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ORIGINAL ARTICLE

# Estimation of Age from Cranial Suture Fusion- an Autopsy based Study

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**Abstract:**

The need for identification of a deceased arises in civil and criminal cases. Skull being a whole compact bone is almost always the best preserved and the one that could be best utilised. Over the years, there has been enough and more controversies regarding the methodology and predictability of the same. The primary objective of the study was to estimate age from fusion of cranial sutures in wet specimens of cranial vault during autopsies. Cross sectional study was done at Department of Forensic Medicine, Government Medical College Thiruvananthapuram for a period of one year after approval from Institutional Ethics Committee. The study sample of 168 was divided uniformly among each decade from 11-80 years, thus coming to 12 males and females in each. Fusion of cranial sutures were scored both endocranially and ectocranially using the Acsadi- Nemeskeri scale. Reliability of various subdivisions of each cranial suture were assessed. Regression formulas from various cumulative scores were then formulated. There was no significant variation in fusion of cranial sutures between males and females. Every subdivision of each cranial suture showed variation with age and cannot be used as a good predictor of age. The cumulative scores of endocranial subdivisions, ectocranial subdivisions, subdivisions around Bregma and Lambda showed uniform distribution and reliability of prediction. Greatest predictability was from the sum of endocranial scores. The methodology in determining age from cranial suture fusion is of utmost significance in establishing identity. An objective scoring technique is more dependable than a subjective analysis.

**Keywords:** Acsadi-nemeskeri scale; Age estimation; Cranial sutures; Ectocranial fusion; Endocranial fusion; Forensic anthropology.

## Introduction:

According to Forensic pathology, 'Identification' is recognition of an individual by means of various unique physical features and biological parameters. Among the integral parts of a biological profile, 'age' has the utmost importance.[1] According to Iscan, "nearly every bone contains an age marker, but it is important to know where to look and how to recognize and interpret them".[1] The methods to estimate age before the age of 25 years (like epiphyseal-diaphyseal closure of long bones and the order of tooth eruption) are reliable and have been proven to have almost 90% accuracy. But the anthropological estimates after the age of 25 has been haphazard. The principal macroscopic changes used are metamorphosis of pubic symphysis, closure of cranial sutures and degenerative changes in vertebral body and joints.[2] Of these, cranial sutures have always been a centre of considerable debate and its reliability has not been conclusively demonstrated by any researchers.[3]

Beginning in the sixteenth century, the sutures were believed to change morphologically with age. Over the years many authors like Singer (1953),[4] Brooks (1955),[5] Herschkovitz et al. (1997)[6] could not correlate their studies with suture fusion and hence asked for a removal of it from the medicolegal protocol. But modern forensic anthropologists like Acsadi and Nemeskeri (1970),[7] Meindl and Lovejoy (1985)[8] support this analysis and say that only a systematic approach would help and the accuracy would be more than 80%. The confusions have not led to a dismissal of interest in cranial sutures but have ignited a flame in the modern anthropologists. Thus, depths of pursuit for finding the relationship between the structural and functional changes of cranial sutures has given rise to trials of newer methodologies.

The primary aim of the study is to estimate age from fusion of cranial sutures in wet specimen of cranial vault during autopsy.

## Materials and methods:

The study was conducted on cases coming for medicolegal post-mortem examination to the Mortuary wing of Department of Forensic Medicine, Government Medical College, Thiruvananthapuram from 01-03-2018 to 28-02-2019.

Sample size calculated was 150.47. In order to have a uniform statistical distribution, sample size was spread uniformly between different age decade groups. Sample size was fixed as 168 in order to have an equal distribution of 12 males and 12 females in each of the seven decade groups (11-20 years, 21-30 years……71-80 years).[8]

Data Collection: The age of the deceased was verified with Aadhar card/ Voter's id/ Driving license. The routine dissection protocol was followed. Each suture was subdivided into parts of equal length for the study. The divisions were based on previous studies according to their variability in fusion with age.[7,9] The subdivisions were as follows:

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**Table 1. Comparison of predictability of various cumulative scores.**

| Sl no | Cumulative Score | R | R2 | p value | Predictability % |
|---|---|---|---|---|---|
| 1 | Endocranial scores | 0.698 | 0.487 | <0.0001 | 48.7% |
| 2 | Ectocranial scores | 0.218 | 0.048 | 0.004 | 4.8% |
| 3 | Total Cumulative | 0.613 | 0.376 | <0.0001 | 37.6% |
| 4 | Bregma | 0.607 | 0.368 | <0.0001 | 36.8% |
| 5 | Lambda | 0.574 | 0.329 | <0.0001 | 32.9% |

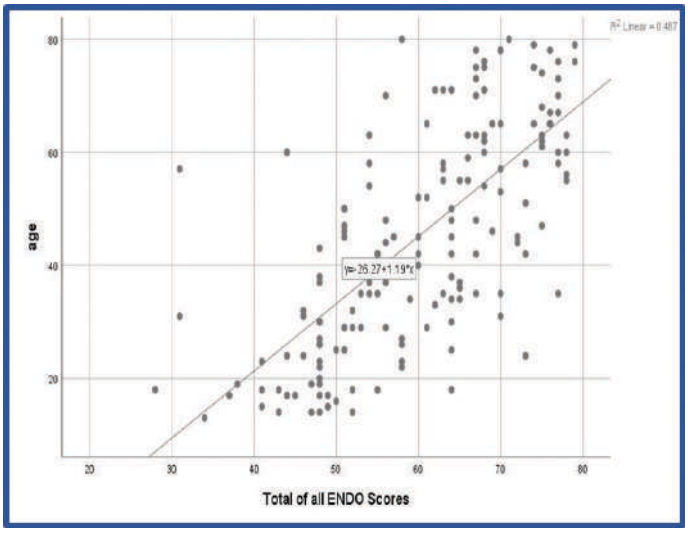


**Figure 1. Graph depicting correlation of sum of endocranial (ENDO) scores with age.**

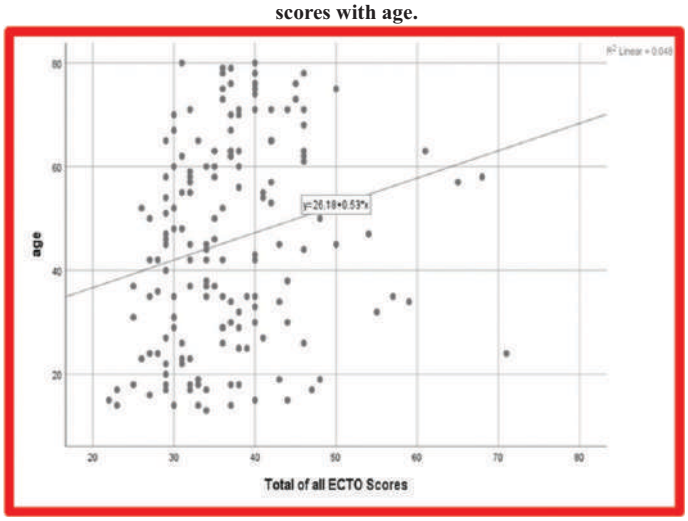


**Figure 2. Graph depicting correlation of sum of ectocranial (ECTO) scores with age.**

1. Sagittal suture (S1, S2, S3, S4) Whole length of sagittal suture was divided into four portions of equal length, S1 being anterior-most and S4 being the posterior-most.

2. Coronal suture (C1, C2, C3) Whole length of coronal suture was divided into three portions of equal length, C1 being medial-most and the C3 being the lateral-most. Right and left side were scored separately.

3. Lambdoidal suture (L1, L2, L3) Whole length of lambdoid suture was divided into three portions of equal length, L1 being medial-most and the L3 being the lateral-most.

4. Tempero-parietal suture (T1, T2) whole length of the suture was divided into two portions of equal length, T1 being anterior and the T2 being the posterior.

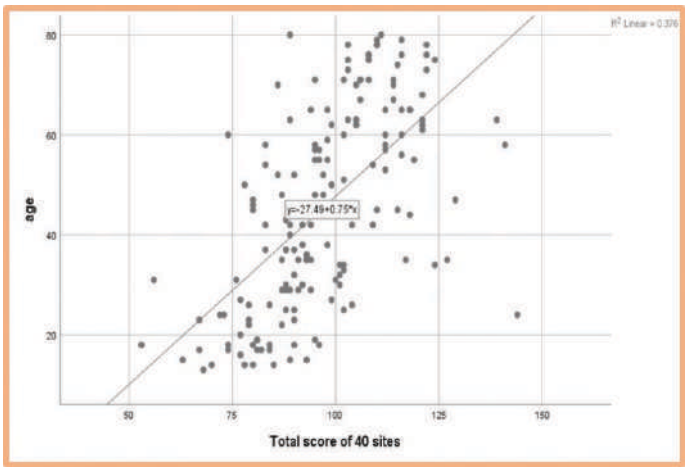


**Figure 3. Graph depicting correlation of sum of all scores (40sites) with age.**

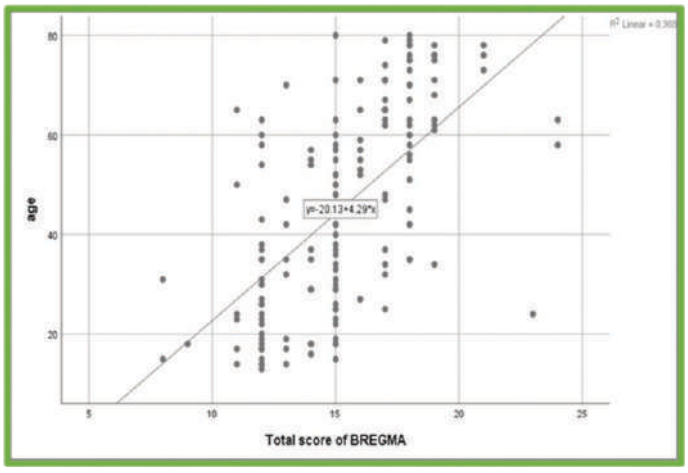


**Figure 4. Graph depicting correlation of sum of scores of sutural subdivisions around Bregma with age.**

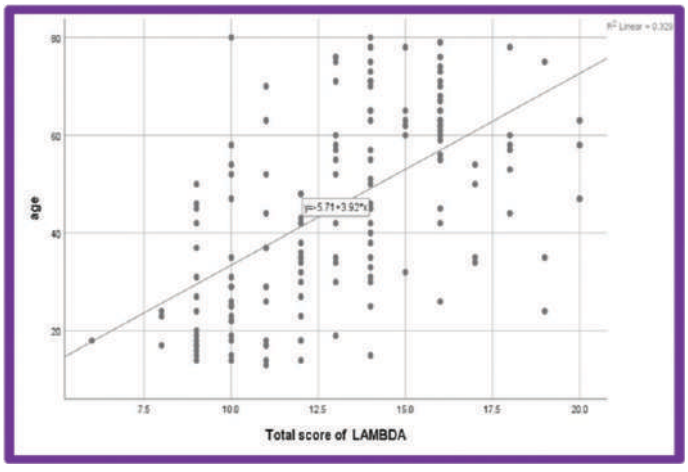


**Figure 5. Graph depicting correlation of sum of scores of sutural subdivisions around Lambda with age.**

The length of each suture was first measured using a calliper and then divided into equal parts. After reflecting the scalp, the scores of each ectocranial sutural subdivision was noted. The endocranial scores were noted after removing the vault in the

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routine method. Brain was removed following the routine procedure and the base of skull examined for fusion of basi-sphenoid with basi-occiput.

In cases, where an interobserver variation was necessary for validation, another reader determined the score of fusion in a similar manner and entered into a separate data sheet. Throughout the confidentiality between the two readers was maintained.

The scoring of each subdivision of the cranial sutures was done according to the Acsadi-Nemeskeri scale ectocranially and endocranially.

Scale for closure: Acsadi- Nemeskeri complex scale

0= Open. There is little space between the edges of adjoining bones.

1= Incipient closure. Clearly visible as a continuous often zigzag line.

2= Closure in process. Line thinner, less zigzags, interrupted by complete closure.

3= Advanced closure. Pits indicate where the suture was located.

4= Closed. Even location cannot be recognized.

Tools used were metre scale (for measuring height in centimetres), Vernier Calliper (for precisely measuring the length of the sutures), Acsadi-Nemeskeri[7] complex scoring scale and pro-forma for data collection.

Statistical analysis: All the data collected were entered into a Microsoft Excel Spreadsheet and analysed using statistical software statistical package for social sciences (SPSS) version 25.0. Firstly, each subdivision of each cranial suture was separately analysed for its correlation with age.

In order to assess the inter-observer variability, kappa test was performed in 89 cases. These scores were compared to quantify the amount of reliability and hence verify the significance of the study. Kappa coefficient analysed was 0.911. This indicates a good agreement between two observers.

Institutional ethics committee clearance was obtained from Human Ethics Committee, Government Medical College, Trivandrum dated (IEC: 14/07/2017/MCT).

Study design: Cross-sectional study involving cases brought for medicolegal autopsy within a definite time interval. Cases of known age between the age of 11 to 80 years were included. Cases suspected of head injury or with any previous head trauma or surgeries were excluded.

**Results:**

A. Age vs scores of each subdivision of cranial sutures.

(i) Endocranial fusion: The study methodology adopted was a scoring technique of four gradations which denotes an ordinal variable. Hence, Spearman's correlation was used to analyse each subdivision endocranially. Almost all sutural subdivisions had a significant probability of increase in its score with age. Along with this, an absence of normal distribution of scores for each subdivision among the study subjects indicate that it cannot be used as a predictor of age when used alone.

(ii) Ectocranial fusion: The findings of the ectocranial fusion has shown reliability only in the first two subdivisions of sagittal and all subdivisions of lambdoid and tempero-parietal. But similar to the endocranial sutures, there are only four gradations which do not have normal distribution in the study population. Even though there are subdivisions which have a positive relation to advancing age, this cannot be used to predict the age.

B. Age vs Cumulative scores of fusion of individual cranial suture

(i) Endocranial fusion: The cumulative score of all endocranial sutural subdivisions showed a positive correlation with age. But this correlation did not have a definite uniform pattern and hence prediction of age from such a score would be difficult.

(ii) Ectocranial fusion: Except for coronal, the other three sutures had significant correlation with advancing age. But, the variance from normal distribution and the limitation of gradations against a wide variety suggest that the prediction of age was difficult from this score.

(iii) Sum of endocranial and ectocranial scores of fusion of each cranial suture: The sum of endocranial and ectocranial scores of each suture shows correlation with age with a significant probability. But being a non-parametric correlation, it could not be considered as a good predictor of age.

C. Age vs Cumulative scores of fusion of all sutures

When computing total scores of multiple sutures, it had a more uniform distribution among the study subjects. The possibility of multiple scores against a variable like age was statistically analysed and was found to be reliable for prediction of age as parametric correlation was applied. The results of Regression ANOVA applied for various cumulative scores derived the following results.

(i) Sum of scores of all endocranial sutures: As the p value of F was found to be <0.0001, it indicates that there is a significant correlation as depicted in Figure 1. The t test was applied, $R^2$ value was 0.487 which indicates that it has a predictability of 48.7%. From the various values got from regression ANOVA a regression equation for the age prediction from the endocranial cumulative scores was formulated.

Age (y) = -26.27 + (1.19 x total of all endocranial scores)

(ii) Sum of scores of all ectocranial sutures: The sum of all ectocranial scores showed a wide permutation and combination of scores with normal distribution. Hence, was concluded to be a good predictor of age as depicted in Figure 2. A regression ANOVA was done, a line was plotted and a regression equation for the prediction of age was formulated. The $R^2$ value was 0.048 which indicates that it has a predictability of 4.8%. The regression equation formulated was

Age (y) = -26.18 + (0.53 X total of all ectocranial scores)

(iii) Total of all cumulative scores of fusion: The total of all sutural scores showed a uniform wide distribution and significant correlation with age as depicted in Figure 3. A regression line was plotted and a regression equation was formulated for the prediction of age. The $R^2$ value obtained was 0.376 which indicates that there is 37.65 predictability.

Age (y) = -27.49 + (0.75 X total of all scores)

(iv) Special sites: In the study of Meindl and Lovejoy, it was stated that fusion at the point Bregma and Lambda showed a satisfactory correlation with age and it can be used solely as an age predictor. According to his assumption, cranial suture fusion starts at the points Bregma and Lambda. Hence, these points were analysed separately.

(a) Bregma: It is the point of intersection of coronal sutures on both sides with sagittal suture in midline. Considering the endocranial and ectocranial subdivisions here, there were six subdivisions for analysis and 24 scores with wide permutations and combinations. On analysis, it had a good uniform distribution and hence was analysed for age prediction as depicted in Figure 4. Formula derived was: Age (y) = -20.13 + (4.29 X total of all scores at Bregma)

(b) Lambda: The point Lambda is formed by the inner thirds of right and left lambdoid along with the posterior one-fourth of Sagittal suture. Similar to Bregma there were 6 subdivisions under study and 4 gradations for each with 24 possible scores and multiple permutations and combinations. Regression ANOVA was done to do the age prediction and the results were as follows. Age (y) = -5.71 + (3.92 X total of all scores at Lambda)

D. Comparison of Age prediction from the various determinant scores: Various cumulative scores with a good prediction probability were analysed using Regression ANOVA for their significance/ p value and all were found significant enough with a p value <0.05. Their predictability percentage were compared using their respective R and R2 values as depicted in Table no:1. Of all predictors, cumulative scores of all endocranial sutures (48.7%) is the most dependable, followed by the total score (37.6%) and Bregma (36.8%). The least dependable one is the ectocranial score with a prediction of only 4.8%.

After deriving the regression equations, new age was calculated from the cumulative scores of the samples. It was then compared to the actual age and their deviations were analysed. Total of endocranial scores showed a minimum deviation of 0.05 years and maximum of 27 years (mean deviation was 2.38 years). Cumulative total of ectocranial scores showed the maximum variation with a minimum of 17 years and maximum of 70 years (mean deviation was 14.81). Total cumulative score showed a minimum deviation of 0.81 years and maximum of 29 years (mean deviation was 3.7 years). Total score around Bregma showed a deviation between 0.81 years and 29 years (mean deviation was 3.7 years). Total score around Lambda showed a deviation between 0.79 years and 21.91 years (mean deviation was 4.1 years). This deviation indicates that ectocranial is the least reliable.

**Discussion:**

In the previous studies with different methodologies, the results derived were of the mean age group of commencement and completion of fusion of cranial sutures.[4,5,9] On contrary to those studies, the present study showed that there is no such set pattern of fusion and it is difficult to predict such a mean age of commencement or closure. When comparing the present observations to the previous literatures, (a) there were a wide number of cases who showed non-fusion of sutures at expected ages of fusion (b) there was no definite pattern of suture fusion among sutures of the same individual (c) the pattern observed was different endocranially and ectocranially (d) the pattern was different endocranially and ectocranially in each suture.

Statistical analysis showed that it is difficult to guess a mean age of commencement and closure of fusion in any of the sutures under study. This is contrary to authors like Krogman,[2] Mukherjee[10] and Apurba Nandy[11] who mention a definite age of commencement and closure. Even though a lot of findings have been derived from the present study, the usual prediction of the mean age group of starting and completion of fusion of cranial sutures was merely impossible from the data of the present study.

Many of the previous literatures mentioned that their study population consisted mainly of skulls from museums which considered a mixture of races and limited data of description. Todd and Lyon,[9] Meindl and Lovejoy[8] and Acsadi- Nemeskeri[7] stated that the main disadvantage of such a study is the mixture of population and races.

It is possible to derive a regression formula for age estimation from cranial suture fusion only if there is more or less a uniform data and that too in equal proportions of age groups. Studies in same race and with equal distribution of sex in equal quadrant age groups were suggested to be the ideal study setting for deriving a regression equation.

Cumulative scores at the point Bregma and Lambda were calculated based on the study by Meindl and Lovejoy[8] who mentioned a hypothetical fact of a possible 'Y ascent' which suggested that sagittal and coronal sutures usually start fusing from the point Bregma, immediately after the closure of anterior fontanelle. He postulated regarding an 'Inverse Y descent' which held the same pattern but in the point Lambda. Out of all the five significant equations derived, the predictability was maximum (48%) for Sum of endocranial sutures. This indicates that endocranial sutures were more reliable than ectocranial sutures. The predictability from ectocranial sutures were as low as 4.39 %

According to the timing of fusion of sutures in the present study, endocranial fusion was much earlier than ectocranial fusion. But no specific time period could be predicted for the commencement of endocranial fusion. No set pattern (e.g. a definite age gap between the endocranial and ectocranial fusion) could be assessed from the data collected in the present study.

Todd and Lyon[9] however mentioned there was no tendency of early fusion endocranially. He added that ectocranial fusion was more variable and it was never complete. Lapsed union was common ectocranially. Acsadi and Nemeskeri[7] mentioned that within every decade, endocranial patterns vary, hence shows a significant score change which would reflect when calculating the age groups.

Patil T L et al.[12] were of the opinion that cranial suture fusion cannot be considered as a marker for estimation of age as the variation is too much. If at all it should be considered as a marker, endocranial fusion was more reliable than ectocranial fusion. On contrary to this, Nandy A[11] had mentioned that even though fusion occurs earlier at the ectocranial surface, the rate of fusion is much

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slower. Hence, to predict a young adult age group, endocranial scores would be more reliable. He spoke about the possibility of tempero-parietal suture having a lapsed union until death.

Ullas Shetty[13] described earlier fusion in endocranial side but he did not comment on the reliability between ectocranial and endocranial fusion. The only observation on that aspect was that ectocranial fusion did not follow a pattern at all and hence it cannot be considered as a predictor of age. In 2012, Kumar et al.[14] mentioned that endocranial fusion occurs much earlier than ectocranial fusion. All these observations from various literatures are in agreement with the present study.

**Conclusion:**

The most challenging task of every forensic pathologist is of establishing identity. Recent developments in science have brought forth alternatives like DNA fingerprinting that are efficient in establishing identity. But the real problem arises when biological material for DNA extraction is not available. In such scenarios, many a time anthropology comes into real play. Many dependable variables in anthropology like fusion of cranial sutures, has faced controversies. Many of the literatures relate these to the subjectivity of the methodology.

The present study adapted an objective methodology which will be more practical to be used in cases of unidentified bodies as well as skeletal remains. The regression formulae derived with very little mean deviations would be of ample help in arriving at more accurate conclusions.

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