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Original Article

Radiology Section

Computed Tomographic Analysis of Medial Clavicular Epiphyseal Fusion for Age Estimation in Western Indian Population: A Cross-sectional Study

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ABSTRACT

Introduction: Forensic age estimation is important in cases related to sexual assault, murder, skeletal remains, and juvenile crimes, where the age of the suspect or victim is unknown. The literature indicates that the age of fusion of the medial clavicular epiphyseal varies from region to region.

Aim: To estimate age from medial clavicular epiphyseal fusion through computed tomographic analysis.

Materials and Methods: This was a cross-sectional observational study with a sample size of 384, conducted over 24 months from January 2020 to December 2021 in the Department of Radiology at a tertiary care centre, Seth GS Medical College and KEM Hospital, Mumbai, Maharashtra, India. The study population included patients who underwent a Computed Tomography (CT) scan of the chest, aged between 18 and 35 years. They were arbitrarily divided into six age groups: 18-20 years, 21-23 years, 24-26 years, 27-29 years, 30-32 years, and 33-35 years. The Schmeling classification was used for age estimation. Chronological age served as the constant, while the stages of radiological fusion of the medial clavicular epiphyseal were the variables. Age estimation by this method involved observing the chronological age at a particular stage of fusion. The mean age of fusion at each stage was calculated. The association among variables was analysed using the Analysis of Variance (ANOVA) test for definite variables. In the present study, the level of significance was set at 0.05.

Results: Of the 384 participants (mean age 26.3±5.1 years; 217 men), 279 (72.7%) showed complete fusion of the medial epiphyses of the clavicle (stage 4 and stage 5). The mean age for medial clavicular epiphyseal fusion in men was 22.66±1.3 years, while for women it was 21.86±1.09 years. The mean age at which stage 5 was achieved was 29.6±3.37 years, indicated by complete fusion without the epiphyseal scar.

Conclusion: The study concludes that all men and women with complete fusion of the medial clavicular epiphyseal were older than 22.6 and 21.8 years of age, respectively.

Keywords: Age estimation, Computed tomography, Medial clavicular

INTRODUCTION

Determination of age is very important in forensic medicine, and it employs physical examination as well as radiological investigations. Radiological methods for age determination using the medial clavicular epiphyseal include radiography and Computed Tomography (CT). Although easily available, conventional radiography has certain limitations, such as the overlap of the medial clavicle by bony structures (the anterior end of the first rib and the posterior end of the second rib) as well as soft tissues (including normal tissues or lung apical pathologies) [1]. CT provides a three-dimensional representation of the anatomy, which overcomes the aforementioned limitations. It is also more sensitive in detecting subtle changes in the bones compared to radiographs. In terms of age estimation, CT offers better results than radiography [1]. Several studies have found that the estimated age differs between radiographic and CT analyses [2-4]. In addition, there are discrepancies in the age of maturation of the clavicular epiphyses between men and women [5-7].

A CT-based study on medial clavicular epiphyseal fusion has not been well established in the literature for the Western Indian population. Hence, the present study aims to estimate age from medial clavicular epiphyseal fusion through CT analysis.

MATERIALS AND METHODS

A cross-sectional observational study was conducted over a duration of 24 months (from January 2020 to December 2021) in the Department of Radiology at a tertiary care centre, Seth GS Medical College and KEM Hospital), Mumbai, Maharashtra,India. Approval was obtained from the institution's ethics committee before the commencement of the study (IEC number: 320/2021). Informed consent was obtained from all individual participants.

Inclusion and Exclusion criteria: All patients undergoing non contrast CT scans of the chest in the age group of 18 to 35 years for any medical or surgical illnesses were included in the study. Fractures involving the clavicle due to trauma or secondary to primary bone pathology were excluded from the study. Approximately 250-300 non contrast CT scans of the chest are performed in present institution each year. A sample size of 384 was selected for the study, considering the expected reduction in scans due to Coronavirus Disease-2019 (COVID-19).

Study Procedure

The study was performed on a 160-slice Multi Detector Computed Tomography (MDCT) scanner, the Aquilion Prime CT unit. All study-related data was collected during the patients' CT scans. Patients did not have to make additional visits solely for the purpose of the study. During the scan, patients were instructed to perform a proper breath-hold. A high-resolution, unenhanced CT of the chest with a slice thickness of 0.5 mm was performed. The scan covered a field of view from the thoracic inlet to the inferior extent of the diaphragm, encompassing the complete lung fields, using the following parameters: KV-120, effective mAs 250-790, time 0.35 sec, detector collimation 0.625 mm, slice thickness 0.5 mm,

matrix size 512×512, and section interval 0.5 mm. Tri-planar and three-dimensional evaluations of both medial clavicular epiphyses were performed.

The data was analysed by a consultant radiologist with 20 years of experience in cross-sectional imaging. Age estimation was conducted by observing the chronological age at a particular stage of fusion, and the mean age of fusion at each stage was calculated. The present study merely observed the age of fusion at each stage and serves as a reference for future studies involving a similar population.

The radiological staging of medial clavicular epiphyseal fusion was assessed using the Schmeling classification [4,8], as shown in [Table/Fig-1].

Stages	Radiological findings
Stage I	Ossification centre is not visible.
Stage II	Ossification centre is visible, but Epiphyseal cartilage is not ossified.
Stage III	Partial ossification of the Epiphyseal cartilage.
Stage IV	Complete ossification of Epiphyseal cartilage with visible Epiphyseal line.
Stage V	Complete ossification of Epiphyseal cartilage without visible Epiphyseal line.

[Table/Fig-1]: Schmeling radiological staging.

STATISTICAL ANALYSIS

Data were analysed using IBM Ststistical Packages of Social Sciences (SPSS) version 26.0, a statistical programme from the USA. Descriptive statistics, frequency, and percentage were employed in the study. The association among variables was analysed using the ANOVA test for definite variables. In the present study, the level of significance was set at 0.05.

RESULTS

Of the proposed sample size of 400, 10 participants denied consent. Three participants did not have any documentation stating their chronological age, and three participants had fractures of the clavicle. Thus, a sample size of 384 was derived. The age distribution of the study population (N=384) ranged from 18 to 35 years. They were arbitrarily divided into six groups: 18-20 years, 21-23 years, 24-26 years, 27-29 years, 30-32 years, and 33-35 years, as shown in [Table/Fig-2]. The distribution of the population among these age groups is also mentioned in the same table. The mean age for the study group was 26.30±5.14 years. Of the total participants, 43.5% were women and 56.5% were men.

Age (years)	Frequency n (%)		Total
	Men	Women	
18-20	36 (16.5%)	28 (16.76%)	64 (16.7%)
21-23	39 (17.97%)	29 (17.36%)	68 (17.7%)
24-26	38 (17.51%)	30 (17.96%)	68 (17.7%)
27-29	34 (15.67%)	27 (16.16%)	61 (15.9%)
30-32	37 (17.05%)	29 (17.36%)	66 (17.2%)
33-35	33 (15.20%)	24 (14.37%)	57 (14.8%)
Total	217 (56.5%)	167 (43.5%)	384 (100%)
Mean age±SD (years)	26.31±5.12		
Range	18-35 yrs		

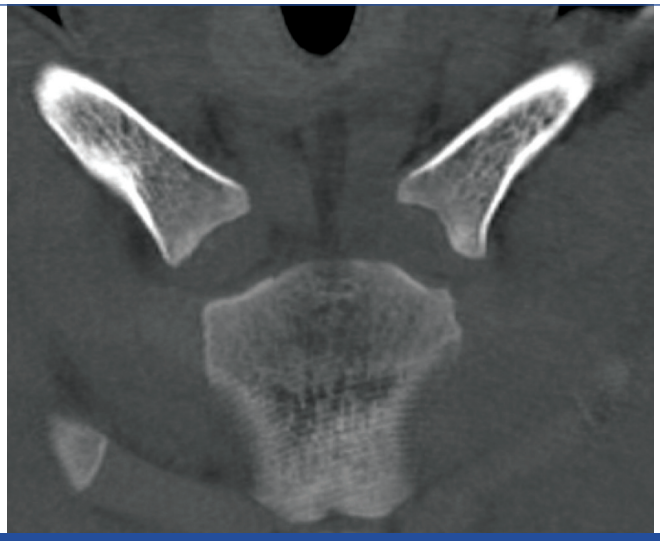
[Table/Fig-2]: Distribution of study subjects according to the age and gender (N=384).

The Schmeling classification [Table/Fig-2] was employed for the stages of fusion of the medial clavicular epiphyses. The stages of fusion according to the age distribution are listed in [Table/Fig-3] and depicted in [Table/Fig-4-8].

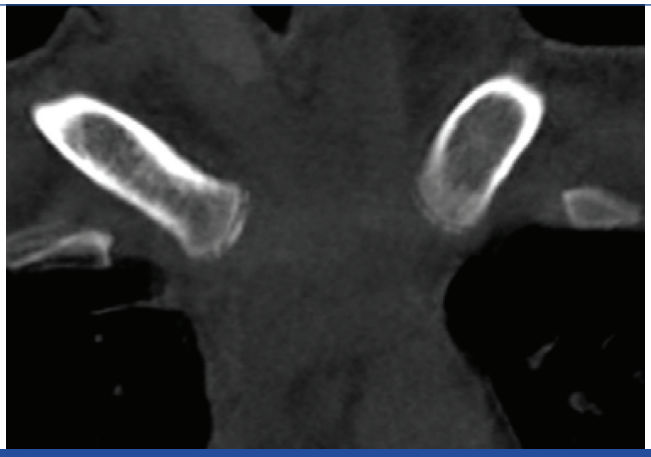
Complete fusion is indicated by stage IV ossification with an epiphyseal scar. The mean age for stage IV fusion was 22.6±1.31 years for men and 21.8±1.09 years for women, respectively. However, the difference in the mean age for fusion between men and women was statistically insignificant, with a p-value of 0.067.

Age (years)	Stage of fusion				
	I	II	III	IV	V
18-20	2 (3.1)	22 (34.4)	35 (54.7)	5 (7.8)	
21-23		6 (8.8)	32 (47.1)	28 (41.2)	2 (2.9)
24-26			6 (8.8)	10 (14.7)	52 (76.5)
27-29			1 (1.6)		60 (98.4)
30-32		1 (1.5)			65 (98.5)
33-35					57 (100.0)
Mean±SD	18.50±0.70	19.76±2.35	20.72±1.89	22.40±1.31	29.64±3.37
ANOVA, p-value <0.001, Significant					

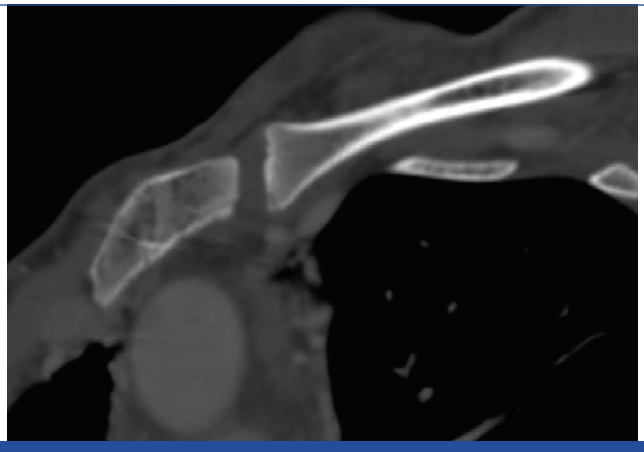
[Table/Fig-3]: Association between age and stage of fusion (N=384).



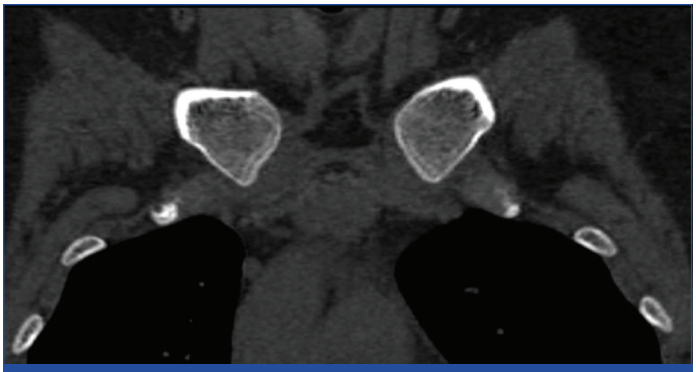
[Table/Fig-4]: Reformatted coronal non contrast CT image of an 18-year-old man shows stage I ossification of both medial clavicular epiphyses.



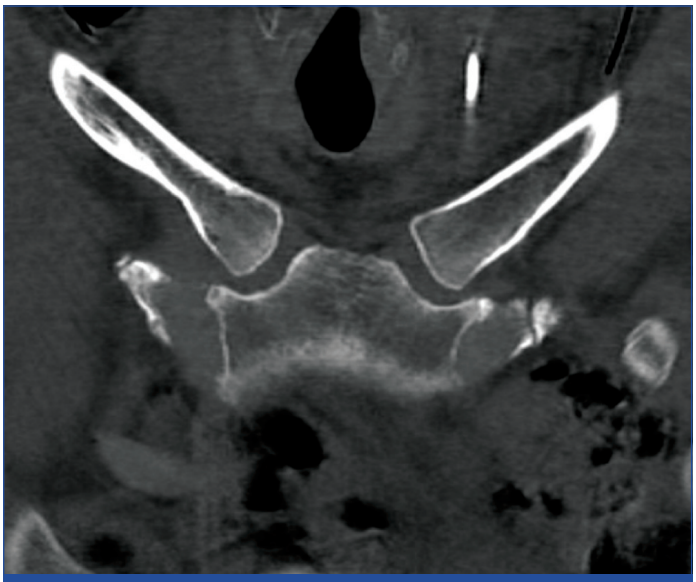
[Table/Fig-5]: Reformatted coronal non contrast CT image of a 20-year-old woman shows stage II ossification of both the medial clavicular epiphyses.



[Table/Fig-6]: Reformatted oblique non contrast CT image of a 23-year-old man shows stage III ossification of medial clavicular epiphyseal.



[Table/Fig-7]: Reformatted coronal non contrast CT image of a 22-year-old man shows stage IV ossification of medial clavicular epiphyses with a thin epiphyseal scar.



[Table/Fig-8]: Reformatted coronal non contrast CT image of a 30-year-old man shows stage V ossification of medial clavicular epiphyses without an epiphyseal scar.

Similarly, the mean age at which stage V is achieved is 29.6±3.37 years, indicated by complete fusion without an epiphyseal scar. A total of 279 participants (72.7%) showed complete fusion. The rest of the participants showed no or incomplete fusion (2 and 103, respectively).

The regression equation for males was 0.0213+0.1605×age, and for females, it was 0.0464+0.1605×age.

DISCUSSION

In the 20th century, the invention of the CT scan machine by Sir Godfrey Hounsfield provided new opportunities for researchers to study age estimation through CT scans. There are several disadvantages to using radiography, as visualisation of the medial end of the clavicle is very difficult due to overlap [9].

Radiological staging in the present study was done as per Schmeling classification [8], which is a widely accepted system [8,10-17]. Recent studies indicate that complete fusion of the epiphyseal cartilage (stages IV and V) occurs at an estimated age of ≥18 years [11-19]. In the present study, authors aim to determine the age at which complete fusion of the epiphyses, i.e., stage IV, occurs.

For stage III of ossification, the mean ages in men and women were 20.5 years and 20.84 years, respectively. Similar findings were noted by Schulz R et al., who reported ages of 20.9 years for men and 20.5 years for women, respectively [11]. Comparable results were noted by Kellinghaus M et al., and Zang K et al., [3,16].

In the present study, the mean age for stage IV ossification was 22.66 years for men and 21.86 years for women. Similar findings were reported by Zang K et al., [16]. Schulz D et al., noted the mean age as 23.76 years, which was quite similar to the present study [10].

Pattamapaspong N et al., found the mean age of fusion to be 25.3 years for men and 24.0 years for women, which was inconsistent with the present study [15]. Additionally, Schulz R et al., reported the mean age of fusion as 25.2 years for men and 25.1 years for women, which was also inconsistent [11]. Similar contradictory findings were reported by Kellinghaus M et al., [3]. These discrepancies may be attributed to factors such as socioeconomic level, ethnicity, and cultural patterns of the population affecting ossification. Shedge R et al., reported the mean age of stage IV fusion as 31.55 years for men and 30.69 years for women, respectively [20]. Although Shedge R et al., conducted their study in India, there is significant demographic diversity between the Rajasthan and Maharashtra regions of India. Furthermore, the present study used a slice thickness of 0.5 mm, compared to the 0.6 mm used by Shedge R et al., [20].

In line with the previous studies, there was no noteworthy difference in the age of fusion between men and women [7,9-11]. However, Ekizoglu O et al., found a significant difference between men and women for stages I and IV [17]. Although authors observed earlier ossification in women, this difference was not statistically significant. This may be attributable to the smaller number of women in the present study. The results of the present study are compared with those of similar previous studies and documented in [Table/Fig-9] [3,10,11,15,16,20].

Study	Total cases	Population	Gender	Stage I (mean±SD)	Stage II (mean±SD)	Stage III (mean±SD)	Stage IV (mean±SD)	Stage V (mean±SD)
Kellinghaus M et al., (2010) [3]	592	Germany	Men	13.28±1.74	17.81±1.37	21.73±0.26	29.63±4.16	31.77±2.74
			Women	12.70±1.69	16.28±1.59	21.14±2.14	28.21±4.21	30.88±3.20
Schulz R et al., (2005) [11]	629	Germany	Men	---	18.9±1.7	20.9±1.9	25.2±2.7	27.6±2.3
			Women	----	18.2±1.6	20.5±2.7	25.1±2.8	27.4±2.3
Schulz D et al., (2006) [10]	100	Germany	No sex separation	-----	17.59±2.09	19.50±2.22	23.76±1.45	------
Zang K et al., (2015) [16]	752	China	Men	15.59 ±0.70	17.12 ±1.19	21.57±2.31	23.70±1.66	----
			Women	15.99 ±0.86	17.30 ±1.30	21.47±2.13	23.77±1.31	----
Pattamapaspong N et al., (2015) [15]	409	Thailand	Men	13.7±1.3	-----	------	25.3±2.0	26.3±2.1
			Women	13.5±1.3	-----	------	24.0±3.0	26.8±1.5
Shedge R et al., (2020) [20]	400	India	Men	14.19 ±3.18	-----	----	31.55±2.69	32.14±3.83
			Women	13.40 ±2.75	-----	-----	30.69±3.93	33.79±2.91
Present study	384	India	Men	----	---	20.5±1.7	22.66±1.3	29.64±3.5
			Women	---	----	20.84±2.0	21.86±1.09	29.64±3.1

[Table/Fig-9]: Comparison of medial clavicular epiphyseal fusion by Computed Tomography (CT) in different studies [3, 10,11,15,16,20].

Limitation(s)

The present study has some limitations. First, the study population did not include participants below 18 years of age; therefore, earlier stages of fusion could not be reliably assessed. Second, the documentation of the chronological ages of the subjects is based on the hospital documentation system. Third, authors did not take into consideration the social and economic status of the subjects, which can influence bone maturation.

CONCLUSION(S)

In conclusion, CT assessment of medial clavicular epiphyseal fusion is vital for evaluating age. The chronological age of an individual can be estimated to be ≥22.6 and 21.8 years in men and women, respectively, when complete ossification is observed on CT.

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