Summary and Conclusion

I. Radiological study on clavicle for age estimation

The ossification status of medial clavicular epiphysis has been retrospectively analyzed in the present research work. An equal number (250 each) of male and female subjects falling in the age group of 12 to 30 years with known date of birth were taken in the study. Data was acquired by performing computed tomography (CT) chest of these patients on 16-slice Multi-detector row CT(MDCT) scan machine using parameter—kVp=120; mAs=150; Pitch factor=1.15; scan time=0.5sec and slice collimation=16x1.5. Data acquired was reconstructed in 2mm thick slices at bone window (W/L= 1500/300-450), using kernel b60f (a filter suitable for viewing osseous structures) to facilitate the fine details of bone development process. It was realized in the study, with the vast experience of finding ossification stages of medial epiphyses of bilateral clavicles that CT (computed tomography) is far better and more reliable modality to study the minute details of growing bone in development process and proper visualization of ossification status. As CT allows better visualization of appearance of ossification center and the course of its fusion with rest of the bone without the overlapping of other anatomical structures shadow lying in that region in the posterior plane such as ribs, vertebral column and other structures of mediastinum. Motion artifacts due to breathing of the patients during scanning have been completely eliminated with fast scanning and completing the scan in single breath hold. Data collected and processed was interpretable in all subjects for staging the ossification status and was highly accurate in providing the range of variation for the timing of union, as the clarity of scans was enhanced with the use of high resolution reconstruction filters like kernel b60f.
The ossification process of medial clavicular epiphysis was evaluated on the basis of five-stage classification criterion defined by Schmeling et al. (2004). The same could be observed from 14 to 30 years of age. In three cases (all female) the process was even observed extending beyond 30 years.

- The stage 1 was found in 33 males and 23 female subjects and observed to be completed by 17 years of age in both the sexes.

- The stage 2 was found in 24 males and 19 females. The onset of stage 2 was found approximately one year advanced (at the age of 14 years) in female subjects as compared to males in present study and also completed one year earlier in females (18 years of age) than males.

- The stage 3 was found in 77 males and 95 females. The commencement of stage 3 was found at same age in both the sexes, but completed one year earlier (at 25 years of age) in females than male subjects.

- The stage 4 has been found in 91 males and 74 females. This stage was also first observed one year later (at 21 years) in males than females, but was completed one year earlier (at 29 years) in case of males than females.

- Stage 5 was found in 29 males and 41 females. The stage 5 was also commenced one year earlier (at 25 years of age) in females as compares to males. No case of stage 5 could be seen before 25 years of age in either of the sex.

Broadly, it can be stated that the growth related activity of medial clavicular epiphysis remained continued right from 14 years to 30 years in both the sexes. Thus, it is important to correlate the age in this particular age group with the ossification of sternal end of the clavicle in addition to the other standard recommendations of age estimation.
procedure for criminal proceedings. Because, the bones of hand and wrist allow age
diagnostic up to 18 years of age and mineralization of roots of wisdom teeth is also
completed by the age of 21 years, thus the ossification stages of clavicle are recommended
to observe for age estimation beyond 21. These three parameters constitute the main part of
the basis of approved recommendations of the ‘Study Group on Forensic Age Diagnostics’
for criminal proceedings. The onset of stage 5 could not be seen before 21 years of age in
either sex in present study as well as in the published literature. Thus, it could be safely
conclude that CT can be used as one of the most preferred modality to find out the age of a
person in 3\textsuperscript{rd} decade of life from the ossification status of sternal end of the clavicle.

II. Technique specific factors:

Some technique specific parameters were also studied in addition to see the effect
of these parameters on the results and described as following;

A. Influence of slice thickness on evaluation of ossification status:

CT scan images in a large sample size of bilateral clavicles of 100 live subjects
were studied to find the effect of the slice thickness and found that it has crucial impact on
the evaluation of clavicular ossification status, because this is one of the main parameter
affecting the spatial resolution of CT scan, along longitudinal axis. Even the slice thickness
of 1 and 3 mm led to different ossification stages in 7 cases.

In all the cases, the ossification stages defined by 1 and 2 mm slice thickness has
been found to be identical, but the stages were found to different in 7 cases for 3mm slice
thickness, in 20 cases for 5mm slice thickness and in 25 cases for 7mm slice thickness as
compared to the stages defined with 1 and 2mm slice thickness. Therefore, it is
recommended that a slice thickness 1 or 2 mm should be used for CT examination of
clavicle to evaluate the ossification stage for forensic age estimation, in order to ensure maximum accuracy and reliability in results. The slice thickness of 2mm is rather beneficial to the subject as, volume dose (CTDI$_{vol}$) is reduced while using technical parameters for acquiring minimum slice thickness of 2 mm as compared to the technical parameters used in order to get 1mm minimum reconstructed slice thickness. The CTDI$_{vol}$ (CT dose index) was equal to 10.50 mGy for 2 mm (minimum) slice thickness and CTDI$_{vol}$ has been increased to 11.54 mGy for the parameters used to facilitate the reconstruction of minimum slice thickness- 1 mm in the scanner, 16-row MDCT (Siemens Sensation 16), used to conduct this study.

Thus, 2 mm found to be the most ideal thickness in performing CT for finding the medial clavicular ossification status to produce high resolution scans in order to get maximum accuracy in the results, without increasing the dose delivered to the subject. Because, mAs has to increased in acquiring data, so as to get thinner slice reconstructed CT images, to reduce noise in the image. Thus, it is useless to further reduce slice thickness (>2mm), rather it is going to increase the dose delivered to the subject. The reconstruction kernel (filter-B60f), suitable for osseous structures should also be used, while reconstructing the acquired data at bone window into 2mm thick slices, so as to reduce the noise and to get adequate edge enhancement (bone edge) in the resultant image.

B. Comparative analysis of clavicular ossification staging as using CT and Digital X-ray:

A comparative study was conducted by retrospectively, evaluating the ossification stages of medial clavicular epiphysis from CT chest and Digital X-rays (chest) of same patients coincidently performed on same day, for their respective diagnostic purpose. The sample size of the study consisted of 100 subjects falling in the age range of 13-30 years.
The aim of this study was to find out, which is better modality for evaluating the ossification status of medial clavicular epiphysis. The reliable assessment of medial clavicular ossification was not possible in 12 clavicles (6% of the sample) with Digital X-rays due to superimposition of other bony structures, but CT has allowed the assessment of ossification status correctly in all the cases (100% of data). The results were not found in agreement with the techniques (modalities) used, CT and Digital X-rays, in 37 clavicles accounting 18.5% of the sample. As the observations are technique specific, it is therefore recommended to use the reference data of X-rays based study for evaluating ossification stage from X-rays and that of CT based study for evaluating the same from CT. The recommended slice thickness for CT based study should not be more than 2mm. To make a recommendation concerning the method of choice for the assessment of clavicular ossification, CT can be termed as the better method in providing successful evaluation in of ossification stages.

C. Reduction of dose with the employment of Automatic Exposure Control (AEC) technique in CT protocols for clavicular ossification staging:

A study was conducted including 100 samples to find out the dose reducing technique in CT protocols. The technique used here for reducing dose delivered to the subject in CT was the employment of Automatic Exposure Control in CT protocols to compare the percentage dose reduction with BMI (Body Mass Index) of the subjects as compared to fixed Exposure Technique (conventional CT technique). It was also studied, whether the quality of scans was affected with this new mode of dose reduction technique. This study was conducted on 16-slice Multi Detector-row CT (MDCT) scan using CARE Dose 4D (AEC software used in Siemens’ CT machines) technique.

No difference was found in the quality of scans, as the reference mAs was kept constant to attain consistency in the number of X-rays contributing in formation of image
and constant contrast to noise ratio (CNR) in all the images. The relationship of BMI was found statistically significant with dose delivered to the patient in this technique. The dose was reduced to almost 50% in a patient with BMI 16.64 kgs/m², but quality was not compromised. Practically all scans acquired, using this technique have permitted the determination of ossification stages of bilateral sternal ends of clavicle successfully, as CNR remained unchanged in all the subjects (Reference mAs kept constant). It was even difficult to distinguish, which technique (fixed or AEC technique) has been used, while evaluating the stages from a blinded set of CT images. But the patient dose was reduced considerably especially in small size young adults. When CT scan is used for age estimation of young adults, particularly in this region, the use of CARE Dose 4D technique found to be beneficial in reducing dose to the subject without compromising the quality of scans, as apices of lungs and axillary tissue of breasts in case of females (hyper-sensitive tissue to ionizing rays induced diseases) are also being exposed while doing CT scan of medial ends of the clavicles.

Thus, it can be suggested that, the dose imparted to the patient can be reduced in small size and young adults by using this technique without compromising the quality of the scan. This technique of individualizing the scan protocols, for every subject depending on body size by the use of AEC in chest CT examination have been found successful in avoiding the radiation exposure dose to the patients, which is not required to produce CT images of diagnostic value.