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ORIGINAL ARTICLE

Study of Fusion of Sagittal Suture on Computed Tomography Skull with Age in Western Maharashtra

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ABSTRACT

Introduction: This study examines the relationship between age and sagittal suture closure patterns using both cross-sectional and external measurements. Age is one of the big three of identification. With changing pattern of fusion we wanted to study if there is an association between age and suture closure at external and cross-sectional area in skull CT films.

Methodology: This study examines the closure patterns of sagittal sutures using CT scans analyzed with Radiant DICOM software, correlating them with chronological age and gender. The suture was divided into three pasts-S1, S2 and S3. A total of 100 images were assessed, with intra- and inter-observer reliability ensured through re-evaluations. The study aimed to explore relationships between cross-sectional and external suture closure patterns using statistical analysis.

Results: Pearson's correlations and linear regression were used to identify statistically significant associations. The cross-sectional areas along the sagittal suture exhibit varying degrees of positive correlation with external measurements, with **S3** having the strongest correlations. External measurements at **S1**, **S2**, **S3** correlated strongly with age, while cross-sectional measurements have weaker positive association.

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Conclusion: External measurements at **S1**, **S2**, **S3** correlated strongly with age, while cross-sectional measurements have weaker positive association. S3 has the strongest correlation between external stage and cross-sectional stage.

KEYWORDS

• Sagittal suture • CT skull • Score • Fusion

INTRODUCTION

In forensic investigations, determining a person's age is crucial for establishing identity, narrowing down missing persons' cases, and assessing legal responsibility or status. The three primary factors in identifying an individual are age, sex, and stature.[1]

Age estimation is valuable when profiling unidentified individuals, particularly in cases involving unexplained remains, human trafficking, or disaster victim identification. It also plays a crucial role in distinguishing between adults and juveniles, which is essential for legal proceedings, as age-based regulations often vary.[2] Forensic professionals employ various techniques, such as analyzing teeth, bones, and secondary sexual characteristics, to estimate age and ensure that investigations and legal proceedings are based on accurate information.[2]

Computed tomography (CT) has simplified the assessment of bone fusion stages and the identification of evolving trends. Its high-resolution, three-dimensional imaging provides detailed visualization of ossification centers, epiphyseal plates, and the extent of skeletal fusion. This level of precision allows for the meticulous study of subtle changes in bone morphology over time, making it invaluable for forensic age estimation. By monitoring these changes, forensic experts can more accurately determine age and analyze growth and development patterns.[3] which is crucial for both identification and legal investigations.[4]

Skull is a unique bone as it undergoes membranous ossification. It grows by apposition of the two tables of skull. The fibrous joints of the skull called the sutures allow for its growth to take place. Sagittal suture is located in the middle of the two parietal bones and is affected by neck muscles not as much as lambdoid and by lateral tension on the sutures also.[5-7]

In forensic medicine, the sagittal suture is a key indicator for age estimation, as its fusion progresses over time, helping distinguish between juvenile and adult remains. It plays a crucial role in identifying skeletal remains and analyzing trauma, such as fractures or suture diastasis, which can indicate the direction of force or intracranial pressure. Abnormalities in the suture may assist in differentiating between natural and unnatural deaths, while also revealing surgical history or cultural skull modifications, making it an invaluable tool in forensic investigations.

As a vital anatomical landmark for radiologists, the sagittal suture aids in skull orientation and symmetry assessment in imaging techniques such as X-rays, CT, and MRI. Its closure patterns are essential for diagnosing conditions like craniosynostosis and age-related changes. Additionally, it helps evaluate pathological conditions such as trauma, midline shifts, or infections. In neurosurgery, the sagittal suture serves as a reference for surgical planning and ventricular catheter placement. Its structural and developmental significance underscores its importance in pediatric, forensic, and diagnostic radiology.[5] While numerous studies have explored age-related changes in extremities,[1,3] research on cranial sutures remains limited, creating an opportunity to investigate current trends.[3] This study aims to bridge this gap by providing valuable insights into the reliability of the sagittal suture as an indicator of age progression, thereby enhancing forensic data.

METHODOLOGY

The CT scans were analyzed using Radiant DICOM software, with 1.5 mm axial sections used to examine the Sagiital suture. Digital images were stored on a compact disc, and only films with documented age verified through the patient's Date of Birth from their Dependent Card, Aadhar card, Birth Certificate, Driving License, or Voter ID were included.

A total of 100 images were evaluated by the first author. To assess intra and inter-observer reliability, 50 films were randomly re-evaluated by both the first and second authors. In cases of scoring discrepancies, the second author's or a radiologist's opinion was sought, with consistent results observed across all randomly selected samples.

The sagittal suture was divided into three sections and scored as follows: 'four' for complete fusion (no visible suture), 'zero' for fully visible sutures, 'three' for over 50% fusion, 'two' for half fusion, and 'one' for less than half fusion. Data analysis was performed using SPSS 20 software, and Pearson's correlation was calculated. The suture was divided into three parts. Mid-point of the suture on the Left side was S1, the mid-point or bregma was S2 and mid-point of the right side was S3. They external suture was studied by Key *et al*.

Aim of the Study: The aim of this study is to study the closure patterns of sagittal sutures and their associations with chronological age and gender.

OBJECTIVES OF THE STUDY

1. To study the association between the cross-sectional closure pattern of sagittal sutures and chronological age and gender.
2. To study the relationship between the external closure pattern of sagittal sutures, as observed in VRT images, and chronological age and gender.
3. To study the association between cross-sectional closure patterns and external suture patterns.

RESULTS

Table 1: Distribution and central tendencies of these variables across a sample of 100 participants

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Age	100	84	12	96	48.33	1.905
Gender	100	1	1	2	1.41	.049
Sagital External 1	100	3	1	4	2.15	.046
Sagital 1 Cross	100	3	1	4	2.05	.107
Sagital External 2	100	3	1	4	1.95	.070
Sagital 2 Cross	100	3	1	4	2.21	.112
Sagital External 3	100	3	1	4	2.39	.057
Sagital 3 Cross	100	3	1	4	2.38	.120

Table 2: Sex distribution of the sample size

Gender				
	Frequency	Percent	Valid Percent	Cumulative Percent
Male	59	59.0	59.0	59.0
Valid Female	41	41.0	41.0	100.0
Total	**100**	**100.0**	**100.0**	

Table 3: Pearson's correlation of sagittal suture -external and cross-sectional view with age

Sagittal suture	Pearson's correlation with external	Remarks
S1 External	.530**	Moderate positive correlation
S1 Cross-sectional	.305	Weak to moderate correlation
S2 External	.609	Moderate positive correlation
S2 Cross-sectional	.192	Weak to moderate correlation
S3 External	.545**	Moderate positive correlation
S3 Cross-sectional	.013	Weak to moderate correlation

These findings suggest external sagittal suture measurements are more strongly correlated with age than cross-sectional measurements, indicating their potential as better predictors of age progression.

Table 4: Pearson's correlation of sagittal suture cross-sectional view with external

Sagittal suture	Pearson's correlation with external	Remarks
S1 Cross-sectional	.532**	Moderate positive correlation
S2 Cross-sectional	.532**	Moderate positive correlation
S3 Cross-sectional	.877	Strongly positive correlation

DISCUSSION

The objectives of our study were to observe if there is an association between cross-sectional and external closure patterns of sagittal sutures with chronological age and sex, examine the relationship between these two closure patterns, and compare their stages of fusion. In this context, our findings contribute to a broader understanding of cranial suture fusion, complementing and contrasting with prior research in the field. The epidemiological data of our study is as depicted in table 1.

The sample consists of 100 individuals, with ages ranging from 12 to 96 years, covering an 84-year span. The mean age is 48.33 years, indicating that the sample predominantly includes middle-aged participants. The standard error of 1.905 reflects a low variation in the mean age estimate.

This study analyzed CT-based sagittal suture widths in 483 infants (1-395 days old), showing a significant decrease from 5.0 mm at birth to 2.4 mm by 1 month, with gradual narrowing thereafter. These normative values help assess suture diastasis in infants.[11] While Mitchell *et al*. emphasizes absolute measurements of suture widths, our study employs quantitative approaches, such as Pearson's correlations, to statistically validate relationships between age and suture closure. Our findings, therefore, have broader implications, extending beyond pediatric radiology to fields such as forensic science and anthropology, where age estimation is essential.

Pearson's correlation of sagittal suture external and cross-sectional view with age.

These findings suggest external sagittal suture measurements are more strongly correlated with age than cross-sectional measurements, indicating their potential as better predictors of age progression.

The Pearson's correlation coefficients between sagittal suture cross-sectional measurements and their corresponding external measurements indicate varying degrees of positive relationships:

- **S1 Cross-sectional** and **S2 Cross-sectional** both show a moderate positive correlation with their respective external measurements ($r=0.532$ $r=0.532$ $r=0.532$, $p<0.01p < 0.01p<0.01$), suggesting a consistent but not very strong relationship between these two aspects.
- **S3 Cross-sectional** shows a very strong positive correlation with its external measurement ($r=0.877$ $r=0.877$ $r=0.877$), indicating a high level of alignment between these two variables.

These findings imply that the external and cross-sectional measurements are more closely related in the S3 region compared to S1 and S2, highlighting differences in how these characteristics interact.

Assil et al. divided subjects into five age groups and assessed suture closure using the Frederic Rating Scale. They reported a positive correlation between age and cranial suture closure, particularly highlighting the sagittal, coronal, and lambdoid sutures.[12] Similarly, our study observed progressive closure patterns with age, with an emphasis on sagittal sutures. However, we extended this understanding by exploring both cross-sectional and external closure patterns, offering a more comprehensive methodological approach. Additionally, Assil et al. concluded that suture closure patterns are consistent across genders, a finding corroborated by our study.[12]

Khandare *et al.* conducted a post-mortem study using CT scans to analyze cranial suture closure for age estimation. They concluded that ectocranial closure patterns were inconclusive for age determination and that complete closure of specific sutures occurred at certain ages (e.g., coronal suture at 66-70 years). While their work focused on endocranial suture fusion, our study provides a complementary perspective by analyzing ectocranial patterns.[(13)]

Singh *et al.* investigated suture closure in individuals aged 40-70 years, categorizing closure into five stages, from no closure (Stage I) to complete closure (Stage V). They reported that the coronal suture began fusing at 40 years and completed between 45-50 years.[10] While Singh *et al.* primarily relied on descriptive statistics[14], our study incorporated Pearson's correlations to provide a statistically robust analysis of closure patterns. Moreover, while Singh et al. concentrated on coronal sutures, our study broadened the scope by examining the interplay between cross-sectional and external closure patterns.

Our study builds upon these foundational works by:

Exploring Cross-sectional and External Patterns: Unlike previous studies, we analyzed both cross-sectional and external closure patterns of sagittal sutures, identifying correlations and comparing their stages of fusion.

Quantitative Statistical Analysis: By using Pearson's correlations and multiple linear regression, we provided statistically significant insights into the association between suture closure patterns and age.

The cross-sectional areas along the sagittal suture exhibit varying degrees of positive correlation with external fusion, with **S3** having the strongest correlations. External measurements at **S1, S2**, **S3** correlated strongly with age, while cross-sectional measurements have weaker positive association.

CONCLUSION

By examining both cross-sectional and external patterns and employing robust statistical methods, our study provides a comprehensive framework for understanding suture fusion across ages and genders, enhancing its utility for age estimation and related applications. The article's strengths lie in its robust quantitative approach, detailed anatomical focus, and potential applications in related fields. However, its limitations lack of broader context, and weak correlations in some areas suggest the need for further research to validate and expand upon these findings. The addition of more nuanced analyses and broader datasets would enhance its utility and reliability. The cross-sectional areas along the sagittal suture exhibit varying degrees of positive correlation with external measurements, with **S3** having the strongest correlations. External measurements at S1, **S2**, **S3** correlated with age, while cross-sectional measurements are less consistent.

STRENGTHS AND LIMITATIONS

This article demonstrates strength through its robust quantitative analysis, utilizing Pearson's correlation to explore the relationship between cross-sectional and external measurements of the sagittal suture with age., lack of demographic context, and weak correlations at certain points, reducing the generalizability of the findings. The cross-sectional areas along the sagittal suture exhibit varying degrees of positive correlation with external measurements, with **S3** having the strongest correlations. External measurements at **S1, S2**, **S3** correlated with age, while cross-sectional measurements are less consistent. Additionally, the absence of causal explanations and consideration of external influences, such as genetics or environmental factors, limits the scope of the results. Future research with larger, diverse datasets and expanded methodologies could strengthen these findings.

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