Macroscopic Study of Temporoparietal Suture Closure at Autopsy for Estimation of Age

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ABSTRACT

Introduction: Age estimation is an integral part of identification of an individual which is needed for social and medicolegal purposes, whether in living, dead or in skeletal remains.

Aim: To evaluate the utility of fusion of temporoparietal cranial suture for estimation of age at autopsy.

Materials and Methods: This cross-sectional study was conducted on the medicolegal postmortem cases that came to the Department of Forensic Medicine and Toxicology, Government Medical College and Hospital, Chandigarh, India during the period between October 2018 and July 2019. A total of 280 cases were studied. The fusion of temporoparietal suture was studied macroscopically during the routine postmortem examination. The temporoparietal suture was studied ectocranially and endocranially by dividing it into two equal parts (T1 and T2), and applying Acsadi-Nemeskeri scale (0-4). Mean and standard deviation were calculated for ectocranial and endocranial suture closure (left and right sides). Also, it was calculated for total mean of the segments (T1+T2) taken together on both sides. Actual age and the scored values were plotted in a linear regression curve and estimated age was calculated. Statistical analysis was carried out by using Statistical Package for the Social Sciences (SPSS) software version 22.0. Spearman's correlation analysis was applied to determine the variable correlations. The p-values of less than 0.05 were considered statistically significant. Estimated age for males and females was tested by Student's t-test of significance.

Results: Out of total 280 cases studied, maximum (219) were males. Maximum number of males and females were found to be in age group of 26 to 35 years. It was observed that closure commenced at the age of 18 to 25 years (Acsadi-Nemeskeri scale mean of 0.87, 0.84 for T1, T2, respectively on left side) and (Acsadi-Nemeskeri scale mean 0.84 for T1 and T2 on right side). Closure was not complete even at the age of 76 years and above (Acsadi-Nemeskeri scale mean 2.67, 2.50 for T1, T2, respectively on left side) and (mean 2.33, 2.67 for T1, T2, respectively on right side).

Conclusion: From the present study, it can be concluded that endocranially temporoparietal suture was closed at 18 years and above of age and it was found unfused even at age of more than 76 years for the identification of an individual especially in advanced age, and was consistent with the studies conducted by various authors.

INTRODUCTION

The anatomy of human skeleton (including teeth) reflects the combined action of genes and environment, which forms the framework for the body. Bones and teeth are the most resistant to many kinds of decay so, they are important tool that helps in the identification of an individual. Age, sex and stature can be estimated from the study of bones and teeth [1]. Although determination of sex in adults does not cause any difficulty [2], determination of age at death in adults remains difficult and is subjected to innumerable errors [3]. The union of cranial sutures is a part of an age-related physiological process and is still used as a method for determination of age and also the macroscopic observation does not necessitate any specific equipment. The fusion of cranial sutures has been mainly used for determination of age as cranium is the best preserved portion of the recovered skeleton [4]. The need for identification arises in everyday medicolegal practice both in criminal and civil cases such as employment, pension, insurance, inheritance claims, disputed sex, missing persons, persons accused of assault, rape, murder, etc. Identification is essential in mass disasters, explosions, decomposed, mutilated bodies, skeletal remains or when an unknown person is found. Age estimation forms an important part of the identification of an individual.

Estimation of age is done by various macroscopic methods based on the order of epiphyseal union of long bones, development and order of tooth eruption, closure of cranial sutures, appearance and fusion of various ossification centers as well as microscopic examination of bone in histological analysis [5]. Under 25 years of age, estimation of age is easily attained using the order of epiphyseal union of long bones and this is possible due to the progressive development of bones [6].

The epiphyseal fusion in cartilaginous bone occurs slightly earlier (by about one year) in females than in males, however the reverse is seen within the closure of sutures of the skull [7]. After 25 years of age, the age determination of unidentified skeletons becomes more difficult for which other methods were developed such as degeneration of the pubic symphysis, rib ends, and cranial suture closure. The degenerative changes that occur in adult skeleton can be influenced by factors including habitual activities and the health of an individual in addition to their age.

Some authors emphasise that it is very unlikely for age to be the only factor affecting suture closure as the human body is "highly adaptive" [8]. Many intrinsic and extrinsic factors play role in suture closure and morphology such as genetics, tensile forces, growing brain, and muscle stresses [9]. Studies in different geographical regions are essential as there is ethnical and racial variability. There are various genetic and environmental factors that influence the pattern of cranial suture such as daily water intake, dietary habits and the climatic conditions. Though age assessment by the closure of cranial sutures has been done since the 16th century, the previous studies included only limited ancestral groups and these samples were often from historic skeletal collections [10].

Very few studies [11-13] have been done in the Northwest region of India for age estimation from cranial suture closure at autopsy and sparse Indian literature is available for temporoparietal suture closure. Hence, the present study was undertaken in the population of

Chandigarh and adjoining areas, with the aim to evaluate the utility of fusion of temporoparietal cranial suture for estimation of age at autopsy.

MATERIALS AND METHODS

This was a cross-sectional study conducted on the medicolegal postmortem cases that came to the Department of Forensic Medicine and Toxicology, Government Medical College and Hospital, Chandigarh, India during the period between October 2018 and July 2019. A total of 280 cases were studied. The study was approved vide letter no. 726/Secy./Theses dated 10/01/2020.

Sample size calculation: The main focus in this study was to see the agreement between cranial suture closure associated with accurate age. Optimum sample size for this study was calculated on the basis of anticipated 50%, 90% confidence level and 5% permissible error. The optimum sample size calculated was 280 cases with known accurate age. The sample size was calculated by the formula

$$n=4p(1-p)/d^2,$$

where 'p' is the percentage coefficient/agreement between the actual age and the estimated age and

'd' is the permissible error in percentage in absolute terms.

Inclusion criteria: The cases of known age that were reported for medicolegal postmortem examination, of ≥18 years of age with age confirmed by documentary evidences available at the time were included in the study.

Exclusion criteria: Unknown/unclaimed bodies or bodies of the persons in which exact age cannot be confirmed, cases showing diseased, deformed or fractured skull which may hamper the study of suture closure and deceased with history of steroid therapy were excluded from the study.

Procedure

The temporoparietal suture was studied macroscopically, both ectocranially and endocranially during the routine postmortem examination. After reflecting the scalp, the calvarium was cleaned of soft tissues and wiped with cloth to make the sutures more prominent. The suture was divided into two equal sections, T1 and T2 and scores studied applying Acsadi-Nemeskeri scale. Then, the calvaria was removed with an electric saw and after removing the periosteum from the skull bone, the suture was studied endocranially by diving into two equal sections. The scoring system of the scale devised by Acsadi-Nemeskeri was applied to the suture. The scores (0,1,2,3,4) were recorded for each section ectocranially and endocranially based on the stage of closure [Table/Fig-1,2,3,4].

[Table/Fig-1]: Showing stage 2 fusion of temporoparietal suture ectocranially (age 50 years). **[Table/Fig-2]:** Showing complete fusion of temporoparietal suture endocranially (age 25 years). (Images from left to right)
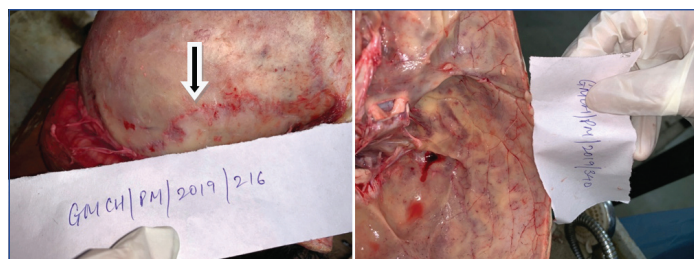
[Table/Fig-3]: Showing Stage 1 fusion of temporoparietal suture ectocranially (age 34 years); **[Table/Fig-4]:** Showing complete fusion of temporoparietal suture endocranially (age 35 years). (Images from left to right)

Acsadi-Nemeskeri Complex Method [14]

0=Open- There is still little space left between edges of adjoining bones.

1=Incipient closure- Clearly visible as a continuous often zig-zagging line.

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

3=Advanced closure- Only pits indicate where the suture is located

4=Closed- Even location cannot be recognised.

STATISTICAL ANALYSIS

The quantitative parameters were described by mean and standard deviation. Estimated age was calculated using regression formula by plotting the score values against the x-axis and the actual age against the y-axis. Estimated age for males and females was tested using Student's t-test of significance. Statistical analysis was done by Statistical Package for the Social Sciences (SPSS) software version 22.0 was used for data analysis. Pearson's correlation analysis was applied to determine the variable correlations. The p-values of less than 0.05 were considered statistically significant.

RESULTS

In the present study, a total of 280 cases were studied of which 219 were males. Maximum number of males and females were found to be in age group 26 to 35 years [Table/Fig-5].

Age (in years)	Total	Male	Female
18-25	55	40	15
26-35	81	64	17
36-45	58	47	11
46-55	43	38	5
56-65	30	24	6
66-75	7	4	3
>76	6	2	4
Total	280	219	61

[Table/Fig-5]: Sex-wise distribution of the study population.

Ectocranially, no significant difference was found on the left and right sides as shown in [Table/Fig-6]. Endocranially, the temporoparietal suture was found to be closed at 18 years of age and above [Table/Fig-7].

Age group (Years)	N	TL1 Ecto Mean±SD	TL2 Ecto Mean±SD	TR1 Ecto Mean±SD	TR2 Ecto Mean±SD
18-25	55	0.87±0.43	0.84±0.37	0.84±0.42	0.84±0.42
26-35	81	1.26±0.49	1.35±0.64	1.32±0.59	1.37±0.70
36-45	58	1.57±0.62	1.53±0.63	1.59±0.75	1.57±0.68
46-55	43	1.58±0.50	1.86±0.83	1.70±0.60	1.70±0.60
56-65	30	1.67±0.66	1.90±0.96	1.67±0.66	1.77±0.77
66-75	7	2±0	2±0	2±0	2±0
>76	6	2.67±1.03	2.50±1.22	2.33±0.82	2.67±1.03
Total	280	1.39±0.64	1.46 ±0.78	1.41±0.69	1.44±0.74

[Table/Fig-6]: Mean and standard deviation of score value of suture closure (ectocranial).
TL1/2 Ecto: Temporoparietal suture left side (ectocranial); TR1/2 Ecto: Temporoparietal suture right side; SD: Standard deviation

Endocranially, the suture was found to be closed and ectocranially the suture was found to be unfused even at the age of 76 years and above, when the segments T1 and T2 were taken together on both sides [Table/Fig-8].

[Table/Fig-9] shows linear regression curve for mean ectocranial temporoparietal suture closure (left) with the actual age plotted against y-axis and the score values against the x-axis. Regression

Age group (Years)	N	TL1 Endo Mean±SD	TL2 Endo Mean±SD	TR1 Endo Mean±SD	TR2 Endo Mean±SD
18-25	55	4±0	4±0	4±0	4±0
26-35	81	4±0	4±0	4±0	4±0
36-45	58	4±0	4±0	4±0	4±0
46-55	43	4±0	4±0	4±0	4±0
56-65	30	4±0	4±0	4±0	4±0
66-75	7	4±0	4±0	4±0	4±0
>76	6	4±0	4±0	4±0	4±0
Total	280	4±0	4±0	4±0	4±0

[Table/Fig-7]: Mean and standard deviation of endocranial temporoparietal sutures. TL1/2 Endo: Temporoparietal suture left side (endocranial); TR1/2 Endo: Temporoparietal suture right side (endocranial)

| Age group (Years)	N	Total mean TL Ecto Mean±SD	Total mean TL Endo Mean±SD	Total mean TR Ecto Mean±SD	Total mean TR Endo Mean±SD
18-25	55	0.85±0.39	4±0	0.84±0.42	4±0
26-35	81	1.30±0.52	4±0	1.35±0.58	4±0
36-45	58	1.55±0.58	4±0	1.58±0.68	4±0
46-55	43	1.72±0.61	4±0	1.70±0.52	4±0
56-65	30	1.78±0.76	4±0	1.72±0.64	4±0
66-75	7	2±0	4±0	2±0	4±0
>76	6	2.58±1.11	4±0	2.50±0.84	4±0
Total	280	1.43±0.67	4±0	1.43±0.67	4±0

[Table/Fig-8]: Mean and standard deviation of total mean of temporoparietal suture closure (left and right), all segments taken together. TL1/2 Ecto- Temporoparietal suture left side (ectocranial); TR1/2 Ecto- Temporoparietal suture right side (ectocranial)

formula derived was $y=11.634x+23.132$ and using this formula the estimated age was calculated. It was observed that the maximum difference of -36.4 years was found at the age of 77 years with a scored value of 1.5 and the minimum difference of -0.1 was found at the age of 29 years with a scored value of 0.5.
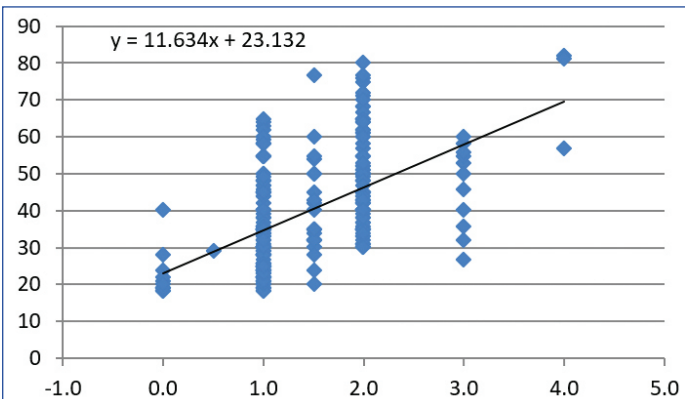
[Table/Fig-9]: Regression chart showing mean ectocranial temporoparietal closure (Left).

[Table/Fig-10] shows linear regression curve for mean ectocranial temporoparietal suture closure (right) with the actual age plotted
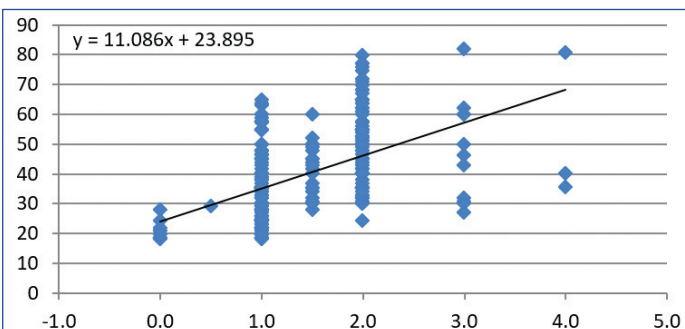
[Table/Fig-10]: Regression chart showing mean ectocranial temporoparietal closure (Right).

against y-axis and the score values against the x-axis. Regression formula derived was $y=11.086x+23.895$ and using this formula the estimated age was calculated. It was observed that the maximum difference of -33.9 years was found at the age of 80 years with a scored value of 2 and the minimum difference of -0.1 was found at the age of 24 years with a scored value of 0. [Table/Fig-11] shows the regression equation, mean and standard deviation for the score value, actual age and calculated age for total number of individuals.

Parameters	Regression equation	Mean score	Mean actual age	Mean calculated age	Mean standard deviation of score
Mean TL ecto	$y=11.634x+23.132$	1.4	39.7	39.0	0.67
Mean TR ecto	$y=11.086x+23.895$	1.4	39.7	39.7	0.67

[Table/Fig-11]: Table showing regression equation, mean and standard deviation for the score value, actual age and calculated age (N=280).

DISCUSSION

Since bones resist putrefaction, they can result in reliable determination of age, sex, stature of an individual. The most reliable method for evaluating age of adults is analysis of the pubic symphysis and auricular surface, however auricular surface is often better preserved in forensic and archaeological contexts [15]. Another method used is degenerative changes in the sternal end of the right fourth rib, however, it was tested on small samples [16]. Finally, union of cranial sutures can be utilised to estimate the age at death. The thought that cranial bones fuse progressively with age has been in existence since the 16th century [1]. However, age estimation by this method has been quite controversial since the mid 20th century but today it is still used as one of the methods for determination of age in the absence of other evidence or with other methods.

Cranial sutures can be seen both on the ectocranial and endocranial surfaces. There is progressive closure of the sutures, each at a different time. It has been used as an age estimation indicator since the 19th century, but its reliability is still inconsistent [17]. The sutures fuse progressively at various times, each having a different time of closure.

In 2002, Verma RK et al., conducted a study in Jaipur to determine the age of living individuals in fourth to seventh decade [12]. The sutures were studied radiologically and concluded that the temporoparietal suture was found to be closed at the age of 80 years. According to the study, the difference between the ectocranium and endocranium was not possible on X-ray of the skull. In the present study, very few cases were studied of age more than 80 years, therefore complete fusion of the suture could not be observed. Another difference in the observations could be due to the macroscopic study of suture closure in the present study.

A study was conducted by Gorea RK et al., in 2004 and age was estimated in old individuals on Computed Tomography (CT) scan of skull with the help of axial sections at different levels [13]. Hundred individuals were studied (both males and females) between the age group of 40 to 70 years of Punjab region. The lambdoid, parieto-mastoid, coronal and squamous sutures were studied ectocranially and grading was done depending upon closure of sutures. Earliest age of fusion of squamous suture was found to be 45 years. The present study was conducted in individuals of 18 years and above and was done macroscopically at autopsy.

In 2014, Khandare SV et al., studied the sutures for estimation of age on CT scan in 100 males of 25 years and above in Mumbai region [18]. The sections taken were axial, coronal and sagittal at different levels. The sutures studied were sagittal, coronal, lambdoid and temporoparietal both ectocranially and endocranially. It was found that the fusion of temporoparietal suture starts at the end of 56 to 60 years and complete closure was found after the age of 70 years.

Another study was conducted by Khandare SV et al., in 2015, in male individuals of 25 years and above in the tertiary referral center

in Mumbai and the suture was studied in one part [11]. It was suggested that ectocranially, temporoparietal suture closure started at the age of 70 years and above. Endocranially, complete closure was observed at the age of 66 to 70 years. In the present study, it was found that the suture was closed at the age of more than 18 years. In contrast to the study cited above, the present study was conducted on male and female individuals for estimation of age and the temporoparietal suture was studied in two parts.

In civil and criminal cases, issues of disputed age are the domain of a forensic expert as the findings are directly related to the administration of law. Age estimation from skull sutures is especially important where only skeletal remains are found, in mass disasters or in decomposed bodies. Various studies have been conducted to study the fusion of sutures and concluded that endocranial fusion is a more significant than ectocranial fusion as sutures along the outer table are more or less serrated whereas they are straighter at the inner table [19-21]. This finding was consistent with the present study. Only a handful of studies [11-13] have been conducted to study the temporoparietal suture ectocranially or endocranially [11-13] and the fusion process by some authors does not distinguish the age of fusion for the ectocranial or the endocranial surface [7,22].

The present study was conducted where temporoparietal suture was studied macroscopically at autopsy for estimation of age. It was studied by dividing it in two equal parts, T1 and T2 and it was observed that ectocranially, the suture starts to close at 18 to 25 years and was not complete at the age of 76 years and above. Endocranially, the suture was found to be closed. This difference in contrast to other studies could be due to the geographical distribution of study, nutritional, endocrinal or hereditary factors. In the present study, the difference between each age group was 10 years, so it can be reduced to get better results. Very few cases were studied of age 60 years and above, so more cases need to be studied of this age to get accurate results of fusion process. Also, this suture can be studied singly, or in combination with other sutures for age estimation using newer methods like X-ray and CT scan along with the conventional methods [Table/Fig-12].

Author	Geographical location of study	Method of study	Age of fusion
Verma RK et al., (2002) [12]	Jaipur	X-ray	80 years
Gorea RK et al., (2004) [13]	Punjab	CT scan	Ecto- 45 years
Khandare SV et al., (2014) [18]	Mumbai	CT scan	>70 years
Khandare SV et al., (2015) [11]	Mumbai	Macroscopic	Endo- 66 to 70 years
Present study	Chandigarh and adjoining areas	Macroscopic	Ecto- >76 years Endo- >18 years

[Table/Fig-12]: Age of fusion of sutures as reported by different authors (all the studies had a sample size of 100) [11-13,18].

Limitation(s)

In the present study, the suture was studied only macroscopically, so radiological investigations like X-ray and CT scan can be included to get better results. Less cases of age more than 60 years were

studied. The temporoparietal suture could not be compared with other sutures for age estimation.

CONCLUSION(S)

In the present study, it was found that temporoparietal suture was found to be closed endocranially, at more than 18 years of age making it inconclusive for age estimation and ectocranially it was unfused even at 76 years of age ectocranially. As this suture is the least studied suture both ectocranially and endocranially, so more studies need to be undertaken so that the data can be used as reference with other sutures, especially in identification of the unknown individuals or cases where only a part of the skull is the recovered portion from skeletal remains.

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