment and surgical treatment planning.

In conclusion, The result of the study corroborated that the maxillary sinus pneumatization initialized during infancy. In addition, this study also presented the age-related MSV degeneration after the age of 20 years old and the similarity between right and left MSV. The knowledge of maxillary sinus morphometrics is essential in surgical approach of maxillary sinus pathology and dental implant procedures.

ORCID

Erli Sarilita: https://orcid.org/0000-0002-4678-2744
Yurika Ambar Lita:
https://orcid.org/0000-0002-3911-2777
Harry Galuh Nugraha:
https://orcid.org/0000-0001-9602-1524
Nani Murniati: https://orcid.org/0000-0001-8115-1545
Harmas Yazid Yusuf:
https://orcid.org/0000-0001-7970-1181

Author Contributions

Conceptualization: ES, YAL, HGN. Data acquisition: ES, YAL, HGN. Data analysis or interpretation: ES, YAL. Drafting of the manuscript: ES, YAL. Critical revision of the manuscript: ES, YAL, HGN, NM, HYY. Approval of the final version of the manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

This study was funded by the Universitas Padjadjaran Internal Research Grant (RPLK) No.1427/UN6.3.1/LT/2020. This study was conducted under the supervision of Oral Biomaterial Research Centre Universitas Padjadjaran. The authors would like to extend gratitude to the donors of the CT images.

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