Role of Computed Tomography in Age Estimation by Schmeling Method Using Analysis of Medial Clavicular Epiphysis

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ABSTRACT

Background: Age estimation has acquired significance due to its application in migration to various countries and legal purposes. It is a big problem in underdeveloped and developing countries, where original and genuine birth records are not available due to non-hospital births. Its application in juvenile courts for legal proceedings is very important. Application of x ray in age estimation is not much reliable in some circumstances. Schmeling method is more precise for age estimation with the help of thin slice CT scan images of medial clavicular epiphysis. **Objective:** The objective of this study was to use the CT scan images for establishing the relationship between ossification of medial clavicular epiphysis (radiological age) and age estimation (chronological age) of individuals. **Study Design:** Retrospective study. **Settings:** Department of Radiology, FJMU/Sir Ganga Ram Hospital, Lahore Pakistan. **Duration:** January 2022 to June 2022. **Methods:** Total 136 good quality CT scan images of patients were retrospectively assessed in this study, having age bracket of 10 to 40 years, including both males and females without any previous history of clavicular trauma or bony deformity. The included CT scans were HRCT Chest and CT Chest with contrast. CT scans of all those patients with known malignancy, post-surgical or post traumatic history of clavicle, taking immunosuppressants or radiation treatment were not enrolled in this study. **Results:** Out of total 136 patients, 66 (48.53%) were females and 70 (51.47%) were males. We found that at the age of 21 years, clavicular epiphyseal ossification stage shifts from 3rd to 4th schmeling stage. Mean age for stage 1 was 11 years for males and 10.5 years for females, for stage 2 was 14 years for both males and females, for stage 3 it was 18.9 years for males and 18.5 years for females, stage 4 was 24.4 years for males and 25.1 years for females and stage 5 was 33.21 years for males and 34.3 years for females. Maximum number of patients were in stage 4 (27.21 %) and 5 (39.71%). **Conclusion:** Considering results of our study, we concluded that an individual aged 21 years or above shows clavicular epiphyseal ossification stage 4 (schmeling), while an individual aged less than 21 years show clavicular ossification stage 3(schmeling). Therefore, application of thin slice CT scan images of medial clavicular epiphysis has utmost legal importance for the age estimation. We recommend computed tomography as an accurate and non-invasive imaging modality for age estimation by analysis of medial clavicular epiphysis, using schmeling method.

Keywords: Epiphysis, Schmeling, Computed tomography.

INTRODUCTION

In forensic medicine, immigration and criminal cases where the regulations differ for minors and majors, age estimation is crucial.[1,2] In addition, migration to various countries around the globe has increased in recent years[3]

and birth records are lacking due to non-hospital births in underdeveloped and developing countries.[4] Identification of people over the age of 18 is seriously important because it helps conclusively identifying victims of mass disasters and is having utmost

importance all over the globe for providing more authentic age estimation for the increasing number of unidentified people.[4] Furthermore judicial authorities request frequently for age estimation to determine the applicability of adult penal law[5] and for providing competitive advantage to athletes where opponent deliberately misrepresents his true age (age fabrication).

According to the 'Study Group on Forensic Age Diagnostics' recommendations, estimation of age must include clinical assessment and examination that documents anthropometric data, secondary sexual characters and age-related disorders of development, a left hand radiograph and a dental examination that analyses an orthopantomogram and records dentition status.[6] If the age of maturity is completed according to radiograph of hand, a further radiography or CT scan images of clavicle are advised for determination of individual's age for those who are at least 18 years old.[7]

Clavicle is the last bone to fully ossify in teenagers and the first bone to start ossification in the embryo. In contrast to the remainder of the clavicle, which ossifies by intramembranous method, the medial end of the clavicle grows through endochondral ossification.[8] This makes it a very helpful tool for determining the age of a living person or a dead body in order to evaluate if someone has achieved the age of legal responsibility, especially between the ages of sixteen and thirty. Different ways to determine age include 3rd molar tooth development, changes in pubic symphysis and other skeletal changes noted on wrist, elbow and clavicular radiograph where epiphyseal union has important role for age determination.[9]

Clavicle is a bone which remains well preserved in forensic context due to its resistance to environmental degradation. Four stage classification system was introduced by Krienter in 1998 who introduced CT scan for evaluating medial clavicular epiphysis regarding age estimation. Subsequent studies revealed that Schmeling method is more accurate for age estimation using thin slice Computed Tomographic images of medial clavicular epiphysis.[10]

In countries like Pakistan, where majority of population is aged 18 years or older and belongs to lower socioeconomic status, age estimation needs to be well established.[11] To date, majority of the available data regarding role of medial clavicular epiphysis for forensic age estimation is from European countries which have different demographic and socioeconomic characteristics, dietary habits, and environmental factors. That is why this study was planned to be carried out in our population. We believe that future research could expand the database on this topic and contribute to the already

available data in Pakistan. This study will use CT scan images to ascertain the relationship between chronological age and ossification of medial clavicular epiphysis.[12]

METHODS

This retrospective study was carried out in the Department of Radiology, FJMU/Sir Ganga Ram Hospital, Lahore, from January 2022 to June 2022. Sampling technique was non probability consecutive sampling.

Total 136 good quality CT scan images of patients having age bracket of 10 to 40 years, were retrospectively assessed in this study, including both males and females without any previous history of clavicular trauma or bony deformity. The included CT scans were CT Chest with contrast and HRCT Chest.

All those CT scans of patients with history of malignancy, surgical or post traumatic history of clavicle, taking immunosuppressants or radiation treatment were not enrolled in this study.

After getting approval from IRB, total 136 patient's (with the age bracket of 10-40 years), CT scan data was collected. Clear images with 1 mm thick slices, taken on CT chest or HRCT chest were thoroughly assessed to classify the schmeling stage of ossification of medial end of clavicle, in all patients to get the prime outcome and the most accurate age estimation feasible. A fixed window setting was not used since the ideal window level and width could vary case-by-case depending on many factors impacting CT exposure.[8] However osseous window was commonly and preferably used.

RESULTS

Table 1 shows the compiled data of HRCT and CT chest of total 136 patients among which 70 (51.47 %) were males and 66 (48.53%) were females. The collected data showed following stages of schmeling classification for clavicular epiphyseal ossification seen among different age groups. No major or significant difference in age was noticed considering two genders of patients. In addition, maximum number of patients presented in stage 4 and 5.

Table 2 shows that maximum number of patients were in stage 4 and stage 5.

Table No.3 shows some variations noted in schmeling stage noted in a few cases in addition to the stages of ossification seen among the following age groups.

All this data concludes that stage 3 can only be seen up to the age of 21 years in both genders while we did not see Stage 4 before the age of 20 years.

Table 1: compiled data of total 136 patients according to age group for each Schmeling stage

Schmeling stage	n=70 Male	Male (age range in years)	Male (mean age in years)	Standard Deviation SD	n=66 Female	Female (age range in years)	Female (mean age in years)	Standard Deviation SD
Stage 1	5	10-12	11	1.3	2	10-13	10.5	0.7
Stage 2	6	13-15	14	0	7	12-16	14	1.5
Stage 3	14	16-21	18.9	1.54	11	16-21	18.5	1.9
Stage 4	17	22-29	24.4	2.64	20	21-29	25.1	2.4
Stage 5	28	28-40	33.21	3.02	26	30-40	34.3	3.41

Table 2: percentage of each Schmeling stage in our data

Stage	Total patients	Percentage
Stage 1	7	5.14 %
Stage 2	13	9.56%
Stage 3	25	18.38%
Stage 4	37	27.21%
Stage 5	54	39.71%

Table 3: Variations noted in Schmeling stages

Age group	Male	Female
10	Stage 1	Stage1
11	Stage1	Stage1
12	Stage1	Stage2(1case)
13	Stage2	Stage2
14	Stage2	Stage2
15	Stage2	Stage2
16	Stage 3 (2case)	Stage3(1case)
17	Stage3	Stage3
18	Stage3	Stage3
19	Stage3	Stage3
20	Stage3	Stage3
21	Stage3	Stage3
22	Stage4	Stage4(1case)
23	Stage4	Stage4
24	Stage4	Stage4
25	Stage4	Stage4
26	Stage4	Stage4
27	Stage4	Stage4
28	Stage 5 (1case)	Stage4
29	Stage4(1case)	Stage4(1case)
30	Stage5	Stage5(3case)
31	Stage5	Stage5
32	Stage5	Stage5
33	Stage5	Stage5
34	Stage5	Stage5
35	Stage5	Stage5
36	Stage5	Stage5
37	Stage5	Stage5
38	Stage5	Stage5
39	Stage5	Stage5
40	Stage5	Stage5

DISCUSSION

When assessing an individual's age, particularly when determining whether they are under or above the legal age of 21, the biological structure known as the clavicle has been utilized to verify the age of majority.[13]

The researchers found that the individuals' socioeconomic status, imaging modalities, and raters all contribute to some staging variation.[14]

Rarely has the grade of ossification at the medial clavicle's epiphyseal cartilage been investigated as a tool for forensic reasons. We have attempted to demonstrate the significance of this indicator in the forensic calculation of chronological age in our settings.

Determining the minimal age at which ossification of the epiphyseal cartilage of medial end of clavicle is complete is most important issue in forensic practice from a medicolegal perspective. To avoid incorrect findings, age estimation methods that exhibit overestimation beyond the permissible range should not be used in forensic applications. In this situation, applying adult criminal law and subjecting the defendant to a harsher penalty could be a result of an overestimation in age diagnosis. It is important to note that age estimation techniques, like the ones we utilized in our study, are constantly being scientifically reviewed in various populations. This guarantees that age estimation techniques are accurate in forensic and therapeutic settings and are based on current scientific understanding.[15,16,17]

The underlying study's design is based on a group of patients who had treatment at the hospital affiliated with the university throughout the designated time period and were of a known age.

Schmeling system of classification for medial clavicular ossification:

Stage 1: ossification centre not visible (not ossified)

Stage 2: ossification centre visible (ossified) but epiphyseal cartilage is not ossified.

Stage 3: epiphyseal cartilage partly ossified.

Stage 4: epiphyseal cartilage fully ossified, epiphyseal scar visible.

Stage 5: epiphyseal cartilage fully ossified without visible epiphyseal scar.

Figure 1: all 5 (A, B, C, D, E) schmeling stages of medial clavicular epiphyseal ossification depicted by HRCT images.
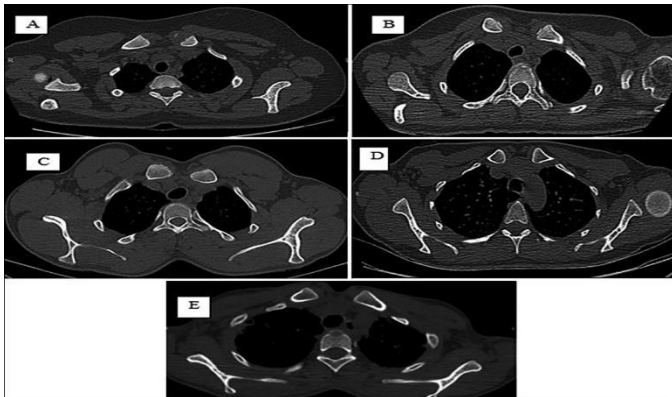
In our study, for both males and females, stage 3 could only be seen up to the age of 21 years. Stage 4 was not seen before the age of 20 years. It appeared at 22-29 years of age in male population and 21-29 years in female population as per observation of our data. On the other hand, complete union of stage 5 did not start before 20 years.

A similar study by Pattamapaspong *et al*,[8] mentioned stage 1 of medial clavicular epiphyseal ossification at 11-16 years for males and females, stage 2 at 14-21 years for males & 12-19 for females, stage 3 appeared in males (15-27 years) and in females (16 to 26 years). While stage 4 in males at 17 -26 years and in females 19-28 years. And in stage 5, the age was 20 to 29 years for men and 23 to 29 years for women.

According to Kreitner *et al*,[18] 4 stage classification method, stage 3 was documented to be found at $16-26$ years, while stage 4 was at $22-29$ years.

According to Kellinghaus *et al*,[19] stage 1 appeared between 10 to 15 years for both genders, stage 2 at 14 to 20 years, in men and at 13-19 years in women, stage 3 at 17 to 26 years in men and 16 to 26 years in women, stage 4 between the ages of 21 and 35 for both sexes, and stage 5 between the ages of 26 and 35 for both genders.

In a study done by Bassed *et al*,[4] in men and women, stage 1 noted between the ages of 13 to 20 and 14 to 18 years respectively. Stage 2 appeared between the ages of 14 and 22 and 14 and 20 years respectively. Stage 3 appeared between the ages of 16 and 23 years in both genders. While Stage 4 appeared between the ages of 18 and 26 years in both genders. Stage 5 appeared between the ages of 20 and 26 in men and 21–26 years in women.

Kreitner *et al*,[18] stated that the differences in ossification ages between our study and previous studies could be explained by the influence of genetics, socioeconomic levels, diet and environmental factors.

CONCLUSION

Our study found that socioeconomic factors may have a role in the disparities in ossification ages between males and females. Due to inadequate nutrition, participants from lower socioeconomic backgrounds typically experience delayed epiphyseal fusion as compared to subjects from higher socioeconomic backgrounds. Computed tomography of medial clavicular epiphysis can therefore provide an extremely useful tool in age estimation of individuals. This improvement in age documentation can help to reduce disparities in age assessment and minimize the burden on legal system in future.

LIMITATIONS

The only limitation noticed in our study was that the study was single center based.

SUGGESTIONS / RECOMMENDATIONS

We recommend high resolution CT and thin slice CT chest for accurate age estimation using analysis of medial clavicular epiphyseal ossification by schmeling classification method.

CONFLICT OF INTEREST / DISCLOSURE

Authors declare no competing interest among them.

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