Introduction

The need of accurate technique for age estimation has increased in the recent times, due to increase in the number of unidentified cadavers, human remains and number of cases requiring age estimation in case of living, with no valid proof of date of birth. Age determination is one of the basic requirements in personal identification of cadavers, human remains and living individuals, which plays an important role in clarifying the issues concerning legal and social ramifications for individual as well as for the community. Deaths have major economic and financial ramifications for relatives arising from issues of inheritance and insurance. Age estimation is one of the standard requests made by police and judicial authorities upon the discovery of a dead body. Age is a primary and crucial factor for preliminary screening procedure, whenever unidentified human remains/skeletal parts are required to match against hundreds of missing individuals (Ritze-Timme et al., 2000).

Ageing from various skeletal parts is very well documented in the published literature, but little work is found in scientific literature about the age estimation in case of living. Age criterion in case of living plays an important role in solving some of the problems, regarding criminal aspect at different age group, but the reference data found in this regard is scanty. There is requirement of population specific analysis and updating in old population standards for new generation, especially in developing countries like India, where birth records are not often well maintained and socio-economic status is also continuously changing with medical and social modernization all over the world. The age criterion, in case of living individuals is a critical aspect in forensic context. It is mainly required for the purpose of criminal and civil aspects, like juvenile status for criminal
responsibility, sports categorization, voting rights, driving license, marriageable age, adoption, old age pension and asylum proceedings.

Currently, many individual techniques are developed from a variety of approaches and the source material of varied complexity is also available to assist the professionals in this endeavor. But, comprehensive approaches of age estimation, using multiple age indicators are found to be relatively superior as compared to the individual one (Baccino et al., 1999). Parameters of skeletal age estimation at death vary greatly in successive development phases of life from infancy to adulthood. A number of indicators are available to estimate the age in young people, right from childhood to early adult period, but aging becomes less accurate with increasing years (Scheuer, 2002). A number of criteria are employed varying in value at different ages. Dentition, ossification centers and epiphyseal union yield reliable information on age up to 25 years (Krogman and Iscan, 1986). Above 25 years, age can be estimated by state of cranial sutures, bony surface of symphysis pubis and other features typical of ages (Mckern and Stewart, 1957), like osteophytes, cortical thickness of long bones (clavicle). Cortical index of paired clavicle obtained from medicolegal postmortem subjects (128 male and 82 females), falling in of age range of 15-85 years was studied by Kaur and Jit (1990) for estimating age. These, age specific features are very reliable methods for skeletal age estimation after maturity. Sequence of age related changes in some bones like sternum, ribs, clavicle, scapula, bones of foot and hand, pelvis and other long bones like femur are well described in the published literature. Clavicle and sternum are relatively less studied and only a few records are available.

The age thresholds of relevance to criminal prosecution in some countries lie between 14 to 21 years (Schmeling et al., 2005), which is 12 years (for girls in Manipur only, Section 375 of I.P.C.) to 21 years in India. The dynamic nature of human skeletal variation is the main reason of using modern skeletal samples to develop forensic standards
for age estimation. Accelerated maturation in terms of menarcheal age and pubertal onset has been documented in the recent literature. Acceleration in pubertal onset may be indicative of acceleration in skeletal maturation, as sexual maturation is closely related to skeletal maturation, (Maresh, 1972). This recent documentation of changes in the length of long bones and cranial dimensions is the reason of using modern skeletal samples to develop new forensic standards (Meadows and Jantz, 1995; Jantz and Jantz, 1999, 2000; Jantz, 2001; Jantz and Wescott, 2002). The standards of development analysis should always be updated for the new generation, so that the errors in applying the old population specific standards to the new generation could be minimized or eliminated.

According to the updated recommendations of the ‘Study Group on Forensic Age Diagnostics’ for criminal proceedings in order to increase the accuracy of age estimation process, the basic examination should include the combination of a physical examination with X-ray examination of the left hand, a dental examination for dentition status and the evaluation of orthopantomogram. If bone development of hand has been completed, an additional radiological examination of the clavicles by means of conventional radiography or computed tomography should be carried out in order to demonstrate that the suspect has reached the age of 21 years (Schmeling et al., 2008).

The ossification of sternal end of clavicle is documented between 18 to 25 years of age in most of the literature published in national as well as international journals. Thus, it is of paramount importance to correlate age in this particular age group with the clavicular ossification, as it acts as supporting parameter in establishing the age of an individual above age of 21 years (criminal liability threshold age). It becomes essential requirement particularly at this age for two reasons. One is, hand and wrist allows age diagnostic up to
the age of 18 years, as development ends by this age and the second is, mineralization of
the roots of the wisdom teeth is finished at the age of 21 years (Klaus and Claus, 2005).

The present work has been carried out to study the ossification stages of medial
Clavicular epiphyseal ossification, as revealed by computed tomography and to correlate
the different ossification stages with age of the subjects in both males as well as females.
The stages are also analyzed using digital X-rays (along with CT in some subjects) in few
cases to discuss about the interpretation problems, to compare the ossification status found
with CT and Digital X-ray and the reasons of disagreements found in the results. Merits
and demerits of one modality over the other have also been discussed and it has been
practically shown in the study, why CT should be the modality of choice to study
clavicular ossification stages.

The study has been completed after standardizing all parameters. The correlation of
age with ossification status of bilateral medial clavicular epiphyses was found for both
males and females. The age intervals corresponding to different ossification stages were
also compared for both the sexes in north Indian population. Bilateral asymmetry in the
ossification status was also recorded in case of both males and females. The computed
tomography of all the subjects included in the study have been performed on 16-slice,
Multi-detector row CT (MDCT) scan machine, that provides short examination time
facilitating acquisition of whole data in single breath hold avoiding respiratory motion
artifacts.

The ossification stages were also analyzed at different slice thickness in CT, so as
to prove that the slice thickness has crucial impact on the evaluation of ossification status
and to find what should be the ideal slice thickness to achieve maximum accuracy in the
results keeping in view the relationship between the quality of CT image and the radiation
dose distributed to the patient.

It has also been discussed in the study, how the quality of image and the dose
delivered to the subject in computed tomography are related to each other. There is a
complex relationship between radiation dose imparted to the subject and image quality in
CT. The quality being analyzed in three components--- spatial resolution, contrast and
noise, depends on the technical factors selected for scanning procedure i.e. kVp, mAs and
Pitch in spiral CT. These factors are to be selected, so as to get images of optimal quality,
but dose is kept to the minimum. It is a trade off of image quality and radiation dose, CT
scan of a number of subjects were also acquired by using one of the most effective dose
reduction technique i.e. employment of Automatic Exposure Control(AEC) technique in
CT protocol, to determine the minimum dose required for optimum quality of the scan. A
relationship between the dose delivered and BMI (Body Mass Index) of the subject was
studied.