INTRODUCTION

Legally, age can be calculated from the date of birth registered in the form of a birth certificate which is a vital written record that documents birth of a child. Estimation of the age of person is a problem that forensic experts come across in both living and dead. Importance of age estimation in living beings can be gauged from the fact that from school-going age to marriage age, from employment security to getting civil rights like property inheritance, age becomes a crucial and deciding factor. It is an essential component in establishing the identity of an individual in insurance claims, pension, marriage disputes, disputed gender, and in case of missing persons. Similarly, when it comes to the criminal responsibility of an individual, age determination becomes a vital issue like in cases of assault, rape, murder, impersonation, and exemption of punishment in criminal cases. In dead individuals, identification has to be established in cases of homicide, unclaimed unidentified dead people, mass disasters, decomposed bodies and recovery of mutilated fragmentary remains. In Pakistan, when inquired, age is told usually on guess work; and sometimes for vested interests, over and under age is recorded on the official documents. As a result, no reliance can be placed on the statement of record of an individual. When precisely needed, the only answer is the medical parameter.

Starting from 2008 to mid-2010, fighting between Pakistan’s Armed Forces and militant groups had led to internal displacement of more than 27.1 million people. The speed and scale of Pakistan’s population displacement is ranked sixth in the world. In this situation of crisis, there is a high failure rate of birth and death registration.

This study will provide data for reference to be used for estimation and certification of 21 years of age, using ossification of medial end of clavicle by radiological method.

The main objective of the study was to determine mean age of complete fusion of medial end of clavicle by radiography in healthy subjects of Karachi.

ORIGINAL ARTICLE

Radiological Mean Age of Fusion of Medial End of the Clavicle: A Parameter of Age

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ABSTRACT

Objective: To determine the mean age of fusion of medial end of clavicle by radiography.

Study Design: Cross-sectional study.

Place and Duration of Study: Departments of Forensic Medicine, Dow Medical College and Ziauddin University, Karachi, from June 2010 to May 2011.

Methodology: The subjects for this study were selected from various government colleges of Karachi. The subjects were analyzed for age and further confirmation was done by interviews where birth records and other physical parameters of age were also assessed. X-rays chest PA view was taken focusing on the medial end of clavicle; and were examined by a consultant radiologist and complete fusion of the medial end was noted. P-value less than 0.05 was considered significant.

Results: The mean age of fusion of medial end of the clavicle was found to be 21 ±1.43 years. Significant difference was observed in male to female age of fusion 21.14 ±1.41 years versus 20.65 ±1.94 years (p > 0.05). Similarly, statistically significant differences were observed between lower to middle income class and higher income class of all society. No difference was observed among various ethnic groups.

Conclusion: Socio-economic factors, such as diet and nutrition, directly affect bone growth and hence bones’ age. The results of fusion of the medial end of the clavicle are not affected by ethnicity; however, it is significantly affected by gender. More studies should be conducted in various parts of the country to make a natural standard in setting up uniform criteria for assessing age at or above 21 years.


INTRODUCTION

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METHODOLOGY

This was a cross-sectional study conducted from June 2010 to May 2011. The subjects for this study were selected from various colleges of Karachi run by Sindh Government and City District Government, Karachi and Dow Medical College, who had confirmed dates of birth from their matriculation certificates. The subjects were analyzed for age at the Department of Forensic Medicine, Dow Medical College, where further confirmation was done by interviews where birth records and other physical parameters of age were also assessed. Oral informed consent was taken from all subjects prior to integration in the study. All the data was recorded in pre-designed proforma by arrangements with Department of Radiology, Dow University of Health Sciences, located at Civil Hospital, Karachi. X-rays chest PA view were taken by focusing on the medial end of clavicle at 100 KV.

Six hundred and seventeen healthy subjects, residents of Karachi city, of various ethnicities, were selected using simple random sampling by statistical software EPI-Info version 6.0. The subjects selected for this study were taken age reference being Kreitner et al. The mean age of fusion of clavicle was 21.0 ±1.43 years. The mean age of fusion of clavicle was observed higher in male (21.14 ±1.41 years) as compared to the female (20.65 ±1.94 years, Table II). A significant difference was observed between mean age of fusion of clavicle for gender, i.e. male and female (p < 0.001).

The break-up in various ethnicities is given in Table II. There was no statistically significant difference seen between the mean age of the fusion of clavicle. Association of different categorical variables, including gender, ethnicity, and SES with fusion of clavicle, was determined by chi-square test, which was found to be statistically insignificant (p=0.396). The difference between the mean ages of fusion of clavicle was statistically significant for different SES (Figure 1).

RESULTS

Out of 624 subjects included in this study, 66.5% were male. Most of the subjects were Punjabi (29.6%), and Urdu speaking (28.2%). Majority (55.4%) belonged to the middle income group. In 43.4%, the clavicle was fused whereas in remaining 56.6%, it as non-fused (Table I).

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Table I: Frequency of gender, ethnicity, socioeconomic status, and radiological findings.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Frequency (n)</th>
<th>Percentages (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>415</td>
<td>66.5</td>
</tr>
<tr>
<td>Female</td>
<td>209</td>
<td>33.5</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sindhi</td>
<td>106</td>
<td>17.0</td>
</tr>
<tr>
<td>Balochi</td>
<td>61</td>
<td>9.8</td>
</tr>
<tr>
<td>Punjabi</td>
<td>185</td>
<td>29.6</td>
</tr>
<tr>
<td>Pathan</td>
<td>96</td>
<td>15.4</td>
</tr>
<tr>
<td>Urdu Speaking</td>
<td>176</td>
<td>28.2</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>99</td>
<td>15.9</td>
</tr>
<tr>
<td>Middle</td>
<td>346</td>
<td>55.4</td>
</tr>
<tr>
<td>Upper</td>
<td>179</td>
<td>28.7</td>
</tr>
<tr>
<td>Radiological findings</td>
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<td></td>
</tr>
<tr>
<td>Fused</td>
<td>271</td>
<td>43.4</td>
</tr>
<tr>
<td>Non-fused</td>
<td>353</td>
<td>56.6</td>
</tr>
</tbody>
</table>
The result of the binary logistic regression analysis for association of age and fusion of clavicle is shown in Table III. The probability of clavicle being fused was more for age 20 - 24 years as compared to age 19 years.

**DISCUSSION**

In medico-legal cases, skeletal age is regarded as most convincing estimate of age. This is of prime importance in establishing criminal liability, especially in developing countries where birth records are lacking and not properly maintained. Up to the age of 18 years, hand skeleton is considered most reliable indicator of skeletal development. Skeletal age is assessed by three methods. The Atlas method is an approach by comparing radiograph of hand with that of an Atlas information to assess age. The bone-by-bone method - an approach where specific bone age is assigned to each bone and average age of bone to be examined is compared; and lastly from ossification tables, which are applied when skeletal regions are to be investigated at one time.

The Atlas method developed by Greulich and Pyle (GP) is the most common method of assessing skeletal maturity and age. The applicability of this Atlas across varying genetic profiles, socio-economic statuses, environmental milieus and disease patterns, were criticized by number of researchers. In a study based on children living in Karachi, Pakistan, there was significant difference in skeletal age assessed by GP Atlas and chronological age. In a similar study in Larkana, Pakistan, similar pattern was found indicating skeletal maturation in Pakistani children, does not conform to standards of GP Atlas.

In 1997 - 1998, Kreitner et al. were the first persons who classified the ossification of medial end of clavicle into four stages. This classification was applicable to the anatomical as well as radiological objectives of the subjects. In 2004, Schmeling defined fifth stage in ossification of medial end of clavicle. The need to define and specify stage V is clearly in context of criminal investigation. When stage V is observed in an individual, it is assured that subject under consideration has attained the age of 21 years at least 5 years prior to examination, and 18 years in age, 8 years prior to examination. However, for simplification in this study, cost effectiveness and keeping in view the diagnostic facilities in Pakistan, we divided stages of ossification of medial clavicular epiphysis, as defined by Kreitner et al., into two stages based on radiological assessment i.e., non-fused and fused.

Various studies have been conducted throughout the globe by various researchers for determination of ossification of medial clavicular epiphysis, using different sample sizes, gender, ethnic groups, methods, and they found different results. As the sample size, ethnic groups were different, their conclusion varied from 19 - 23 years. Whereas, it is 21 ±1.43 years in the present study conducted on medial clavicular epiphysis on the subjects of Karachi. In 1997, Kreitner et al. studied the time-frame of fusion of medial clavicular epiphysis in European population taking 380 subjects. Onset of fusion of medial end of clavicle was seen at 22 years of age and complete union was seen at 27 years. The last study was done by Bassed et al. in 2011 on Austrian population, assessing medial end of clavicle using computed tomography scan. This study revealed fusion of medial end of clavicle at 21 years of age.

Kreitner et al. put forward the theory that radiology can detect incipient ossification better than autopsy, but the problem with radiological method is superimposition of shadows of ribs, vertebrae and mediastinum on different body regions. Webb and Suchey studied the
Radiological mean age of fusion of medial end of the clavicle: a parameter of age

medial clavicular epiphysis ossification on anatomical preparations and mean age of fusion was found to be 21 years.\textsuperscript{10} The reason for this earlier fusion in anatomical preparations was due to the fact that naked eye assessment may discern cartilage growth over a longer period than as compared to radiological assessment. Some researchers lay stress on establishment of radiation-free imaging techniques for assessment of clavicular ossification in order to reduce the radiation exposure in medico-legal age estimations. Some researchers studied ossification of medial clavicular epiphysis through ultrasonographic technique and magnetic resonance imaging.\textsuperscript{11,12} The age interval observed for ossification stages are consistent with the known data from radiological and computed tomographic assessments. Computed tomography examinations for assessing age from ossification of medial clavicular epiphysis are now considered to be the gold standard.\textsuperscript{4} When computed tomography (CT) results are compared with conventional radiography, it was reported that in only 2 cases out of 99 cases, the results were different. It was concluded that in age estimation practice, it is necessary to use conventional radiographic reference studies for the ossification stage classification by conventional radiography and CT reference studies for ossification stage classification by CT. Another important aspect by CT methodology is that to gain maximum accuracy in results, the slice thickness should not be more than 1 mm.\textsuperscript{4} CT is definitely more superior technology because of its higher spatial resolution; but disadvantage of CT is that it has higher radiation dose.

In Pakistan, medico-legal age assessment is done at the district health centre level, where facilities of ultrasonography, MRI and CT scan are not available. However, conventional X-rays can be done even at this level. A standard is required which can be utilized at every level of health facility. Further, CT scan, MRI and ultrasonography of any given area require specialized expertise to interpret the findings. The choice of radiography in this study is to establish a standard that can be evenly utilized by a medical man throughout Pakistan.

Studies from the West have shown that ethnic origin does not have a notable influence on the pace of skeletal development.\textsuperscript{13} This applied to the Pakistani ethnic groups as well, as shown in this study.

The mean age of fusion of clavicle was significantly higher in males (21.14 ±1.41 years) as compared to the females (20.65 ±1.94 years). Although this is in agreement with the generally acceptable patterns of earlier fusion in females,\textsuperscript{8} it is in disagreement with the difference of about 2 years as given by various authors across the globe.\textsuperscript{14,15}

The difference between the mean ages of fusion of clavicle was statistically significant for different socio-economic status as seen in Figure 1 (p < 0.001). The most important factors in this respect are malnutrition, which delays skeletal maturation. Human Development Index (HDI) is a comparative measure of life expectancy, literacy, education and standard of living for countries worldwide. It is a standard means of measuring wellbeing. It is used to distinguish whether the country is developed, developing or an under-developed country and also to measure the impact of economic policies on quality of life. Pakistan stands on 7th in low human development and 125th among 169 countries on the UN's 2010 HDI.\textsuperscript{16} HDI is a new and modified index to depict the socio-economic status of an individual in a country. A higher HDI means higher socio-economic status and increases the probability of having mature clavicles; and low socio-economic status generally delays fusion of medial end of clavicle. This finding is in conformity with other studies all over the world, i.e. lower socio-economic status leads to delay in bone and skeletal age development.\textsuperscript{4,8,13,15}

The results in the present study show that standards formulated for fusion of medial clavicular epiphysis by foreign researches are not applicable to Pakistani nationals. The factors which influence skeletal maturity and time-frame of ossification of clavicle must be taken into account while assessing age in medico-legal cases. Forensic Age Diagnostics recommended combining physical examination with X-ray of left hand, dentition status, dental X-ray, and X-ray examination of medial end of clavicle.\textsuperscript{8} When interpreting the results, the guidelines recommend that data from the above tests should be compared with reference studies relevant to the specific individual in question. They finally recommend that when the final expert assessment has been made, the results of each of the tests performed should be recorded separately and that the age estimated should be identified as the most probable and specifying the degree of probability of each estimated result.\textsuperscript{17}

The factors which must be taken into account are socio-economic factors as bones of people having poorer socio-economic and nutritional status tend to fuse later.\textsuperscript{18} If the nutritional deficiency becomes extreme, skeletal maturation is delayed;\textsuperscript{13} and geography and climate, as subjects in warmer climates tend to have earlier fusion of the bones.\textsuperscript{19}

In addition a trend for earlier fusion over the past few decades has been reported,\textsuperscript{20} which could be up to 0.22 - 0.66 years/decade from the 1960's to the 1990's.\textsuperscript{21}

In addition to the above factors, it has been reported that within the same socio-economic group, obese subjects tend to mature earlier in respect to the skeleton compared to underweight children.\textsuperscript{22} Those having earlier sexual maturity have earlier fusion of bones.\textsuperscript{21}
and small for date infants have delayed skeletal maturation.21

CONCLUSION

Based on the results of this study, it is concluded that mean age of fusion of medial end of clavicle is 21 ±1.43 years in the studied population of Karachi. There was a difference in time-frame of ossification of clavicle in both genders. The onset of fusion was 1 - 1.5 years earlier in females than males. The inter-ethnic differences play no role whatsoever in the time-frame of ossification of the clavicle. Factors like diet, socio-economic status and nutritional status play an important role in skeletal maturation and should always be taken into account while doing age estimations in criminal proceedings.

REFERENCES
