ORIGINAL ARTICLE

Age estimation by the spheno-occipital synchondrosis assessment through computed tomography scan

Mohamad Furqan Bahari, Shahridah Kassim*

Centre of Medical Imaging, Faculty of Health Sciences, Universiti Teknologi MARA, (UiTM), UiTM Kampus Puncak Alam, 42300 Bandar Puncak Alam, Selangor, Malaysia

***Corresponding Author**

Shahridah Kassim, PhD
Email: shahri6746@uitm.edu.my

Abstract:

Age estimation is a process where chronological age of a person is estimated by studying the age of their bones or teeth. Careful selection of the bones used in the study is important to achieve a close accurate age estimation of a person. The aim of this study was to investigate the relationship between the spheno occipital synchondrosis (SOS) and age for the Malaysian population. The relationship is further studied by determining the correlation of the Malaysian SOS with age for each gender using two different methods. A total of 166 Computed Tomography (CT) Head images 1 mm (male, n = 84, female, n = 82) were collected at the Department of Radiology, Hospital Universiti Sains Malaysia (HUSM). The SOS in the 166 CT images was analysed using qualitative and quantitative approach. The qualitative analysis was done by staging the synchondrosis fusion state into four stages and the fusion state is assessed by a radiologist. The quantitative analysis was done by recording the mean Hounsfield Unit (HU) number of the SOS after reconstruction into 3-Dimension (3D) volume rendering (VR) image. Pearson's correlation coefficient test was used to determine relationship between the SOS and age for each gender using the two methods. Qualitative analysis showed a strong correlation in synchondrosis fusion stages and age for each gender (male, $r = 0.885$, $p < 0.05$ and female, $r = 0.871$, $p < 0.05$). Quantitative analysis using mean HU number generated by 3D VR also gives moderate and strong correlation for male ($r = 0.672$, $p < 0.05$) and female ($r = 0.737$, $p < 0.05$), respectively. Strong correlation of age with the SOS gives an overview and potential of utilizing the SOS for age estimation using both methods.

Keywords: medical imaging; age estimation; spheno-occipital synchondrosis

1. INTRODUCTION

Age estimation is one of the important features in assessing identification for a living person as well as deceased person. The determination of age is often required in employment, competency as witness in testimonial capability, and voting rights. It is also requested by courts and other government authorities if the real age of a person is unknown. This identification can then be used for appropriate legal actions to uphold justice as best as possible[1]. In a forensic setting, bodies that are decomposed or partially recovered can be useful with today's technological powers. Information can then be gathered through structures found such as age, gender, and to some extent, species[2]. Human bodies that are left unburied starts to decompose in a time frame of four to six weeks with several factors which can affect the decomposition time such as temperature, rainfall, pH, and exposure of the body to the open surroundings[3]. Weight is also a factor that affects the decomposition rate. Smaller body sizes of less than 35 kg have a three times faster decay rate than larger body sizes of 60 kg to 90 kg[4].

Age estimation can be done through three methods the first one being the morphological assessment of the tooth, another is through the use of biochemical study and lastly, is through radiological study[5]. Usually, forensic anthropologist uses the teeth to gather information in which the process is called dental identification. Information such as dental age (DA) is often carried out to identify a body. DA is an accepted form of age estimation due to the teeth morphological development, which is not affected much by malnutrition and hormonal changes compared to skeletal development[6].

Combining multiple studies can increase the precision of age estimation[7]. Bones are an example of additional anatomy used in age estimation. The bones have good ability in withstanding mechanical destruction and decay. Although bones seem to be a feasible anatomy to be used in age estimation, bones development is somewhat dependent on nutrition gained and environmental factors[8]. An example of a bone used in age estimation is the spheno occipital synchondrosis (SOS). The SOS can be defined as a joint space between two immovable bones found in the base of the skull[9]. These bones fuse throughout a person's aging process and are usually seen

© 2019 Faculty of Health Sciences, UiTM

closed after reaching young adulthood[10]. The SOS have different closure timing that can be used to derive conclusion through Bassed, Briggs and Drummer [9]and Pate, Tingne and Dixit[11] studies. There are three synchondroses found on the skull base which are the spheno occipital, intersphenoid and sphenoethmoidal. The spheno occipital synchondrosis is used in this study because it is the last to fuse while the other synchondrosis closes as early as childhood [12].

With recent development of Computed tomography (CT), it has become a tool used in anthropological investigation. The images produced are represented by a variable called the Hounsfield Unit (HU)[13]. Due to its superior visualization of the skull base, this gives a greater accuracy in determining the closure. Furthermore, CT scan offers a fast and non-invasive diagnostic tool with the tradeoff of it, giving a higher dosage than any other diagnostic imaging modality[14]. CT age estimation is simple, non-invasive, and have good reproducibility that can be used for both living subjects and non-living subjects [5]. With CT's HU number quality, a more quantitative age estimation approach can be studied [15]. This study aimed to investigate the relationship between the SOS and age for the Malaysian population.

2. MATERIALS AND METHODS

2.1 Research Design

This study was a retrospective study to investigate the relationship between SOS and age for each gender. The relationship was investigated using two methods. The first method used ~~is~~ was a qualitative assessment by dividing the fusion state of the SOS into four different stages being opened, less than half closed, more than half closed and completely closed. The second method used was a quantitative assessment by using a fixed sized region of interest (ROI) placed at the center of the SOS. From the ROI, a 3D VR was produced, and the mean HU was recorded to investigate relationship with age.

2.2 Sample and Sampling Technique

Random sampling was used when selecting the data. A total of 166 Computed Tomography (CT) Head images with 1- mm slice thickness (male, n = 84, female, n = 82) were collected at the Department of Radiology, Hospital University Sains Malaysia (HUSM). Only images of Malaysian citizens were used with an age range of 5 years old until 25 years old. Images without underlying bone disease and growth disorder that are reconstructed into 1.0mm or lower were used.

The CT head images were acquired using the MDCT Toshiba Acquilion 64-slice with the parameter during acquisition being constant at 300mAs tube current and 150kVp. All scanned images were obtained in DICOM format and personal information were discarded except for age, data of birth (DOB), sex and ethnicity.

For the qualitative assessment, CT Head images obtained were focused on the SOS at the mid-sagittal level to provide uniformity and visualization of the SOS. The fusion state of the SOS was evaluated by a radiologist and were divided into four stages named stage 1 – stage 4 with each stage corresponding respectively to opened, less than half closed, more than half closed and completely open as shown in Figure 1.

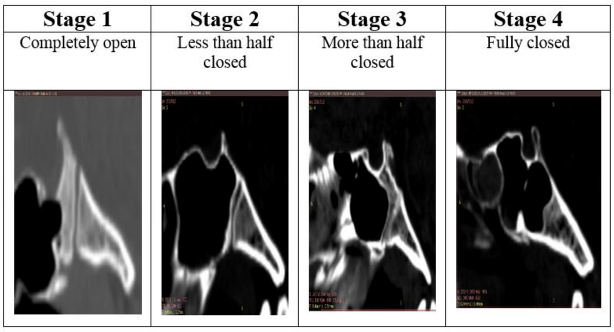

Figure 1: Synchondrosis fusion stages

For the quantitative assessment, CT Head images were reconstructed into 3D by VR technique using software called 3D Slicer (version 4.10.1). The ROI size used was 26mm X 20mm X 17mm for left to right, superior to inferior, and anterior to posterior, respectively. The ROI was placed in the middle of the SOS sufficiently encompassing the SOS. A threshold sampling method of the SOS was then carried out to include 200 HU number until 1000 HU number to include soft bone and cortical bone of the SOS. The mean HU was then recorded for each sample.

2.3 Statistical Analysis

Pearson's correlation coefficient was used to analyze the relationship of the SOS and age for each gender for both qualitative and quantitative assessment. Statistical analysis was performed using IBM SPSS Statistics Software (version 21).

3. RESULTS AND DISCUSSION

Figure 3 shows the female exhibits higher overall HU readings in the younger stages of age than males as shown in Figure 2. This suggests that the female synchondrosis becomes denser earlier than boys. Average total synchondrosis HU for boys at age 25 was higher than female seem to suggest that male has denser bone than female.

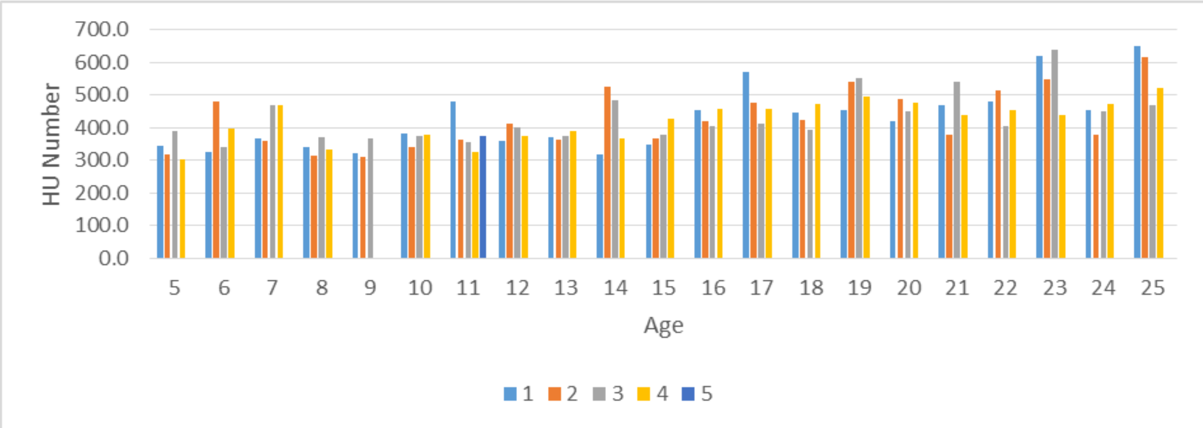

Figure 2: Distribution of HU Number collected from images through all ages for males

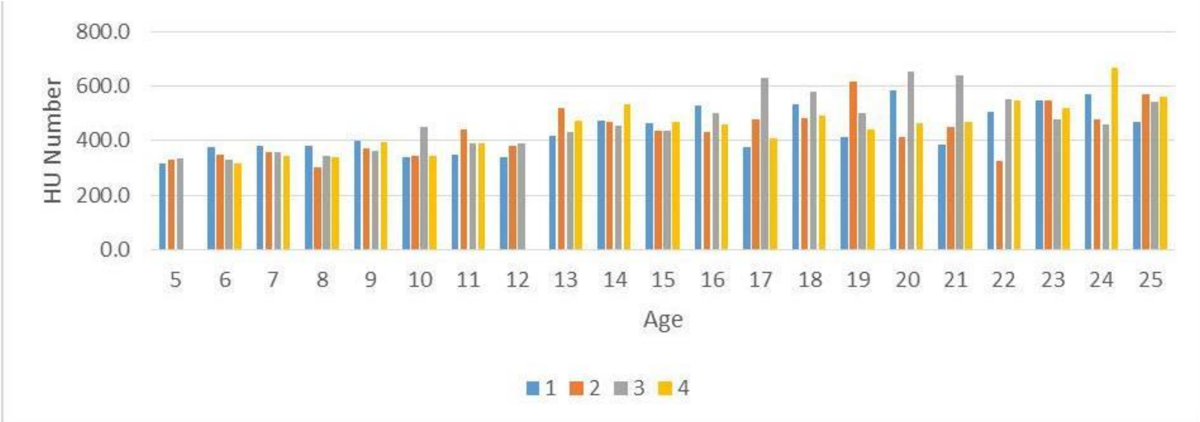

Figure 3: Distribution of HU Number collected from images through all ages for females

At the early stage of the synchondrosis, male was observed to last until age 14 whilst female last only until 11 years old. The maturity of the synchondrosis for male was observed to start at the age 14 whilst female, the maturity begins as early as age 13. From Figure 3, it shows that at the age of 16, female shows full maturity of the synchondrosis whilst male full maturity starts at age 20.

The correlation between the HU number and age scored by the male data was $r = 0.672$, where $p < 0.001$. The correlation of HU number and age by the females scored $r = 0.737$ where $p < 0.05$. This shows that both of them have a strong correlation with the female correlation being stronger than the males.

In Table 1, it shows that the correlation between the synchondrosis stage and age scored by the male data was $r = 0.885$, where $p < 0.05$. In table 3.5, the correlation of synchondrosis stage and age by the female scored $r = 0.871$ where $p < 0.05$. This seems to suggest that both of them have a strong correlation.

Table 1: Correlation score of synchondrosis stage and age for male

Correlations			
		Age_N	Stage_N
Age_N	Pearson Correlation	1	.885**
	Sig. (2-tailed)		.000
	N	84	84
Stage_N	Pearson Correlation	.885**	1
	Sig. (2-tailed)	.000	
	N	84	84

**. Correlation is significant at the 0.01 level (2-tailed)

© 2019 Faculty of Health Sciences, UiTM

Table 2: Correlation score of synchondrosis stage and age for female

Correlations			
		Age_N	Stage_N
Age_N	Pearson Correlation	1	.871**
	Sig. (2-tailed)		.000
	N	83	83
Stage_N	Pearson Correlation	.871**	1
	Sig. (2-tailed)	.000	
	N	83	83

**. Correlation is significant at the 0.01 level (2-tailed).

Our results suggest that there is a strong correlation between the synchondrosis fusion stage and age for both males and females with males showing stronger correlation by a slight margin. This finding was the same when compared to a study where the correlation scored by males and females was r = 0.804, $p < 0.05$ and r = 0.753, $p < 0.05$ [16]. The correlation value may be smaller, but for both studies, the male showed a higher correlation than the female. This may be due to the male's synchondrosis fusion being slower than in female's giving more weight of correlation to the males [12].

In the second technique, the investigation was done to find the correlation of the mean HU number generated by a 3D VR of the synchondrosis and the age. The score of the Pearson's correlation coefficient scored by the males and females were r = 0.672 and r = 0.737. Moderate and strong correlation was observed in male (0.672) and female (r=0.737), respectively.

For the descriptive data analysis, the mean HU number seen in the female's synchondrosis was seen higher when compared to the male's mean HU number during childhood (age 5 to age 12). But during the stages of young adulthood (age 18 to age 25), the male's mean HU number of the synchondrosis was seen higher than the female's. Higher HU numbers seen in females during childhood suggest that as the synchondrosis is maturing, the density of the bone become higher because of ossification[10]. This is further supported by Batawil and Sabiq [17], showing that HU number correlates to the density of the structure. In the adulthood phase, the mean HU number for males was seen to be higher than females suggesting that the synchondrosis of the male becomes denser than the female after full maturation. Density and mass of bone for males and females were also studied to be different with the male's bone density resulting in higher than the female's shown by Naganathan and Sambrook [18] and Nieves and Associates [19]. The descriptive analysis for the staging method shows that the earliest age of maturity seen in female synchondrosis was earlier than male at age 13 and at age 14, respectively. Full maturity of female and male was also seen at age 16 and age 20, respectively. The synchondrosis is seen to mature earlier in females than males propose that the growth of female is more rapid than male.

4. CONCLUSION

In conclusion, both methods of analyzing the SOS gives a strong correlation with the qualitative method being more observer-dependent while the mean HU number from 3D VR being more quantitative. Strong correlation of age with the SOS gives an overview and potential of utilizing the SOS for age estimation using both methods.

ACKNOWLEDGEMENT

Authors would like to acknowledge staff at the Department of Radiology, Hospital Universiti Sains Malaysia (HUSM) for support given throughout the completion of the project.

REFERENCES

[1] A. Schmeling, R. Dettmeyer, E. Rudolf, V. Vieth, and G. Geserick, "Forensic age estimation", *Deutsches Ärzteblatt International*, vol. 113, no. 4, pp. 44–50, Jan. 2016.

[2] H. Birx and S. R. Marcus, "Forensic anthropology," *21st Century Anthropology:A Reference Handbook*, pp. 314–321, 2012.

[3] R. C. Janaway, S. Percival, and A. Wilson, "Decomposition of human remains," in *Microbiology and Aging: Clinical Manifestations*, 2009, pp. 313–334.

[4] A. Sutherland, J. Myburgh, M. Steyn, and P. J. Becker, "The effect of body size on the rate of decomposition in a temperate region of South Africa", *Forensic Science International.*, vol. 231, no. 1–3, pp. 257–262, 2013.

[5] M. Puranik and S. R. Uma, "Dental age estimation methods : a review," *International Journal of Advanced Health Sciences*, vol. 1, no. 12, 2015.

[6] B. S. Manjunatha and N. K. Soni, "Estimation of age from development and eruption of teeth," *Journal of Forensic Dental Sciences*, vol. 6, no. 2, pp. 73–76, 2014.

[7] S. Manica, "Overall challenges in age estimation – from bones to teeth," *Revista Brasileira de Odontologia Legal.*, vol. 5, no. 2, 2018.

[8] M. Macha, B. Lamba, J. Sai, S. Avula, and S. Muthineni, "Estimation of correlation between chronological age, skeletal age and dental age in children- a cross-sectional study," *Journal of Clinical and Diagnostic Research*, vol. 11, no. 9, pp. 1–4, 2017.

[9] R. B. Bassed, C. Briggs, and O. H. Drummer, "Analysis of time of closure of the spheno-occipital synchondrosis using computed tomography," *Forensic Science International*, vol. 200, no. 1–3, pp. 161–164, 2010.

[10] L. A. Opperman, P. T. Gakunga, and D. S. Carlson, "Genetic factors influencing morphogenesis and growth of sutures and synchondroses in the craniofacial complex," *Seminars in Orthodontics*, vol. 11, no. 4, pp. 199–208, 2005.

[11] R. S. Pate, C. V. Tingne, and P. G. Dixit, "Age determination by spheno-occipital synchondrosis fusion in Central Indian population," *Journal of*

Forensic and Legal Medicine, vol. 54, no. 39, pp. 39–43, 2018.

[12] B. K. Hall, "The temporomandibular joint and cranial synchondroses," in *Bones and Cartilage*, Elsevier, 2015, pp. 515–527.

[13] L. E. Romans, "*Computed tomography for technologist"*, vol. 6, no. 2. 2011.

[14] K. Okamoto, J. Ito, S. Tokiguchi, T. Furusawa, "High-resolution CT findings in the development of the sphenooccipital synchondrosis, *American Journal of Neuroradiology*. vol. 17, no. 1, pp. 117–120, 1996

[15] J. A. Brink, J. P. Heiken, G. Wang, K. W. McEnery, F. J. Schlueter, and M. W. Vannier, "Helical CT: principles and technical considerations.," *RadioGraphics*, vol. 14, no. 4, pp. 887–893, 2013.

[16] H. Salina, A. Flavel, A. Nurliza, M. N. Mohamad Helmee, and D. Franklin, "Quantification of spheno-occipital synchondrosis fusion in a contemporary Malaysian population," *Forensic Science International*, vol. 284, pp. 78–84, 2018.

[17] N. Batawil and S. Sabiq, "Hounsfield unit for the diagnosis of bone mineral density disease: A proof of concept study," *Radiography*, vol. 22, no. 2, pp. e93–e98, 2016.

[18] V. Naganathan and Æ. P. Sambrook, "Gender differences in volumetric bone density : a study of opposite-sex twins," *Osteoporosis International*, vol. 14, no.7, pp. 564–569, 2003.

[19] J. W. Nieves *et al.*, "Males have larger skeletal size and bone mass than females, despite comparable body size," *Journal of Bone and Mineral Research*, vol. 20, no. 3, pp. 529-535 2005.

© 2019 Faculty of Health Sciences, UiTM