Application of modified reverse panoramic radiograph on lambdoid suture for age estimation

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Background: Cranial suture closure has long been recognized as a character of human development related to aging. For this reason, it has been utilized for various forensic and archaeological studies to determine the age of an unidentified/or skeletonized individuals. Various cadaveric studies have established the role of lambdoid suture in age estimation, but not routinely practiced. The objective is to establish if any correlation exists between individual's age and lambdoid sutures closure status (ectocranially) in mortals through modified reverse panoramic radiograph (RPRg).

Methods: Total number of 85 subjects, 25 years and beyond were included in the study, and divided into four groups with an age interval of 10 years. Assessment of lambdoid suture closure was done according to Frederic Rating Scale on modified RPRg. Data obtained was subjected to statistical analysis using Spearman's correlation test.

Results: A significant difference was observed between the age group and suture closure. Correlation coefficient of 0.570 was obtained, and was interpreted as a good correlation between the age and suture closure status with a P value of <0.001.

Conclusions: Lambdoid suture can be very effective and practical tool for age assessment in mortals through modified RPRg (ectocranially).

Keywords: Suture; cranial; lambdoid; suture closure; reverse panoramic radiograph (RPRg); age estimation

Introduction

Identification is a key for establishing one's identity in forensic science with medico-legal importance. Age estimation is an important step in constructing a biological profile from human skeletal remains and skeletal elements because of their imperishable quality can serve as an excellent indicator for age estimation even in mortals (1). In adults skeletal aging methods are focused on; the pubic symphysis, auricular surface, sternal rib ends, cranial sutures etc. (2).

Cranial sutures have been of great interest for age estimation, as its closure varies according to age (2). Lambdoid suture of all the cranial suture has been suggested to be the last vault suture to attain closure at around 45 to 50 years (Indians) (3,4) and has its forensic importance. Anatomically, lambdoid suture has been divided into three different positional parts from medial to lateral into pars lambdica, pars intermedia, and pars asterica (1) (*Figure 1*). Closure pattern of lambdoid suture has been proposed to take place from endocranial to ectocranial aspect (3) and from most medial to lateral aspect (5).

Various autopsy and or cadaveric studies have been done on cranial suture for age estimation (2,3,5) but, studies specifically on lambdoid sutures in mortals using radiographs for age estimation are very sparse. There is no indicated skull radiographic technique to obtain the
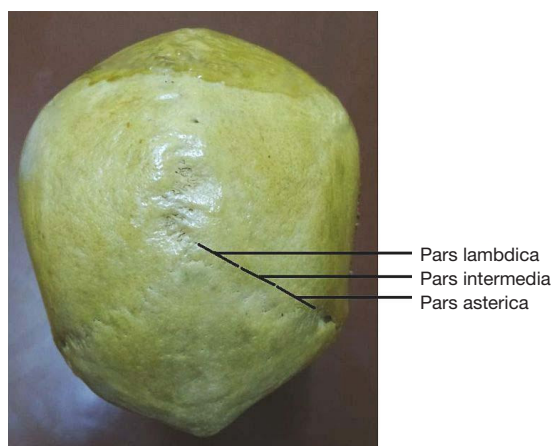
Figure 1 Anatomic parts of lambdoid suture.

Figure 2 (A) Subject placement on digital panoramic machine; (B) anterio-posterior subject adjustment; (C) lateral aspect of subject adjustment.

radiographic image of lambdoid suture. Literature search revealed, Markus *et al*. [1986] described a radiographic technique known as "reverse panoramic radiograph" (RPRg) which can provide a view of various anatomic structures like mastoid air cells, lambdoid suture and occipital bone, but not practiced regularly due to its limitations (6). The present study was undertaken to establish, if any correlation exists between individual's age and lambdoid suture closure status on modified RPRg. To best of our knowledge, this is the first study of its kind where age estimation has been done on lambdoid suture in mortals through utilization of modified RPRg technique.

Materials and methods

This prospective and unicentric study was conducted on 85 randomly selected healthy subjects, visiting the department of Oral Medicine and Radiology. Subjects were divided into four groups, with an age interval of 10 years: group A (25-35 years); group B (36-45 years); group C (46-55 years); and group D (55 years and above). 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.

After confirmation of age of the subjects from birth certificate, driving license, passport, aadhar card and or from 10th mark sheet, a proper case history was recorded on a prescribed performa. However, individuals with history of skull surgery, trauma, or developmental anomaly related to skull, history or clinical characteristics of endocrine
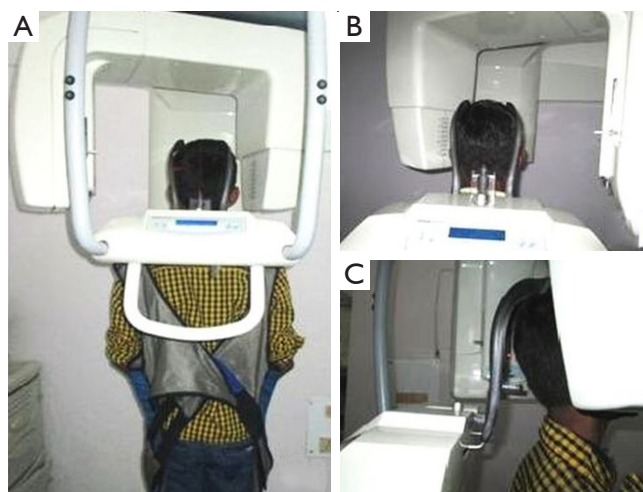
disturbances, nutritional diseases or hereditary facial asymmetries and without age proof, were excluded.

In the present study, RPRg technique was modified and utilized for analysis of the lambdoid suture. Subjects were positioned in reverse manner in Kodak 8000C Digital Panoramic and Cephalometric system at standard exposure parameters (80 kVp, 10 mA, and 13.9 s), and an adequate radiation protection measures, maintaining the mid sagittal plane centered within the image layer of the X-ray unit. In order to obtain a clear radiographic image and to avoid any distortion, subject's occiput was placed within the focal trough, with chin lowered at 20-30 degree below the horizontal plane (*Figure 2*). This modified arrangement of patient placement in the present study, helped us in obtaining the clear radiographic image of pars asterica and to some extent of pars intermedia, but pars lambdica get superimposed by the shadow of cervical vertebrae. Even after multiple trials and modifications, this superimposition was unavoidable, so only pars asterica was considered in the present study.

Suture closure pattern was assessed on the basis of Frederic Rating Scale which is based on anatomic appearance of suture (*Table 1*) from 0 to 4 (7). In order to avoid bias and to minimize error rate, the scoring was done by two observers with their mutual consensus. Scores were recorded in specially designed proforma. Non parametric statistics was used to establish the correlation, and for this purpose spearman's correlation test was applied

and frequency distribution of various suture score was established in different age groups.

Results

The present study comprised of 61 males and 24 females with mean age of 29 years (group A), 38.92 years (group B), 49 years (group C) and 66 years (group D). Score 1 was observed in highest frequency (40.0%) by the subjects in group A (25-35 years), score 2 in highest frequency (50.0%) in group B (36-45 years), score 3 in highest frequency (42.1%) in group C (46-55 years), and score 4 in highest frequency (36.4%) in group D (55 years and above) (*Table 2*). Due to the varying degree of latitude within each grade, non-parametric statistics; Spearman's correlation was used to analyze the data and to establish correlation between the variables. Correlation coefficient of 0.570 was obtained and interpreted as good correlation between the age and suture closure status with a P value of <0.001, statistically significant.

Discussion

Cranial sutures are line of junction of skull bones separated by a zone of connective tissue (sutural ligament), and are known to attain closure during the life time of an individual. The skull vault comprises mainly of three major sutures i.e., coronal, sagittal, and lambdoidal sutures (1). Sutures appear

simple and straight in younger age groups but as the age advances these acquire a more complex anatomy (developing interdigitations by process of growth) (8).

Fouad *et al.* (1) had mentioned the importance of cranial sutures in personal identification and concluded that "no two skulls can have identical suture pattern". Beside this, various authors had also mentioned the importance of suture closure pattern especially in lambdoid suture for age estimation (2-5,9,10). Each limb of lambdoid suture is divided into three parts; pars lambdica, pars intermedia and pars asterica (medial to lateral), and of these pars asterica being the last to attain the suture closure (2,9).

Forensic radiology (antemortem and postmortem) has been an important tool in medico-legal investigations and identifications (1). It has also been used in various autopsy/cadaveric studies as a tool for age estimation, through the analysis of cranial sutures (2,8-10). Very few studies have been undertaken on mortals to establish the role of lambdoid suture in age estimation (3,4). Thus the present study was undertaken in mortals to establish, if any correlation exists between individual's age and lambdoid suture closure status on RPRg. Parmar *et al.* and Gaur *et al.* observed suture closure activity of sagittal, lambdoid and coronal suture for age estimation using radiographic technique. Parmar *et al.* analyze digital X-ray of the skull, both anterio-posterior and lateral view; whereas, Gaur *et al.* didn't mention the name of radiographic technique they have used in their study (3,4).

Authors have quoted different age limit for lambdoid suture closure and none of them has specified any standardized radiographic technique for its assessment. RPRg radiographic technique is relatively an innovative technique in imaging of occipital region, temporomandibular joint (TMJ) and associated structure, mastoid air cells and lambdoid suture (6). In the present study, we had modified and to some extent standardize RPRg radiographic technique to observe lambdoid suture.

Table 1 Frederic rating scale for suture closure pattern

Suture score	Amount of suture closure
0	Open
1	Less than 50% closed
2	More than 50% closed
3	Most of the part of suture closed
4	Totally closed with no visible suture line

Table 2 Frequency distribution of various suture score according to age

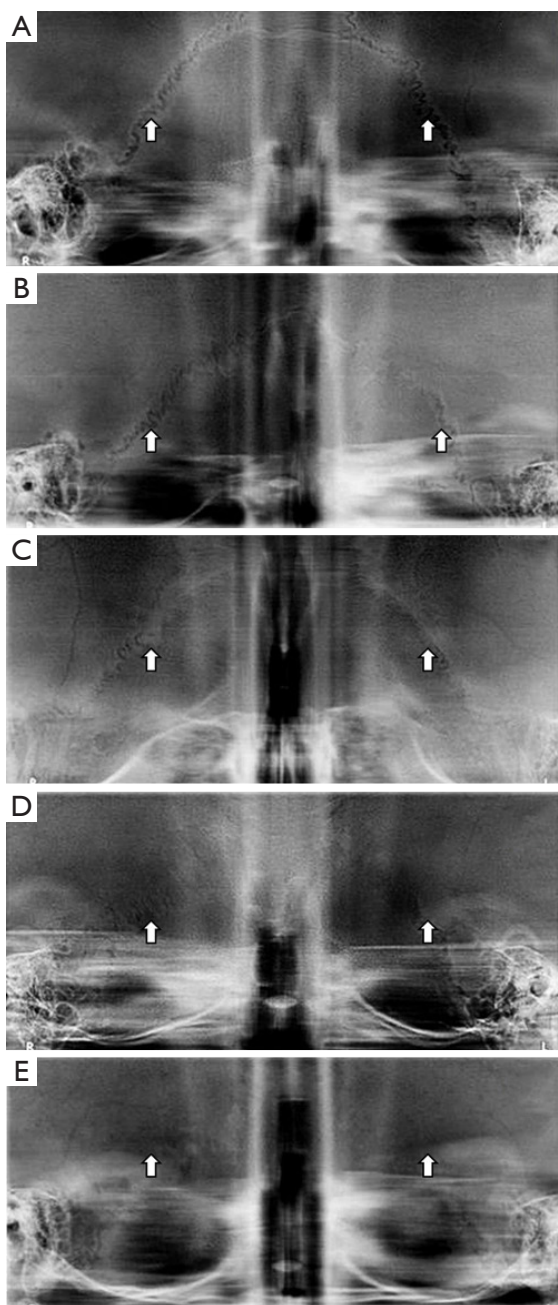| Suture closure	Group A count (%)	Group B count (%)	Group C count (%)	Group D count (%)
Suture open	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Closure of suture less than 50% (score 1)	8 (40.0)	6 (25.0)	2 (10.5)	0 (0.0)
Closure of suture more than 50% (score 2)	9 (45.0)	12 (50.0)	6 (31.6)	5 (22.7)
Closure of most of the part of suture (score 3)	2 (10.0)	5 (20.8)	8 (42.1)	9 (40.9)
Complete closure of suture (score 4)	0 (0.0)	1 (4.2)	3 (15.8)	8 (36.4)

Figure 3 Frederic rating scale. (A) Score 0; (B) score 1; (C) score 2; (D) score 3; (E) score 4. (Radiographs from the present study).

Todd, Lyon and Hrdlicka have observed that cranial sutures closure starts from the endocranial to ectocranial surface. They also found that the endocranial suture closure was more reliable for age estimation than ectocranial suture closure, which had "lapsed union". Jangjetriew *et al.* concluded that the sum of endocranial suture closure

score (composite score) is statistically more significant for age estimation (2). These studies were done on skulls of immortals, where they can easily observe both the endocranial and ectocranial suture closure. Meindl and Lovejoy studied various points on vault sutures in immortals, and concluded that suture closure can provide valuable estimates of age at death in both archeological and forensic context when used in conjunction with other skeletal age indicator (7).

Literature search revealed various suture closure scoring system used by different authors i.e., Acsadi and Nemeskeri [1970], Perizonius [1984], Meindl and Lovejoy [1985] and Buikstra and Ubelaker [1994]. In the present study we considered Frederic's five point rating scale to assess ectocranial lambdoid suture closure status (*Figure 3*), because it is based upon the anatomical appearance of suture which can be easily interpreted on the radiograph and scored easily.

In the present study, first evidence of lambdoid suture closure was observed before the age of 25 years. Closure of suture nearly 50% is attained between the age group of 38-40 years, whereas by the mean age of 49 years most of the lambdoid suture usually attains closure. As the age further advances (mean age of 66 years) complete obliteration/closure of suture line was observed, and was also statistically significant. Findings of the present study are also supported by the observation done by Parikh (11), Singh *et al*. (12), Dikshit (13), Karmakar (14), and Mukherjee (15) on Indian population where lambdoid suture attain closure between 45-50 years. Nandy (16) and Vij (17) have also postulated that complete closure of lambdoid suture is attained by the age of 55 years.

Parmar *et al*. analyzed 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 (3). Whereas, Sahni *et al*. studied skull of northwest Indian and concluded that commencement and complete obliteration of a segment or the entire suture is so erratic that it is not useful for age estimation (18).

During present study, even after modification of RPRg radiographic technique, certain limitations were observed: first, endocranial lambdoid suture analysis cannot be done and/or assessed; second, pars asterica and to some extent pars intermedia can be assessed, but pars lambdica got superimposed by the cervical vertebrae shadow; third,

lambdoid suture closure begin from 25 years and fully calcified at around 65 years, so it is difficult to access the age of the individual by this technique, before the age of 25 years and after the age of 65 years; fourth, this technique is not routinely practiced and/or well documented.

From the present study, we can conclude that the ectocranial analysis of lambdoid suture through modified RPRg radiographic technique is very effective and practical age estimation tool, especially in mortals. It can be used alone or in conjunction with other age estimation techniques. Though, it is a pilot study, analysis of larger sample size is still entailing to device a formula for age estimation through this technique.

Acknowledgements

Footnote

References

1. Fouad AA, Metwalley HE, Seif EA, El-Megid, LAM. Study of skull sutures as a tool for identification. J Forensic Med Clin Toxicol 1999;7:57-70.

2. Jangjetriew B, Thamtakerngkit S, Wongchanapai W, Sangvichien S. Cranial suture closure and age determination in the Thai population. Siriraj Med J 2007;59:226-31.

3. Parmar P, Rathod GB. Determination of age by study of skull sutures. Int J Current Res & Rev 2012;4:127-33.

4. Gaur VB, Sahai VB, Singh A, Kharat A. Determination of Age in living by closure of Cranial Sutures A Radiological Study. J Indian Acad Forensic Med 2007;29:32-4.

5. Masih WF, Gupta S, Jaiswal P, Chand AE, Saraswat PK. Morphological study of vault suture & its correlation with age in central Rajasthan. Natl J Med Res 2014;4:19-22.

6. Reddy SS, Kaushik A, Prakash SDR. Clinical applications of reverse panoramic radiography. Dent Hypotheses 2011;2:190-8.

7. Meindl RS, Lovejoy CO. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. Am J Phys Anthropol 1985;68:57-66.

8. Sabini RC, Elkowitz DE. Significance of differences in patency among cranial sutures. J Am Osteopath Assoc 2006;106:600-4.

9. Vijay Kumar AG, Agarwal SS, Bastia BK, Shivaramu MG, Honnungar RS. Fusion of Skull Vault Sutures in Relation to Age-A Cross Sectional Postmortem Study Done in 3rd, 4th & 5th Decades of Life. J Forensic Res 2012;3:173.

10. Kapadia D, Rathva A, Kubavat DM, Nagar SK. Study of sutures: anatomical variations in the fusion of sutures. Int J Recent Trends Sci Technol 2013;8:94-9.

11. Parikh CK. Parikh's Textbook of Medical Jurisprudence and Toxicology. 5th ed. New Delhi: CBS Publishers and Distributors, 1990.

12. Singh P, Oberoi SS, Gorea RK, Kapila AK. Age estimation in old individuals by CT scan of skull. J Indian Acad Forensic Med 2004;26:10-3.

13. Dikshit PC. Textbook of Forensic Medicine and Toxicology. 2nd ed. New Delhi: Peepee Publishers, 2013.

14. Karmakar RN. Forensic Medicine and Toxicology. Oral, Practical and M.C.Q. 3rd ed. Kolkata: Academic Publishers, 2010.

15. Mukherjee JB. Forensic Medicine and Toxicology. 4th ed. Kolkata: Academic Publishers, 2011.

16. Nandy A. Principles of Forensic Medicine including Toxicology. 2nd ed. Calcutta: New Central Book Agency, 1995.

17. Vij K. Textbook of Forensic Medicine and Toxicology: Principles and Practice. 5th ed. New Delhi: Elsevier, 2011.

18. Sahni D, Jit I, Neelem, Sabjeev. Time of closure of cranial suture in northwest Indian adults. Forensic Sci Int 2005;148:199-205.