Original Research Paper

Gross and Radiological Study of Fusion of the Sternebrae of Mesosternum for Determination of Age in Native Population of Haryana

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Abstract

Now a day, determination of age and sex of skeleton remains or of advanced decomposed body is an important task for the Forensic Expert to help in the investigation of concern case. It may arise in case of homicide, fire, explosion or mass disasters such as flood, earthquake, railway or aircraft accidents, etc. for determination of identity. In developing countries like India, because of illiteracy, ignorance regarding the age proof is much more. Importance of official records like birth and death, vast majority of population fail to give information of such vital events to the appropriate authorities entitled with these jobs. This causes paucity in such information when needed in a medico legal case. Sternum as a single bone can be used for age determination in young adult, middle age and old persons.

The present study has been conducted in the Department of Forensic Medicine and Radiology, Pt. B. D Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, with an attempt to study the mesosternum of sternum in the purview of existing parameters of the determination of age. It includes a study of fusion of sternebrae with each other in relation to age. A total of 200 Sternums of known age and sex (100 males and 100 females) of aged group 10-35 years, were collected from identified dead bodies that were brought to the Department of Forensic Medicine for post-mortem examination. The study was conducted by gross and radiological methods and finding were correlated by statistical methods. The study showed that the fusion of sternebrae of mesosternum occurs between 15-25 years, from below upward.

Keywords: Sternum, Mesosternum, Sternebrae, Gross and Radiological findings, Fusion.

Introduction

The age of the subject at death along with sex are the most important parameters and constitute vital indications of identity excluding a sizable portion of the population and narrowing down the field of investigation whether the context is bioarcheological, paleontological or forensic in nature. Determination of age at death from the
adult skeleton is one of the most important objectives of Forensic Medicine. Unless the age of a person is determined, the identity of a person, live or dead, stands incomplete.\cite{1}

Various studies have been done on estimating the age of an individual from the ends of long bones, clavicle, hip bone, etc. on a routine basis.\cite{2} However, age determination from other bones has proved useful, when the former are rendered unusable and incomplete due to natural or physical forces. Study of sternum as an individual parameter for determination of age and sex has been attempted by various workers. The first recorded study on the sternum for age determination is by Wenzel in 1788. He described the difference in the ratio between the length of manubrium and that of mesosternum in both sexes. It was followed by the studies of Fiegel (1837), Dwight (1890) and Ashley (1956).\cite{3}

The pioneers in the field of skeletal age determination, Todd and Stewart made it very clear that every bone has the potential to show the effects of age.\cite{4} In this regard, Sternum can chosen for age determination because it shows changes with the advancement of age.

Ossification of bones provides a very useful method of estimation of age in the living. These changes can be made out by X-rays and thus provide the medico-legal specialist with a very strong tool.\cite{5} Sternum as a single bone can be used for age determination in young adult, middle age and old persons. It becomes even more important when only the trunk of a person is available for age determination. Moreover, it can be removed easily during autopsy without causing any deformity in the dead body.

The stages of Radiological epiphysial closure were first described by McKern and Stewart in their study conducted in 1957, as used by Sangma et al.\cite{6} Another grading system has been used by Bhise et al which is the modification of above grading system, which is a more practical of the above grading system.-

**Stage I (F1): Non-union**- When epiphysial cartilage does not begin to decrease in thickness.

**Stage II (F2): Commencement of fusion**- 1/4th united with decreased thickness.

**Stage III (F3): Incomplete union**- ½ united with epiphysial and shaft fusion starting.

**Stage IV (F4): Complete union**- when the epiphysial cartilage is bony in architecture and its density is not distinguishable from epiphysis and diaphysis in the surrounding area, but epiphysial line (epiphysial scar) is visible.

**Stage V (F5): Complete union**, no scar line is visible.

The present study is an attempt to study the mesosternum of sternum in the purview of existing parameters of the determination of age. It includes a study of fusion of sternebrae with each other in relation to age.

**Material & Methods**

Place of study: - The present study was conducted in the Department of Forensic Medicine and Radiology, Pt. B. D Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak.

A total of 200 Sternums of known age and sex (100 males and 100 females) were collected from identified dead bodies that were brought to the Department of Forensic Medicine for post-mortem examination. The information of each case was recorded on a Proforma that included PMR number, sex, age, date of birth and gross & radiological findings. Informed consent was obtained from the nearest of the kin accompanying the dead body to the mortuary on a standard Consent Form.

The study was conducted on individuals aged between 10-35 years. Deceased with any congenital anomalies, partially destroyed, fractured, burnt, deformed or abnormal sternum were excluded from study.

**Examination**

After removal of sternum from the body, these were put in plastic jars containing solution of sodium-hypochloride and jars were labeled with the case details. These were kept for a week for maceration and cleaned and examined intermittently. After cleaning all the remains of
attached muscles and ligaments from the sterna, these were dried and examined grossly for degree of fusion by observing the separation of sternal elements. Thereafter, un-separated sterna were placed in labeled plastic pouches and taken to Radiology Department for X-ray examination. Each specimen was radiographed using Siemens Heliophos D 500 mA X-ray machine, with its inferior surface resting directly on the cassette, 100 cm from the X-ray source with an exposure of 42 kVp and 5 mAs. The cassettes were processed with digital AGFA CR System. Antero-posterior view of the bones were X-rayed to study fusion between segments of mesosternum. The films were examined for the presence of fusion between the segments of mesosternum. Thereafter, the mesosternum were cut vertically in midline for gross examination for fusion of sterna. Then, epiphysial closure of mesosternum were graded based on method used by Bhise et al.

### Observation & Results

**Table 1:** Distribution of subjects on basis of age and sex (n=200)

| Age Groups   | Female (n=100) | Male (n=100) | Total (n=200) |
|--------------|----------------|--------------|---------------|
| 10-15 years  | (n) (%)        | (n) (%)      | (n) (%)       |
| 16-20 years  | 20 (50.0%)     | 20 (50.0%)   | 40 (100%)     |
| 21-25 years  | 20 (50.0%)     | 20 (50.0%)   | 40 (100%)     |
| 26-30 years  | 20 (50.0%)     | 20 (50.0%)   | 40 (100%)     |
| 31-35 years  | 20 (50.0%)     | 20 (50.0%)   | 40 (100%)     |
| **Total**    | **100** 50.0% | **100** 50.0%| **200** 100%  |

The above table depicts the age and sex wise distribution of the mesosternii taken for study. Equal number of samples (n=20) were taken in the different age groups.

**Table 2:** Distribution of fusion of 1st and 2nd Sternebrae among males and females as observed by gross examination (n=200)

| Age Group    | Gender | 1st and 2nd Sternebrae | Total (n=200) | Significance* |
|--------------|--------|------------------------|---------------|--------------|
|              |        | No fusion | Complete fusion |               |              |
| 10-15 years  | Male   | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
|              | Female | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
| 16-20 years  | Male   | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
|              | Female | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
| 21-25 years  | Male   | 15 (75.0%)  | 5 (25.0%)      | 20 (100%)     | p=0.723      |
|              | Female | 14 (70.0%)  | 6 (30.0%)      | 20 (100%)     | p=1.000      |
| 26-30 years  | Male   | 0 (0.0%)    | 20 (100.0%)    | 20 (100%)     | p=1.000      |
|              | Female | 0 (0.0%)    | 20 (100.0%)    | 20 (100%)     | p=1.000      |
| 31-35 years  | Male   | 0 (0.0%)    | 20 (100.0%)    | 20 (100%)     | p=1.000      |
|              | Female | 0 (0.0%)    | 20 (100.0%)    | 20 (100%)     | p=1.000      |
| **Total**    |        | **109** 54.5% | **91** 45.5%   | **200** 100%  |              |

p-value > 0.05 is not statistically significant

*Chi-square test

**Table 3:** Distribution of fusion of 2nd and 3rd Sternebrae among males and females as observed by gross examination (n=200)

| Age Group    | Gender | 2nd and 3rd Sternebrae | Total (n=200) | Significance* |
|--------------|--------|------------------------|---------------|--------------|
|              |        | No fusion | Complete fusion |               |              |
| 10-15 years  | Male   | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
|              | Female | 20 (100.0%) | 0 (0.0%)       | 20 (100%)     | p=1.000      |
| 16-20 years  | Male   | 13 (65.0%)  | 7 (35.0%)      | 20 (100%)     | p=0.288      |
|              | Female | 16 (80.0%)  | 4 (20.0%)      | 20 (100%)     | p=1.000      |

Dr Avinash Kumar et al JMSCR Volume 07 Issue 05 May 2019
Table 4: Distribution of fusion of 3rd and 4th Sternebrae among males and females as observed by gross examination (n=200)

| Age Group | Gender | 3rd and 4th Sternebrae | Total (n=200) | Significance * |
|-----------|--------|------------------------|---------------|----------------|
|           |        | No fusion | Complete fusion |                |                |
| 10-15 years | Male   | 13 (65.0%) | 7 (35.0%) | 20 (100%) | p=0.519 |
|           | Female | 11 (55.0%) | 9 (45.0%) | 20 (100%) | p=1.000 |
| 16-20 years | Male   | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
|           | Female | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
| 21-25 years | Male   | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
|           | Female | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
| 26-30 years | Male   | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
|           | Female | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
| 31-35 years | Male   | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
|           | Female | 0 (0.0%) | 20 (100.0%) | 20 (100%) | p=1.000 |
| Total     |               | 24 (12.0%) | 176 (88.0%) | 200 (100%) | p-value > 0.05 is not statistically significant |

Table 5: Distribution of fusion of 1st and 2nd Sternebrae among males and females according to radiological findings (n=200)

| Age Group | Gender | 1st and 2nd Sternebrae | Total (n=200) | p-value* |
|-----------|--------|------------------------|---------------|----------|
|           |        | No fusion | Commence-ment of fusion | Incomplete fusion | Complete fusion |                |
| 10-15 years | Male   | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 1.000 |
|           | Female | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 1.000 |
| 16-20 years | Male   | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 0.727 |
|           | Female | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 1.000 |
| 21-25 years | Male   | 6 (30.0%) | 6 (30.0%) | 5 (25.0%) | 20 (100%) | 1.000 |
|           | Female | 12 (60.0%) | 12 (60.0%) | 12 (60.0%) | 20 (100%) | 1.000 |
| 26-30 years | Male   | 0 (0.0%) | 0 (0.0%) | 20 (100.0%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 20 (100.0%) | 20 (100%) | 1.000 |
| 30-35 years | Male   | 1 (5.0%) | 1 (5.0%) | 20 (100.0%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 20 (100.0%) | 20 (100%) | 1.000 |
| Total     |               | 9 (4.5%) | 13 (6.5%) | 91 (45.5%) | 200 (100%) | p-value > 0.05 is not statistically significant |

From the above tables (table no. 2, 3, 4), it is observed that, in males, the earliest complete fusion of 1st and 2nd sternebrae was seen in age group 21-25 years (6 out of 20 i.e 30.0%); 2nd and 3rd sternebrae in age group 16-20 years (4 out of 20 i.e 20.0%); 3rd and 4th sternebrae in age group 10-15 years (9 out of 20 i.e 45.0%). The difference of fusion of all sternebrae among males and females were found to statistically not significant.
Table 6: Distribution of fusion of 2<sup>nd</sup> and 3<sup>rd</sup> Sternebrae among males and females according to radiological findings (n=200)

| Age Group | Gender | 2<sup>nd</sup> and 3<sup>rd</sup> Sternebrae | Total (n= 200) | p-value* |
|-----------|--------|--------------------------------------------|----------------|----------|
|           |        | No fusion | Commencement of fusion | Incomplete fusion | Complete fusion |        |
| 10-15 years | Male   | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 1.000 |
|           | Female | 20 (100.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | \  |
| 16–20 years | Male   | 6 (30.0%) | 5 (25.0%) | 3 (15.0%) | 6 (30.0%) | 20 (100%) | 0.659 |
|           | Female | 9 (45.0%) | 5 (25.0%) | 3 (15.0%) | 5 (25.0%) | 20 (100%) | 1.000 |
| 21–25 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| 26–30 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| 31–35 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| Total     |        | 55 (27.5%) | 10 (5.0%) | 6 (3.0%) | 129 (64.5%) | 200 (100%) |      |

p-value > 0.05 is not statistically significant

*Chi-square test

Table 7: Distribution of fusion of 3<sup>rd</sup> and 4<sup>th</sup> Sternebrae among males and females according to radiological findings (n=200)

| Age Group | Gender | 3<sup>rd</sup> and 4<sup>th</sup> Sternebrae | Total (n= 200) | p-value* |
|-----------|--------|--------------------------------------------|----------------|----------|
|           |        | No fusion | Commencement of fusion | Incomplete fusion | Complete fusion |        |
| 10-15 years | Male   | 7 (35.0%) | 4 (20.0%) | 2 (10.0%) | 7 (35.0%) | 20 (100%) | 0.795 |
|           | Female | 5 (25.0%) | 5 (25.0%) | 1 (5.0%) | 9 (45.0%) | 20 (100%) | \  |
| 16–20 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| 21–25 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| 26–30 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| 31–35 years | Male   | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
|           | Female | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 20 (100%) | 20 (100%) | 1.000 |
| Total     |        | 12 (6.0%) | 9 (4.5%) | 3 (1.5%) | 176 (88.0%) | 200 (100%) |      |

p-value > 0.05 is not statistically significant

*Chi-square test

From the above table, (table no. 5, 6, 7), it is observed that, the earliest radiological complete fusion of 1<sup>st</sup> and 2<sup>nd</sup> sternebrae was seen in age group 21-25 years (5 out of 20 i.e 25.0 %, 6 out of 20 i.e 30.0 %) in males and females respectively; 2<sup>nd</sup> and 3<sup>rd</sup> sternebrae was seen in age group 16-20 years (6 out of 20 i.e 30.0 %, 3 out of 20 i.e 15.0 %) in males and females respectively and 3<sup>rd</sup> and 4<sup>th</sup> sternebrae was seen in age group 10-15 years (7 out of 20 i.e 35.0 %, 9 out of 20 i.e 45.0 %) in males and females respectively. Commencement of fusion of 1<sup>st</sup> and 2<sup>nd</sup> sternebrae was seen in age group 21-25 years (6 out of 20 i.e 30.0 % and 3 out of 20 i.e 15%) in males and females respectively; 2<sup>nd</sup> and 3<sup>rd</sup> sternebrae was seen in age group 16-20 years (5 out of 20 i.e 25.0% and 5 out of 20 i.e 25%) in males and females respectively and 3<sup>rd</sup> and 4<sup>th</sup> sternebrae was seen in age group 10-15 years (4 out of 20 i.e 20.0% and 5 out of 20 i.e 25%) in males and females respectively. Incomplete radiological fusion of 1<sup>st</sup> and 2<sup>nd</sup> sternebrae was seen in age group 21-25 years (6 out of 20 i.e 30.0% and 7 out of 20 i.e 35%) in males and females respectively; 2<sup>nd</sup> and 3<sup>rd</sup> sternebrae was seen in age group 16-20 years (3 out of 20 i.e 15.0% and 3 out of 20 i.e 15.0%) in males and females respectively; 3<sup>rd</sup> and 4<sup>th</sup> sternebrae was seen in age group 10-15 years (2 out of 20 i.e 10.0% and 1 out of 20 i.e 5.0%) in males and females respectively. The difference of fusion of all the sternebrae among males and females were found to statistically not significant.
The Kappa measure of agreement of fusion of 1st and 2nd sternebrae; 2nd and 3rd sternebrae; 3rd and 4th sternebrae, by gross examination and radiological findings was found to be 0.802, 0.834 and 0.725 respectively.

Discussion
There are considerable variations in ossification of bones in different regions of the same country. These characteristics are influenced by various factors like geographical location, climate, diet, heredity, socioeconomic status, habits, etc. especially in a multi ethnic country like India. Therefore, it is difficult to follow a single standard data for determination of age for the entire country.

Many workers around the world have done a lot of research on estimation of age based on the ossification of long bones. Age of an individual below 25 years can be opined to an age range of 2 years, though the findings get lesser as age progresses. For older individuals, however, age related findings on bones are fewer still. The use of the sternum for age estimation, however, is having greater promise as the changes encourages all ages. However, studies done on the fusion of the sternebrae of mesosternum are scarce.

Keeping the above in view, in the present study, the status of fusion sternebrae of mesosternum for determination of age in males and females of Haryana was studied and the results were compared with previous similar studies.

Table 8: Comparison of Status of Fusion of 1st & 2nd; 2nd & 3rd; 3rd & 4th Sternebrae of Mesosternum with Earlier Studies

| Study                     | Earliest Age of Fusion of Sternebrae of Mesosternum in years |
|---------------------------|---------------------------------------------------------------|
|                           | 1st & 2nd Sternebrae | 2nd & 3rd Sternebrae | 3rd & 4th Sternebrae |
|                           | Male | Female | Male | Female | Male | Female |
| Indian Studies            |      |        |      |        |      |        |
| Rai et al, 2013 (Punjab)  | 26-30| 26-30  | 21-25| 21-25  | 16-20| 16-20  |
| Kaneriya et al, 2013 (North west India) | 25   | 25     | 20   | 20     | 15-20| 15-20  |
| Tailor et al, 2013 (North West India) | 21-30| 21-30  | 11-20| 11-20  | 11-20| 11-20  |
| Manoharan et al, 2016 (South India) | 16-21| 16-21  | 16   | 16     | 14   | 14     |
| Foreign Studies           |      |        |      |        |      |        |
| Baker et al. 2005 (Texas) | 21-30| 20     | 21-30| 21-30  | 4-10 | 4-10   |
| Bayarogullari et al, 2014 (Turkey) | 21-30| 21-30  | 21-30| 21-30  | 21-30| 21-30  |
| Present Study (Haryana-2016) | 21-25| 21-25  | 16-20| 16-20  | 10-15| 10-15  |

The present study sample showed an earlier fusion gap of 5 years in earliest age of fusion of 1st and 2nd sternebrae; 2nd and 3rd sternebrae; 3rd and 4th sternebrae of mesosternum as compared to the study of Rai et al in a Punjab population sample, despite both sample being taken from the common population stock.

Table 11: Comparison of results of previous and present studies on fusion of sternebrae of Mesosternum

| Author                     | Fusion between sternebrae |
|----------------------------|---------------------------|
| Douglas J.A Kerr11         | 6th to 25 years           |
| Ashley14                   | At childhood, puberty and at 21 years |
| Girdany and Golden15       | 1st and 2nd between 12 to 25 years |
|                            | 3rd and 4th between 4 and 8 years |
| P.V. Guharaj16             | Between puberty and 25th years |
| Modi17                     | From below upwards between 14 and 25 years |
| Parikh C.K18               | From below upwards between 14 and 25 years |
| M.K.R. Krishan19           | From below upwards between 14 and 25 years |
| Krishan Vij20              | From below upwards between 14 and 25 years |
| Present Study (Haryana-2016) | From below upwards between 15 and 25 years |
**Photo 1:** Showing No fusion of all Sternebrae (Gross & Radiological)

**Photo 2:** Showing Complete fusion of 3\(^{rd}\) and 4\(^{th}\) Sternebrae and No fusion of 2\(^{nd}\) and 3\(^{rd}\), 1\(^{st}\) and 2\(^{nd}\) Sternebrae (Gross & Radiological)

**Photo 3:** Showing Complete fusion of 3\(^{rd}\) and 4\(^{th}\) Sternebrae, No fusion of 2\(^{nd}\) and 3\(^{rd}\), 1\(^{st}\) and 2\(^{nd}\) Sternebrae (Gross & Radiological)
Conclusion
The common age range for fusion of the sternabrae are as follows:

(i) $1^{st} - 2^{nd} = 21 - 25$ years  
(ii) $2^{nd} - 3^{rd} = 16 - 20$ years  
(iii) $3^{rd} - 4^{th} = 10 - 15$ years

The present study has attempted to provide a reference for age determination from the fusion of sternabrae of mesosternum for a population of Haryana. The fusion of sternabrae of mesosternum are independent of sex of individual.

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