



Xiphisternum Fusion Patterns and Their Utility in Age Estimation: A Cross-Sectional Radiological Analysis.

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Abstract: Age estimation is crucial in forensic and medico-legal contexts. This cross-sectional study evaluated the utility of radiological assessment of xiphisternum fusion for age estimation in individuals aged 31-45 years. Radiographs were analyzed to determine the presence or absence of complete fusion of the xiphisternum joint. The study found that 63% of participants exhibited fusion, with a slightly higher occurrence in females (33%) than males (30%). The mean age of fusion was 40.05 ± 4.89 years in males and 40.95 ± 3.87 years in females, while non-fusion occurred at a mean age of 35.83 ± 3.38 years in males and 33.30 ± 3.09 years in females. Statistical analysis revealed no significant difference in fusion rates between genders (Chi-Square = 0.287, $p = 0.592$). The findings indicate that xiphisternum fusion can be a supplementary tool for age estimation, though its reliability requires further investigation.

Introduction

Age estimation stands as a cornerstone of forensic science, playing a pivotal role in various medico-legal investigations. The ability to accurately determine an individual's age is crucial in scenarios ranging from criminal investigations and mass disaster victim identification to civil cases involving undocumented individuals. In essence, age estimation bridges critical gaps in personal identification, significantly impacting legal proceedings and humanitarian efforts. The human skeletal system undergoes predictable developmental changes throughout life, providing valuable clues for age estimation. These changes, particularly the ossification and fusion of skeletal elements, are widely utilized in forensic anthropology and radiology. Among these, the study of sternal ossification, and specifically the fusion of the xiphoid process to the sternal body, has garnered increasing interest. The sternum, comprising the manubrium, body, and xiphoid process, exhibits a complex pattern of ossification. The xiphisternum joint, where the xiphoid process articulates with the sternal body, undergoes progressive fusion with advancing age. This process, observable through radiological examinations, presents a potential avenue for age estimation, particularly in adult populations where other developmental markers may be less reliable. Traditional age estimation methods often rely on dental development, skeletal maturation of the hand and wrist, and pubic symphysis changes. However, these methods may exhibit limitations, especially in adult age ranges. Dental changes, for instance, can be influenced by environmental factors and individual habits. Similarly, the reliability of pubic symphysis assessment may decrease with age. Therefore, the exploration of alternative skeletal markers, such as xiphisternum fusion, is warranted.

Radiological imaging, including conventional radiography and computed tomography (CT), provides a non-invasive means of visualizing the sternal skeleton and assessing the degree of xiphisternum fusion. The objective evaluation of fusion stages through these imaging modalities offers a potential advantage over subjective assessments. However, the application of xiphisternum fusion in age estimation necessitates a thorough understanding of its variability across different populations and age groups. Factors such as sex, ethnicity, and nutritional status may influence the timing and pattern of fusion. Therefore, population-specific studies are essential to establish reliable age estimation norms. Furthermore, the accuracy and reliability of radiological assessment of xiphisternum fusion require rigorous validation. Establishing standardized criteria for fusion staging and evaluating the inter-observer and intra-observer variability of radiological assessments are crucial steps in ensuring the method's applicability in forensic practice. This research aims to contribute to the existing body of knowledge by investigating the relationship between radiological findings of xiphisternum fusion and chronological age in a cross-sectional study. By analyzing radiographs from a defined population, this study seeks to establish age-related patterns of xiphisternum fusion and assess its potential as a supplementary tool for age estimation. The findings of this research may have implications for forensic investigations, particularly in cases where other age estimation methods are limited. By providing greater insight into the value of radiological assessment of the xiphisternum, it is hoped that this will contribute to the general advancement of forensic science.

Material and Methods:

We have carried out our study in the Department of Forensic Medicine and Toxicology, of a tertiary care center situated in GIMSH, Durgapur, India. Sample size calculation was done by using online web based software OpenEpi. Version 3 developed by CDC. According to the study conducted by Wadhwan et al⁸ In their study, mean age for complete fusion in males and in females was 65.81 ± 10.68 years and 58.36 ± 5 years respectively. Two-sided significance was taken at 95% and power of the study was fixed at 80, minimum sample size obtained was 20 in each group. A total of 60 individuals from this region comprising both sexes in equal proportion between the age group of 31 to 45 years were taken. Samples were recruited by a simple random sampling method. Only cases whose exact age is available from birth records (date of birth certificate or Aadhar card) and who gave consent, were included in this study. Persons with any visible deformity to the anterior chest wall were not included in the study. Over-exposed or underexposed X-ray films were excluded from the study. People on hormonal therapy, having medical conditions impairing growth were also be excluded from the study. Radiological examination Cases those, written consent was obtained, were radiologically examined for the lateral view of the sternum with the exposure factors 20-25 mAs and 75-85 kVp for the fusion of the xiphi-sternal joint for determination of age. Fusion Status Fusion: Only the complete fusion of the Xiphoid process Statistical analysis Microsoft Excel (Windows 11; Version 365, Microsoft Corporation, New York, USA), was used to enter the data. Statistical Package for Social Sciences version 23.0 (SPSS

RESULTS

A Total of 30 consented individuals from each sex, in the age range of 31 to 45 years were included in the present study. The age range is further sub-classified into the age groups of 31-35 years, 36 - 40 years, and 41 - 45 years with 20 individuals from both sexes included in each group. The mean age for the males and females was 38.36 years and 38.4 years respectively. The status of xiphisternum fusion was determined as explained in the method. Cases were placed according to age group, separately for each sex, and the mean age for both fusion and non-fusion was calculated for each sex. To observe the proportion of fusion status in each sex cases were classified according to age groups. To observe the total number of fused and unfused cases against the age, a scatter plot was drawn. Cases with non-fusion of xiphisternum were clustered at early age group (31-35 years) and in later age group (41-45 years) cluster of fused cases were seen. The results of the status of xiphisternum fusion were cross tabulated with sex to obtain a p-value. All the cases showing fusion and non-fusion of the xiphisternum joint were analysed and the mean age for fusion and non-fusion of all the cases was calculated. In the present study, the earliest fusion of the xiphoid process with the body of sternum was observed at 31 years in male and at 32 years for female. Fusion of xiphoid process with body of the sternum seen latest at 44 years in males & at 40 years in females which are the latest fusion in our study.

DISCUSSION

Determining age holds significant importance in forensic settings in the deceased and also in the living. In cases involving the deceased, it primarily aids in identification by establishing a biological profile, which can then be compared to records of missing persons. For living individuals, the objective is to address legal or civil matters related to age.⁹ In the present study, 30 cases from each sex were included. A higher incidence of fusion was noted in females (66.6%) as compared to males (60%) in their group (n=30). A slightly lower mean age of fusion (40.05 ± 4.89 years) was noted in males as compared to females (40.95 ± 3.87 years). The observed mean age of non-fusion was less (33.30 ± 3.09 years) in females as compared to male (35.83 ± 3.38 years). The above findings suggest that the process of fusion took longer time in males as compared to females. Comparing the fusion status between sexes in all the age groups (Table 4), out of total cases (60), 5% of male showed fusion as compared to 3.3% of females in the 31-35 years age group. In the later age group fusion was observed more in females as compared to males. Fusion was observed in all the cases except one case of males, in the age group of 41-45 years. Of the total cases fusion was observed in 63.3% of cases, comprising 30% male and 33.3% female. The Chi-Square test did not reveal any statistically significant difference ($p > 0.005$) in the fusion of xiphisternum in males and females. A radiological study conducted by Reddy et al¹⁰ on 420 healthy individuals, comprising equally of males and females, in the age range of 25-60 years. They observed a lateral view of the sternum on X-ray. In their study mean age at which the fusion of the xiphoid process with the body of the sternum occurred was 40 years in males and 42 years in females. The findings of our study are also comparable to their study. An autopsy study was conducted by Kumar et al¹¹ on 100 cases (70 males and 30 females). The mean age of the complete fusion of the xiphoid process with the body of the sternum was observed as $50.83 \text{ years} \pm 1.641$ in males. The mean age range was higher ($58.58 \text{ years} \pm 2.831$) in the case of females in their study. The higher mean age of fusion compared to the present study could be explained by the fact that they have included 68 samples aged more than 40 years. The results of the present study were

inconsonance with their study where we also did not find any statistically significant difference in the age of fusion of the xiphoid process with the body of the sternum between males and females. A radiological study conducted in Delhi¹², observed complete fusion of the xiphoid process with the body of the sternum occurs after the mean age of 49.74 years in the case of males and 50.39 years in the case of females. A postmortem study on 100 cases conducted by Manoharan et al¹³ in Tamil Nadu observed an “absence of fusion between the xiphoid process and the body of the sternum below 32 years in males and, below 40 years in case of females.” They concluded that fusion of the xiphoid with the body occurs between 32 – 60 years regardless of sex. The present study also found similar observation where fusion was noted as early as 31 years for males and 32 years for females. The maximum age range in our study was up to 45 years thereby, the mean age of fusion of the xiphoid process was less in the present study as compared to other studies

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