Original research paper

Computed Tomographic Studies on Ossification Status of Medial Epiphysis of Clavicle: Effect of Slice Thickness and Dose Distribution

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Abstract

The accuracy of technique adopted for Forensic age diagnostics of young adults and adolescents especially in case of livings lies in the standardization of the technical parameters used. The emerging radiological techniques, when used in standardized way may minimize the possibilities of misinterpretation, as it has been practically shown in present study. CT scans of 100 live subjects were performed on 16-slice (Siemen’s Sensation 16) CT scan machine and the volumetric data acquired was reconstructed into five separate sets of slice thickness for each one of the subjects included in the study and the ossification status for each set of slice thickness was determined for all the subjects separately. The results are almost identical while evaluating ossification stages from 1 and 2 mm thick slice data but the differences are found in the ossification stages when evaluated using 3 mm, 5 mm and 7 mm slice thickness as compared those found in 1 and 2 mm slice thickness. It was concluded that by increasing slice thickness the rate of error-nous interpretation are also increasing.

Thus, the minimum reliable thickness to produce high resolution scans in order to get maximum accuracy is 2 mm for staging medial clavicular ossification from CT scan and the reconstruction should be done using kernel (filter) B60F at window setting osteo (1500/450HU).

Key Words: Forensic, ossification, Clavicle, Computed Tomography, Slice Thickness, Dose Distribution

Introduction:

The demand of estimating age of adolescents and young adults has increased in the recent years due to the increasing cross border migration [1]. Age estimation in cadavers, human remains and living individuals is generally needed to solve the issues with significant legal and social ramifications for individual as well as for the community. The accuracy of the technique to be used for age estimation especially in case of living individuals is of utmost importance in both the situations criminal as well as civil. The newer radiological techniques proved invaluable inventions of modern era for diagnostic purpose, may also be used for age diagnostics in forensic context.

The proper way of using these techniques has reduced the possibilities of misinterpretation to the minimum and raised the accuracy level of the results to the maximum.

The current state of forensic age estimation of living subjects is mainly considered for the purpose of criminal prosecution [2]. Forensic age estimation in living adolescents and young adults undergoing criminal proceedings is generally performed to determine whether the defendant of questionable age has reached the age of criminal responsibility and whether general criminal law of adults can be applied[3].

In most countries the age threshold of legal relevance ranges between 14 to 21 years of age [4]. When it is necessary to prove that the subject has attained the age of 21 years, an additional x ray examination or CT scan of clavicle is recommended along with the recommendation of the “Study Group On Forensic Age Diagnostics”, which includes physical examination of the suspect, an x ray of left hand and dental examination and orthopantomogram to know about the dental status.

Clavicular Epiphyseal ossification is must in case it is necessary to prove the proband has reached the criminal liability threshold of 21 years, as the other system on which the development analysis is based are fully matured by this time[5]. If bone
development of hand has been completed, an additional radiological examination of the clavicles should be realized. [6]

Kreitner et al. stated that the ossification status of medial extremity of clavicle can easily be assessed by computed tomography as conventional radiographs which were the basis of analysis in some comprehensive studies are sub optimal because of the overlapping of the ribs, vertebrae and mediastinal shadows. Interpretation of the stages of medial epiphyseal development is even prevented in some cases. Conventional tomography is time consuming and lack clarity. Computed tomography eliminates all these problems. [7]

Schulze et al [8] has reliably determined the ossification status of medial epiphysis of clavicle in 556 cases, aged between 15 to 30 years of age using the classification of stages used by Schmeling et al. [9]. He discussed that partial volume effect in CT using thicker slice was possible explanation of early visualization of stage 5 (21 years) in his study as compared to 26 years in the study of Schmeling et al. and established the effect of slice thickness on staging the ossification status. Mulher et al [10] has determined the ossification stages for different slice thickness 1mm, 3mm, 5mm and 7mm separately in each one of 40 subjects included in the study to prove that inadequate choice of slice thickness can lead to misinterpretation of ossification status.

Schulze et al [11] suggested the use of reconstruction kernel (filter) suitable for osseous structure and to view the scan in bone window to study the status of ossification of medial epiphysis of clavicle for better visualization.

The method of clavicle examination also appeared to be significant. For the age interval in which mature clavicles have been observed, the predicted probability of being mature clavicles is greater when X-rays or CT scans are used instead of dry bone specimens. Inappropriate slice thickness of CT scan can affect age diagnosis, as an almost completely fused clavicle may be diagnosed as being mature when details are lost due to greater thickness. [12]

Present study is aimed to study the chances of interpretation errors while defining the ossification stages of medial epiphysis of clavicle due to technical parameters selected for scanning and how does the resolution affect the results. The slice thickness is an important parameter of CT scanning which depends on the choice of pitch ratio in helical CT, which in turn influences z-axis resolutions. The choice of higher pitch ratio value therefore reduces spatial resolution performance [13]. The radiation dose (as expressed in CTDI vol) is inversely proportional to pitch.

The trade off in increasing pitch is an increase in effective slice thickness, which in turn results in increased volume averaging and reduced image signal (contrast between object to be detected and background) [14]. Thus the slice thickness depending upon the choice of pitch ratio value in turn influences both image quality as well as dose distribution to the patient and suboptimal quality scans may lead to interpretation problem while doing staging to define ossification status, but the dose distribution to the patient is correspondingly increased to produce scans of optimal quality at less slice thickness to increase contrast to noise ratio in the resultant CT image. [13, 14]

Materials and Methods:

CT scans of 100 live subjects (55 males and 45 females) falling in the age group of 12 years to 30 years, originally performed for their diagnostic purpose as contrast enhanced CT chest, neck angiography, pulmonary angiography and bronchial artery angiography on 16 slice (Siemen’s Sensation 16) CT Scan machine, retrospectively analyzed to find out the ossification status of bilateral medial clavicular epiphyses at different slice thickness.

The CT examination of all the patients were performed acquiring volumetric data using technical parameters:

KVp - 120; MA - 140/150; Rotation time - 0.5sec; Pitch – 1.15; slice collimation- 16 x 0.75; FOV 294 mm; Matrix 512 x 512. The volumetric data acquired from spiral CT scans performed using above mentioned parameters reconstructed into axial scans of slice thickness - 1mm, 2mm, 3mm, 5mm and 7 mm using kernel B-60 (filter suitable for osseous structures) at window width / window level 1500 / 450 H.U. (osteo).

The respective ossification stage was determined corresponding to each slice thickness separately for both side in case of all the subjects involved, using following classification criteria. [8]

- Stage I: Ossification centre not ossified.
- Stage II: Ossification centre ossified but epiphyseal cartilage not ossified.
- Stage III: Epiphyseal cartilage partially ossified. (Fused)
- Stage IV: Epiphyseal cartilage completely ossified, but epiphyseal scar is still visualized.
- Stage V: Epiphyseal scar is no longer visible.

The radiation dose distributed to the patient as calculated by the dosimeter inhibited in the scanner itself while performing the examination was CTDIvol = 11.54 mGy.

Results:

All CT scan images obtained after reconstruction at different slice thickness permit the evaluation of ossification status. Following results show the difference in the ossification stages of the
same subject at different slice thickness. Results are almost identical while evaluating ossification status from 1 and 2 mm but the differences was found in results between 1 and 3 mm slice thickness in about 7 cases out of 100 patients CT scans. The stages were found different in 5 mm slice thickness as compared to the stages defined from 1 and 2 mm slice thickness in 20 samples among the sample size of 100 patients and staging interpreting the ossification stages using 7 mm slice thickness exhibited different results in 25 cases out of 100 cases.

**Relationship of slice thickness and rate of error in determination of ossification stage**

<table>
<thead>
<tr>
<th>Slice Thickness</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mm</td>
<td>0</td>
</tr>
<tr>
<td>2mm</td>
<td>0</td>
</tr>
<tr>
<td>3mm</td>
<td>7</td>
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<tr>
<td>5mm</td>
<td>20</td>
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<tr>
<td>7mm</td>
<td>25</td>
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</tbody>
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With the increase of slice thickness of CT scan, the %age of fallacious results increases i.e. at 1mm and 2mm there is no difference and at 3mm is 7%, 5mm is 20% and at 7mm is 25% i.e. with increase of slice thickness, the percentage of fallacious results increases.

**Discussion:**

Computed tomography is advantageous as it allows imaging of medial epiphysis of clavicle without overlapping. Kreitner et al.[6] examined 380 CT scans of patients aged 20-30 years. Slice thickness was 8mm in 202 cases, 5mm in 88 cases, 4mm in 54 cases and 1.2,3mm in 36 cases. They recommended ideal slice thickness of 3mm for imaging of sternoclavicular joint using pitch factor 1.3 to 1.7 and 3 mm reconstruction increments and table speed of 4 to 5 mm per second. Though they did not mentioned quantum of error, while various slice thickness was used.

Schulz et al. [7] examined CT scans of 629 patients aged between 15 and 30 years and evaluated the medial epipysial cartilage of clavicles. The slice thickness of the scan suitable for the evaluation considered in this study were 7mm in 546 cases, 5 mm in 2 cases, 3 mm in 4 cases, 2mm in 1 case and 1 mm in 3 cases. The question, how does the slice thickness affect the interpretation of the ossification stages corresponding to the age intervals, the authors advised to be examined in the further study but in their opinion in order to achieve best possible results and ensure maximum accuracy in age estimation practice, the slice thickness of 1 mm is most ideal to perform CT scan.

The findings of present study are in conformance with this and found that 1mm and 2mm slice thickness of CT scan images give the best results without any error for the purpose of defining medial clavicular ossification stages. Muhler et al. [9] determined ossification stages of 40 live subjects at different slice thickness reconstructing the data acquired into CT imaged of 1, 3, 5 and 7 mm thick slices and found different stages while assessing at different slice thickness.

They concluded the slice thickness has a crucial impact on the evaluation of clavicular ossification status found that even the slice thickness of 1 and 3mm led to different results in one case; the ossification status was also different in three cases using slice thickness of 3 and 5 mm for staging and same differences were encountered for slice thickness of 5 and 7 mm in another three cases and suggested in the end to use slice thickness of 1mm for CT examination of clavicle to evaluate the ossification stages for forensic age estimation purpose.

In order to ensure a maximum of accuracy in forensic age estimation practice, it is recommended to perform thin-slice CT scans. Thus thin-slice multidetector CT images of the individuals aged between 10 and 35 years were analyzed successfully in 502 cases using the classification criteria of staging used by Schmeling et al. [8] in a retrospective study by Kellinghaus et al.[15] and found that the findings of their study were in line with those from the only CT based studies on clavicle ,except from the fact that stage 5 first occurred at the age of 26, which is 5 years later as compared to the other studies by CT ,but with thick slices(7mm). This vast difference assumed to occur due to partial volume effect with thick-slice CT images by a visual deception of the epipysial scar occurring with stage 4.

The present study found that the results defining the ossification status at different slice thickness were different in 25 cases among the sample size of 100 live subjects.

This difference in results depending upon slice thickness was mainly caused by partial volume effect and decreased resolution using greater slice thickness. The resolution along longitudinal axis is inversely proportional to the slice thickness, as the slice thickness increases the resolution will be decreased, which apperently partly or fully masks the fine
anatomical structures like cartilaginous epiphyseal plate creating confusion between stage 2 and 1 or epiphyseal scar creating confusion between stage 4 and 5. Some time it was difficult to clarify whether the epiphyseal plate has been fused completely or not yet appeared while defining the stage from 5 or 7 mm thick slice.

Conclusions:
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 special resolution of CT scan, specifically longitudinal axis. Even the slice thickness of 1 and 3 mm led to different ossification stages in 8 cases.

In all the cases the ossification stages defined using 1 and 2 mm slice thickness has been found identical. Therefore we recommend 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 factor 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 2mm 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 (min) slice thickness and CTDI vol has been increased to 11.54 mGy for 1mm (min) reconstructed slice thickness in our scanner 16-rowMDCT(Siemens Sensation 16).

Thus 1 or 2 mm is the only reliable thickness to produce high resolution scans in order to get maximum accuracy in the results and reconstruction should be done using kernel (filter) B60f at window.

References:
5. Klaus R. and Claus G. (2005); Assess the age of Adolescents and young adults in crime procedures. Int. Poster J Dent Oral Med.; 7(2); poster 275