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ORIGINAL ARTICLE

Observation on the closure of lambdoid suture in relation to age, sex and population variations using a novel radiographic technique – a prospective study

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ABSTRACT

Objectives: To study and compare the patterns of lambdoid suture closure bilaterally; to specify any relationship between progression of the union of lambdoid suture and age; to detect sexual and population variations in lambdoid suture closure.

Methodology: A total of 98 subjects of both sexes, 20 years and beyond were included in the study. The state of fusion of the lambdoid suture was examined using a modified reverse panoramic radiograph (RPRg). Frederic's five-point rating scale was used to assess lambdoid suture closure status. Data obtained were subjected to statistical analysis.

Results: Cohen's Kappa measure of the agreement gave a figure of 0.96 for intra-examiner testing and 0.97 for inter-examiner testing. These values represent a good agreement. Grade 0 was observed in 16 (16.3%), grade 1 in 44 (44.9%), grade 2 in 09 (9.2%), grade 3 in 13 (13.3%) and grade 4 in 16 (16.3%) of the cases. The maximum numbers of cases were in age group 35–39 (24 (24.4%)) followed by age group 25–29 (19 (19.4%)). In the present study, there were 64 (65.3%) males and 34 (34.7%) females. When the comparison between males and female subjects was made, the closure was earlier in females. Most of the participants belonged to Arabian population (38 (38.7%)) followed by South Asian (33 (33.7%)) and least were from South East Asian population (27 (27.6%)). There were significant differences in suture closure in relation to age but insignificant with respect to sex and population.

Conclusions: Assessment regarding the age of an individual is possible but the sex and population of an individual cannot be determined.

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Age estimation; lambdoid; reverse panoramic radiograph (RPRg); skull suture

Introduction

There are three main elements in the procedure of paleo-anthropological and forensic identification of exhumed human remains: race, sex and age determination at the time of death [1]. Age determination is also needed for employment, marriage, majority, management of the property, voting right, competency as the witness and testamentary capacity [2]. However, age-related processes show great variation, both within and between populations; hence accurate and reliable assessment of age-at-death is a prerequisite for further investigations [3].

Different methods are utilized in age estimation in different periods of life [4]. Age of individuals <25 years can be estimated with relative accuracy, based on the different methods. However, age estimation becomes a difficult task in adulthood and old age group because as age advances there is wide variation in estimated ages and the actual age [5]. In adults, skeletal aging methods are focused on the pubic symphysis, auricular surface, sternal rib ends, cranial sutures, etc. [6].

Based on the hypothesis that suture closure is part of an age-related physiological process, cranial suture closure is one trait that has been used since the sixteenth century for age estimation after 2nd decade of life not only due to the greater interest in the skull, but also because the cranium is frequently the best-preserved portion of the archaeologically recovered skeleton [7]. Though the cranial sutures and their degree of closure and morphology have primarily drawn interest in age estimation studies, several authors have looked at variations in sex. This information is necessary since differences in suture closure and morphology based on sex would require the creation of unique standards for males and females [8].

Various autopsy and or cadaveric studies have been done on cranial suture for age estimation and sex determination but studies specifically on lambdoid sutures in mortals using radiographs for age estimation are very sparse. Various authors have quoted different age limits for lambdoid suture closure and none of them has specified any standardized radiographic technique for its assessment. The literature

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search revealed a radiographic technique known as modified 'reverse panoramic radiograph' (RPRg) which can provide a view of lambdoid suture [6].

The current research was undertaken to analyse the age, sex and population variation of the individuals on the basis of the radiological closure of lambdoid suture of the skull of living persons in the known age group of different populations using modified RPRg. To the best of our knowledge, this is the first study of its kind where assessment of sexual and population variations based upon the pattern of lambdoid closure suture in mortals through utilization of modified RPRg technique has been done.

Aims and objectives

1. To study the patterns of the closure of lambdoid suture (ectocranially).
2. To specify any relationship between progression of the union of lambdoid suture and age.
3. To identify possible differences in lambdoid closure between the sexes.
4. To analyse and compare the lambdoid suture closure among individuals of different populations namely the Arabian (Saudi Arabians and Egyptians), South Asian (Indian, Pakistani and Bangladeshi) and South-East Asian (Filipino).

Methodology

Study design

This is a prospective study of the relationship between lambdoid suture closure and age and sex in individuals from three different sets of the population.

Study duration: October 2016 to February 2017.

Sample population, size and characteristics

This study was conducted at College of Dentistry, Jouf University, Kingdom of Saudi Arabia (KSA). In this study, 98 subjects (male and female both) between the age group of 20 years and beyond with age interval of five years were selected among patients being referred for treatment to the College/seeking treatment at the College by systematic random sampling method. The patients were radiographed for the closure of lambdoid suture ectocranially. The study was approved by the Institutional Human Ethics Committee which is in accordance with Helsinki Declaration, and written informed consent was obtained from each subject after explaining the purpose and method of the study. The individuals who were born in other governorates and residing in KSA were also included in the study. The exclusion criteria considered were (1) cases with skull fractures, (2) case with a pathological condition of bones and (3) cases without age proof. The date of birth of the subjects was confirmed from birth certificates, driving license and/or passport. Clinical examination was done just to exclude any abnormalities in growth that may alter bone age.

Radiographic procedure

In the present study, modified RPRg technique was utilized for analysis of the lambdoid suture. Subjects were positioned in a reverse manner in Soredex Cranex D Digital Dental X-ray unit at standard exposure parameters (81 kVp, 10 mA and 13.9 s), and an adequate radiation protection measures, maintaining the mid-sagittal plane centred within the image layer of the X-ray unit.

Grading of suture status

In the present study, we used Frederic's five-points rating scale [9] to assess lambdoid suture closure status because it is based upon the anatomical appearance of the suture which can be easily interpreted on the radiograph and scored easily. According to the extent of suture, the lambdoid suture was classified into following five stages:

Grade 0 – open, not fused
Grade 1 – fused but not obliterated
Grade 2 – less than 50% obliterated
Grade 3 – more than 50% obliterated
Grade 4 – 100% obliterated.

The obliteration of the sutures was ascertained ectocranially by the first two authors independently to avoid observation bias. Our experience with this system has led us to conclude that this is not difficult to judge in all but a few cases and that the above system is highly repeatable from one observer to another.

In each case, the identification number, sex and date of birth of the person, the date of the examination and the ossification status of the lambdoid suture were recorded in specially designed proforma which was then reduced to tables and subjected to computer-aided statistical analysis.

Statistical analysis

All statistical analyses were performed using SPSS for Windows version 17 (Statistical Package for Social Science, Chicago, IL). Inter- and intra-examiner agreements were determined using Cohen's Kappa coefficient. Descriptive statistics were calculated. Nominal and discrete variables were compared with Chi-square test and continuous variables were compared with ANOVA (Tukey's HSD). p Value $<.05$ was considered as statistical significant.

Results

Cohen's Kappa measure of the agreement gave a figure of 0.96 for intra-examiner testing and 0.97 for inter-examiner testing. These values represent a good agreement and demonstrate that the stages of closure for the lambdoid are distinct and easily interpreted. Grade 0 was observed in 16 (16.3%), grade 1 in 44 (44.9%), grade 2 in 09 (9.2%), grade 3 in 13 (13.3%) and grade 4 in 16 (16.3%) of the cases. There

was no significant variation in the pattern of lambdoid suture closure on right and left sides both ectocranially.

The maximum numbers of cases were in 35–39 years age groups (24 (24.4%)) followed by 25–29 years age groups (19 (19.4)%) (Table 1). In establishing the significance of age in the grading of the ectocranial sutures, an analysis of variance (ANOVA) was used, with the grade of the suture as the independent variable and age as the dependant variable. Mean age for grade 0 suture is 31.6 ± 13.1, grade 1 is 32.9 ± 9.3, grade 2 is 41.3 ± 10.2, grade 3 is 46.4 ± 11.8 and grade 4 is 42.4 ± 13.5 which is statistically significant (p=.00) and Tukey's post hoc analysis revealed that grade 1 and grade 4 sutures are significantly different from each other (Table 2).

In the present study, there were 64 (65.3%) males and 34 (34.7%) females and male to female ratio was about 2:1. In most of the age groups, male subjects dominated the female except in the age groups 40–44 and 45–49 where females outnumbered males. The youngest participant aged 20 years for both the sexes whereas the oldest participant included was a 65-year-old female and a 67-year-old male. The minimal age of fusion (grade 1) was observed in 22 years in males and 21 years in females. Although all the stages were observed both in the youngest (20–24 years) and in the oldest (≥50 years) age groups, higher staging was observed as the age progressed for an individual. When the comparison between males and female subjects was made, the closure was earlier in females. There was no significant difference in sex wise distribution of ectocranial closure status in lambdoid suture (p value>.05). Age and sex wise distribution of ectocranial closure status in lambdoid suture is presented in Table 3.

In KSA, numerous groups other than Arabian are present in different provinces. On comparing the participants based upon population, majority belonged to Arabian population (38 (38.7%)) followed by South Asian (33 (33.7%)) and least were from South East Asian population (27 (27.6%)). No significant differences in time of closure were observed among participants from the different population groups with regard to age and sex (Table 4).

Table 1. Distribution of lambdoid suture according to suture grade and age.

Age group (years)	Suture grade, *N* (%)					Total, *N* (%)
	0	1	2	3	4	
20–24	06 (37.5)	07 (15.9)	00 (00)	00 (00)	01 (6.2)	14 (14.3)
25–29	03 (18.8)	11 (25)	01 (11.1)	01 (7.7)	03 (18.8)	19 (19.4)
30–34	00 (00)	06 (13.7)	02 (22.2)	00 (00)	01 (6.2)	09 (9.2)
35–39	04 (25)	11 (25)	01 (11.1)	04 (30.7)	04 (25)	24 (24.4)
40–44	00 (00)	03 (6.8)	02 (22.2)	02 (15.4)	01 (6.2)	08 (8.2)
45–49	00 (00)	02 (4.5)	01 (11.1)	02 (15.4)	02 (12.5)	07 (7.1)
≥50	03 (18.8)	04 (9.0)	02 (22.2)	04 (30.7)	04 (25)	17 (17.3)
Sub-total	16 (16.3)	44 (44.9)	09 (9.2)	13 (13.3)	16 (16.3)	98

N: number of individuals.

Table 2. Relationship between suture grade and age.

Suture grade	Number of Subjects	Age (years)		ANOVA	
		Mean	SD	*F*	*p* Value
0	16	31.6	13.1	6.06	.00
1	44	32.9	9.3		
2	09	41.3	10.2		
3	13	46.4	11.8		
4	16	42.4	13.5		
Total	98	36.8	12.2		

Discussion

Suture or obliteration of sutures can be attributed to the presence or lack of physical forces acting on the skull [10]. The degree of obliteration of skull sutures is a very important and most commonly studied aspect for age estimation in adult, but its reliability is still inconsistent [8]. However, in most cases, the use of cranial suture closure is still recommended as part of the biological profile when used in conjunction with other skeletal age indicator [7]. The lambdoid suture is the most patent suture among the cranial sutures and because of external forces acting on it, such as

Table 4. Distribution of participants from different geographical places.

Population	Gender, *N* (%)		Total, *N* (%)	χ^2	*p* Value
	Male	Female			
Arabian	25 (39.1)	13 (38.2)	38 (38.7)	.067	.97
South East Asian	18 (28.1)	09 (26.5)	27 (27.6)		
South Asian	21 (32.8)	12 (35.3)	33 (33.7)		
Total	64	34	98		

Table 3. Age and gender wise distribution of ectocranial closure status in lambdoid suture.

Age group (years)	Gender	Suture, *N* (%)					Total, *N* (%)	χ^2	*p* Value
		0	1	2	3	4			
20–24	Male	04 (50)	06 (21.4)	00 (00)	00 (00)	01 (7.1)	11 (17.2)	.99	.61
	Female	02 (25)	01 (6.3)	00 (00)	00 (00)	00 (00)	03 (8.8)		
25–29	Male	00 (00)	09 (32.1)	00 (00)	01 (11.1)	03 (21.4)	13 (20.3)	11.42	.02
	Female	03 (37.5)	02 (12.5)	01 (25)	00 (00)	00 (00)	06 (17.7)		
30–34	Male	00 (00)	03 (10.7)	02 (40)	00 (00)	01 (7.1)	06 (9.4)	2.25	.32
	Female	00 (00)	03 (18.8)	00 (00)	00 (00)	00 (00)	03 (8.8)		
35–39	Male	02 (25)	07 (25)	01 (20)	02 (22.2)	04 (28.6)	16 (25)	3.54	.47
	Female	02 (25)	04 (25)	00 (00)	02 (50)	00 (00)	08 (23.5)		
40–44	Male	00 (00)	00 (00)	00 (00)	01 (11.1)	01 (7.1)	02 (3.1)	5.33	.15
	Female	00 (00)	03 (918.8)	02 (50)	01 (25)	00 (00)	06 (17.7)		
45–49	Male	00 (00)	00 (00)	00 (00)	02 (22.2)	01 (7.1)	03 (4.7)	4.96	.18
	Female	00 (00)	02 (12.5)	01 (25)	00 (00)	01 (33.3)	04 (11.8)		
≥50	Male	02 (25)	03 (10.7)	02 (40)	03 (33.3)	02 (14.2)	12 (48.8)	3	.39
	Female	01 (12.5)	01 (6.3)	00 (00)	01 (25)	02 (66.6)	05 (14.7)		
Sub-total	Male	08 (12.5)	28 (43.8)	05 (7.8)	09 (14.1)	14 (21.8)	64	5.65	.23
	Female	08 (23.5)	16 (47.1)	04 (11.8)	04 (11.8)	02 (5.8)	34		

χ^2: Chi-square test.

the greater number of muscles affecting the lambdoid suture when compared with the sagittal suture [10].

In the present study, the reason for choosing lambdoid suture as an age, sexual and population variation marker is as follows [6, 11]:

1. Considerable variation in the time of lambdoid suture closure has been suggested in the past by various authors.
2. Very few studies have been undertaken on mortals to establish the role of the lambdoid suture in age estimation.
3. Since the suture fusion may be affected by sex, geographic location, climate variations and ancestry, an attempt has been made to assess sexual and population variations.

Grade 1 was more commonly observed followed by grade 0 and 4 which were equally distributed and the least was grade 2. There was no significant variation in the pattern of lambdoid suture closure on right and left sides both ectocranially. Similar findings were concluded in the studies conducted by Murlimanju et al. [10], Parsons and Box [12] and Sabini and Elkowitz [13] in which when compared with the sagittal suture, the lambdoid suture was significantly more likely to be patent and least likely to be obliterated. Furthermore, Vijay Kumar et al. [8] and Parsons and Box [12] in their studies found that there were no differences in closure periods for the left or right side of the skull.

The cases in the present study ranged from 20 years and beyond, of which maximum belong to age group 35–39 years. This finding is consistent with the study conducted by Kampan et al. [5], Dikshit [14], Karmakar [15], Mukherjee [16], Nandy [17] and Vij [18]. Chandra et al. [6] found significant difference in suture closure between the age groups and concluded that lambdoid suture can be a very effective and practical tool for age assessment in mortals through modified RPRg (ectocranially). Similarly, Parmar and Rathod [19] analysed sagittal, lambdoid and coronal suture closure with respect to age in mortals, and concluded that the best results for age estimation can be achieved from sagittal suture followed by lambdoid and coronal suture, and both endocranial and ectocranial suture closure should be considered during age estimation. However, Krogman [20] found the complete closure lambdoid suture at the age of 31 and Sahni et al. [21] and Vijay Kumar et al. [8] studied human skull and concluded that commencement and complete obliteration of a segment or the entire suture are so erratic that it is not useful for age estimation.

In the present study, there were 64 (65.3%) males and 34 (34.7%) females and male to female ratio was about 2:1. In most of the age groups, male subjects dominated the female except in the age groups 40–44 and 45–49 years where females outnumbered males. We observed that lambdoid suture fusion starts at the age of 22 years in males and 21 years in females. As the age further advances, complete obliteration/closure was observed. Our study is compatible with the study conducted by Vijay Kumar et al. [8] and Masih et al. [22] where lambdoid suture started closing earlier in the females than in the males. However, Brooks [23] reported that female cranial sutures tend to remain open much more frequently than in males; cranial suture closure is somewhat sexually dimorphic, and it should not be used as any more than 'a secondary confirmation, with caution' in males and never in females. The findings in the present study are not consistent with the studies done by Kampan et al. [5], Parsons and Box [12], Parmar and Rathod [19], Sahni et al. [21] and Perizonius [24] where suture closure in females typically commenced later than in males. However, according to Meindl and Lovejoy [9] closure of lambdoid suture occurs at the same time in both sexes.

In KSA, numerous other population groups are present in different provinces. Most of the participants were Saudi Arabians which is obvious since this study is carried out in KSA. English literature search did not show any studies related to population wise assessment of lambdoid closure suture patterns. The present results indicated that, in general, the observer agreement is good for both intra and inter-observer variability (Cohen's Kappa: 0.96 and 0.97, respectively). The results of the inter- and intra-examiner error testing revealed that scoring this age marker is reliable and reproducible both with one observer and also between different observers. There were very few differences between examiners and no instances of greater than one stage scoring discrepancy.

Limitations of the study

1. The study population is quite small to form any regression equation.
2. To know suture closure better and more accurately, various other modalities like osteology, histology may have to be combined with the present radiographic study.
3. Studies of the ectocranial suture closure have the potential to miscalculate age and to overcome this, the study of both endocranial and ectocranial suture closure should be done [19].
4. Region wise multicentric studies should be done in selected populations or geographic identical populations to remove various bias factors like climate, diet and nutrition.

Conclusions

Our findings support the view that, with modified RPRg, an assessment regarding the age of an individual is possible. Whereas sex and population of an individual, gauged only on the radiographic analysis of the degree of ectocranial closure of the lambdoid suture of the skull, is a highly unreliable and ineffective procedure.

Disclosure statement

The authors declare that they have no competing interests.

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