Mapping Cervical Vertebral Maturation Levels with the Dimensions of Frontal Sinuses in a Sample of Indonesian Children

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Abstract

This study was aimed at mapping cervical vertebral maturation levels with the dimensions of the frontal sinuses.A total of 30 lateral cephalometric radiographs of children aged 8–16 years that were taken from June 2016 to June 2019 were evaluated in this study using a cross-sectional analytical method. The sample of children was divided into 6 cervical vertebral maturation stages and then clustered into 3 groups, prepubertal, pubertal, and postpubertal. The dimensions of the frontal sinus were obtained from the calculation of the length and width of the sinus, and then the height and width were divided to achieve the sinus index. Dimensions of the frontal sinus (height and width) in boys were greater than those in girls but experienced an increase along with cervical vertebral maturation in both boys and girls. However, girls experienced retardation during the postpubertal period. There was an increase in the frontal sinus dimensions (height and width) in boys and girls according to the cervical vertebral maturation stage, and the dimensions (height and width) in boys were greater than in girls.

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Introduction

Growth and development are 2 different events, but they are related to each other and are difficult to separate. Growth is often associated with changes related to the amount, number, size, or dimension, whereas development implies the increase in the ability of the more complex structures and functions of the body and is therefore related to the outcome of the maturation process. Maturation itself refers to the progress toward a more mature state, which indicates a change from simple to more complex biological, psychological, motor, and sensory skill functions.[1]

Rapid growth occurs in the first year of life and then it gradually decreases until the emergence of growth spurt in adolescents. Growth spurt in males occurs around the age of 12–14 years, and in females, it occurs around the age of 10–12 years.[2,3] Growth process in children is related to the level of maturation that can be identified by sexual, somatic, skeletal, and chronological age and dental age maturation.[4,5]

Several biological indicators can be used to assess skeletal maturity, namely, the increase in height, hand and wrist maturations, the development and eruption of teeth, menarche, and cervical vertebral maturation. Earlier, the hand and wrist method was often used as it was considered to be accurate to assess skeletal maturation; however, it is now replaced with the cervical vertebral maturation method that has the same level of validity. The cervical vertebral maturation method uses lateral cephalometric radiography, which is a type of routine radiography used in determining orthodontic diagnoses and hence does not require additional radiographs and reduces radiation doses.[6]

This method has 6 levels of cervical vertebral maturation stages based on the morphology of C2, C3, and C4, ranging from cervical stage (CS) 1 to cervical stage (CS) 6 (Figure 1). There are 2 steps to determine these stages, namely evaluation of the shape of the inferior border of the three vertebral bodies and evaluation of the shapes of C3 and C4.[6,7]

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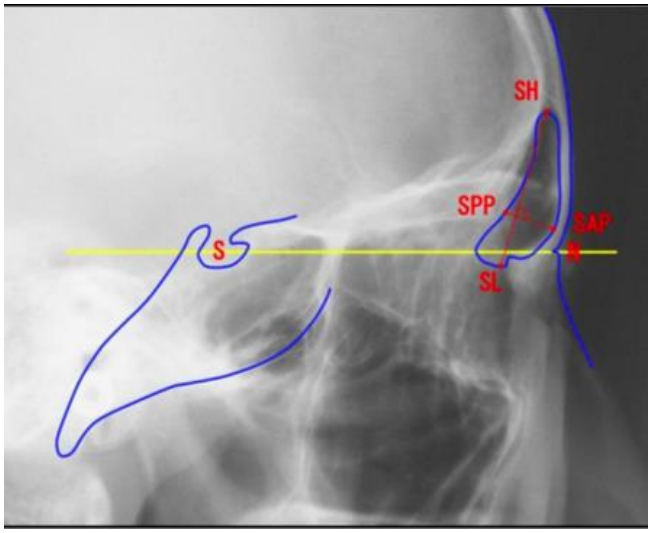

Figure 1. Measurement of the Dimensions of the Frontal Sinuses (Height and Width).

Assessing the enlargement pattern of the sinuses is one of the new methods for exploring the developmental status of children; however, this strategy is still debated. It has been stated that this pattern of sinus enlargement corresponds with height development and increasing age. Studies conducted in Indonesia have described that the enlargement of the frontal sinus has a close relationship with the hand–wrist ossification process during the peak growth period.[2,4,8,9]

With developments in medicine, the hand–wrist ossification method used for assessing skeletal maturation in children is now replaced with the cervical vertebral maturation method. Consequently, studies were conducted on Caucasoid race to explore the relationship between the frontal sinus and cervical vertebral maturation.[5] However, a similar research has never been performed in Indonesia, whose population belongs to different types of races, with the majority belonging to the race deutromelayu.[10–13] As reported in the literature, the Caucasoid and deutromelayu races have different physical and biological characteristics, which consequently encourages researchers to conduct studies in this aspect in Indonesia.[14] Deutromelayu race consists of Aceh, Minangkabau, Javanese, Sundanese, Malay, Betawi, Manado, Bali, and Madura. According to the 2010 population census in Jakarta alone, there were >75% of deutromelayu races, so that it can be concluded that the majority of residents in Jakarta belong to one of these races.[10–13]

Therefore, this study was aimed at mapping cervical vertebral maturation levels with the dimensions of the frontal sinuses.

Materials and methods

A cross-sectional analytical method was applied in this study, wherein data were obtained from RSGMP University of Indonesia in the form of lateral cephalometric radiographs, which were taken from June 2016 to June 2019. Approval for conducting this study was obtained from the ethical committee of the University of Indonesia (050350319). The total sample was 30 subjects who were categorized into 6 stages of skeletal maturation, as follows: CS 1 and CS 2 (prepubertal), CS 3 and CS 4 (pubertal), and CS 5 and CS 6 (postpubertal) (Figure 2).

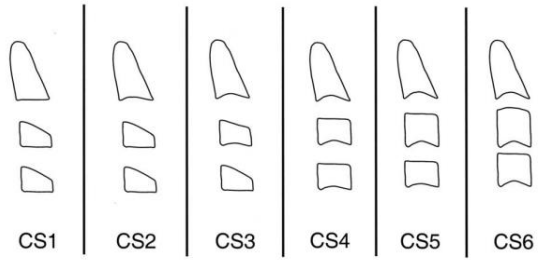

Figure 2. Evaluation of the cervical vertebral maturation level[6].

The inclusion criteria were Indonesian population, good-quality photographs of children aged 8–16 years, with patient identities such as age and sex, but disguised at the time of study, and observed in the state of class 1 radiographic skeletal malocclusion radiographic and class molar 1 angle relationship. Photographs that were more than 3 years old and those with incomplete data were excluded from the study.

Lateral cephalometric X-rays were analyzed visually by tracing. The first step was drawing a straight line from the sella turcica to the nasion, followed by measuring the dimensions of the sinuses using the Erturk method. The height of the frontal sinuses was obtained from the highest point (SH) to the lowest point (SL), and the width of the sinus was drawn perpendicular to the long line from the sinus anterior point (SAP) to the sinus posterior point (SPP) (Figure 1). The sinus index was calculated by dividing the height by the width of the sinuses. This sinus index is commonly used

to facilitate the evaluation of the skeletal maturity level of patients. This ratio is generally preferred because the sinus size varies according to physical and gender aspects.[4,15]

A line is drawn from the sella turcica to the nasion, and then the height is measured by drawing a line from the highest point of the sinus (SH) to the lowest point of the sinus (SL). Next, the width of the sinus is obtained from a perpendicular line of the length of the sinus connecting from the sinus anterior point (SAP) to the sinus posterior point (SPP).[4]

The cervical vertebral maturation level was estimated by the same lateral cephalometry approach using the Baccetti method by tracing the body shape and the lower border of the cervical bones C2, C3, and C4. There are several forms of the mandibular body, such as trapezoid, rectangular, horizontal, square, and rectangular vertical. This method is divided into 6 stages of maturation, namely CS1 to CS6 (Table 1). [6,7]

CVM Stages	Details
CS1	The lower borders of all the cervical vertebral bodies appear flat. C3 and C4 trapezoid forms become narrow from the posterior to the anterior
CS2	The lower border of C2 is concave. Both C3 and C4 vertebral bodies are still trapezoid
CS3	The lower borders of C2 and C3 are concave. The C3 and C4 vertebral bodies appear in trapezoid or rectangular horizontal forms.
CS4	Concave forms in the lower borders of C2, C3, and C4 are visible. C3 and C4 are rectangular horizontal.
CS5	C2, C3, and C4 are concave. At least one C3 or C4 is of square form
CS6	C2, C3, and C4 cavities still appear clear. At least one of C3 or C4 is rectangular vertical.

Table 1. Evaluation of the cervical vertebral maturation level according to the Baceceti methods[10].

Reliability of data was assessed using the kappa test to evaluate the stages of cervical vertebral maturation, wherein the intraoperator and interoperator value was 0.868. Reliability of the dimensions of the sinuses was analyzed using the Bland–Altman plot with the limit of agreement between −5 and 5; therefore, it was concluded that the data had good reliability. Statistical analyses were conducted using the SPSS for Mac Version 24 software.

Results

The dimensions of the frontal sinuses and the cervical vertebral maturation levels showed no statistically significant differences with respect to gender ($p > 0.05$).

Based on the cervical vertebral maturation stages, the subjects were divided into 3 major groups, as follows: prepubertal, consisting of the cervical vertebral maturation stages CS 1 and CS 2; peak pubertal, consisting of the stages CS 3 and CS 4; and postpubertal, consisting of the stages CS 5 and CS 6.

As shown in Table 2, the average height and width of the frontal sinuses in boys increased from the prepubertal to peak pubertal and postpubertal periods, whereas the frontal sinus index increased during the prepubertal and peakpubertal periods and decreased during the postpubertal period. In girls, the average height and width of the frontal sinuses increased during the peak pubertal period and decreased during the postpubertal period; however, the frontal sinus index decreased from the prepubertal to peak pubertal and postpubertal periods.

	Prepubertal (CS1 & CS2)				Peak pubertal (CS3 & CS 4)				Postpubertal (CS 5 & CS6)			
	Boys		Girls		Boys		Girls		Boys		Girls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Width of sinuses	8.5	1.32	7	3.08	8.7	1.78	8.5	1.61	10.66	2.88	7.18	1.46
Height of sinuses	21.5	6.5	25.4	8.20	31.7	2.58	31.8	4.30	33.5	5.76	28.37	5.80
Index of sinuses	2.49	0.43	3.99	1.72	3.98	0.66	3.83	0.923	3.26	0.97	3.98	0.68

Table 2. The dimensions of the frontal sinuses during the cervical vertebral maturation stages.

Table 3 shows the height and width of the frontal sinuses, which were greater in boys than in girls; however the frontal sinus index appeared to be greater in girls than in boys.

	Gender	N	Mean	SD
Width of sinus	Boys	11	9.18	2.05
	Girls	19	7.55	2.02
Height of sinus	Boys	11	29.41	6.64
	Girls	19	28.16	5.77
Index of sinus	Boys	11	3.29	.98
	Girls	19	3.92	.97

Table 3. Frequency distribution frontal sinuses by gender.

Discussion

The frontal sinuses begin to form since the fourth month of the fetus and can be identified at the age of 5 years; they can be visualized through radiography at the age of 8 years and undergo the maximum growth at the

age of 20 years.[2,4,16] The development of the frontal sinuses begins around the fourth or fifth week of pregnancy and then continues not only during the period of intrauterine growth but also during the postnatal period through puberty and early adulthood.[5,17] Growth spurt occurs around the age of 12 years in boys and 10 years in girls; it is completed at age 16 years.[2,18] This fact was considered for the selection of subjects in this study with an age range of 8–16 years and then divided into categories of cervical vertebral maturation stages.

The results of this study showed that the length and width of the frontal sinuses would gradually increase as the cervical stage increased in both boys and girls, whereas in girls, the increase is observed up to the peak pubertal period and then slowed down during the postpubertal period. This finding is consistent with previous research demonstrating that the length and width of the sinuses increase with the stages of vertebral cervical maturation, and it has also been theorized that girls undergo the growth spurt phase earlier than boys, so that the postpubertal period also occurs faster in girls than in boys. Thus, when compared to the postpubertal period with sex, girls will be seen slower than boys. [2,5,15]

Results shown in Table 3 indicate a difference between the length and width of the sinuses in boys and girls. Boys have a larger sinus size than girls. This is consistent with the theory that the width of the frontal sinuses is greater in boys than in girls.[4,8,15,19] In the forensic field, the differences in the size of the frontal sinuses between boys and girls can be used to establish gender in postmortem examination.[3] The average value in this study were 9.18 ± 2.05 in boys and 7.55 ± 2.02 in girls. This result is consistant with that of previos studies, wherein the sinus was 11.37 in boys and 8.46 in girls. is consistent with that of previous studies, wherein the sinus was 11.37 in boys and 8.46 in girls, whereas in this study, the average values were 9.18 ± 2.05 in boys and 7.55 ± 2.02 in girls.[16]

The sinus index can be used to assess the level of skeletal maturity in patients in a much easier manner. The sinus index is obtained by dividing the length by the width of the frontal sinuses. This ratio is preferred because the sinus size varies according to physical and gender aspects.[5,15] However, in this study, the sinus index decreased from the prepubertal to peak pubertal and postpubertal periods; therefore, as mentioned in previous studies, the sinus index cannot be considered as an indicator of maturity.[5,15,20]

Conclusions

This study has demonstrated increases in the dimensions of the frontal sinuses (height and width) in boys and girls in accordance with the cervical vertebral maturation levels, and the height and width of the sinuses were greater in boys than in girls.

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Declaration of Interest

The authors report no conflict of interest.

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