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The influence of slice thickness on assessment of clavicle ossification in forensic age diagnostics

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Abstract Computed tomography scans originally obtained to assess the ossification status of the medial clavicular epiphyses of 40 live subjects for forensic age estimation purposes were analysed. From the data acquired we reconstructed images with slice thicknesses of 1, 3, 5 and 7 mm, and based on the classification of stages by Schmeling et al. (Int J Legal Med 118:5–8, 2004), we determined the ossification stage for each reconstructed slice thickness, separately for both sides. Of the 80 clavicular epiphysal plates examined, seven displayed slice-thickness-dependent differences at certain ossification stages. In one case a slice thickness of 1 mm led to a different diagnosis of the ossification stage than a slice thickness of 3 mm, in three cases the diagnoses differed between the slice thicknesses of 3 and of 5 mm, and in another three cases, between 5 and 7 mm. We therefore conclude that for age estimation purposes, the slice thickness should be 1 mm to ensure maximum accuracy and diagnostic reliability.

Keywords Forensic age diagnosis · Ossification · Clavicle · Computed tomography · Slice thickness

Introduction

Age diagnostics of live subjects in criminal proceedings, to assess their criminal liability and decide whether general criminal law in force for adults applies, is one of the more recent research areas of forensic medicine [5–7, 10, 11]. In

many countries the age thresholds of relevance to criminal prosecution lie between 14 and 21 years [1]. In line with recommendations drawn up by the Study Group on Forensic Age Diagnostics (<http://www.charite.de/rechtsmedizin/agfad/index.htm>) for determining the age of live subjects for the purpose of criminal investigation, a forensic age estimate should consist of a physical examination, an X-ray of the left hand and a dental examination which records dentition status and evaluates an orthopantomogram. In addition, a radiological or computed tomography (CT) examination of the medial clavicular epiphysis is recommended to establish whether a person has attained 21 years of age [9].

Computed tomography studies on the time frame for ossification of the medial epiphysal plate of the clavicle were published by Kreitner et al. [3, 4] and Schulz et al. [11]. When discussing the results, Schulz et al. [11] raised the question on whether CT scans with a slice thickness greater than 1 mm can lead to errors when determining the ossification stage of the clavicle. The aim of the present work was to examine whether, and if so, how, the slice thickness of CT scans influences the evaluation of the ossification status of the clavicles.

Material and methods

We analysed CT scans of 40 live subjects (2 women, 38 men), originally performed for the purpose of forensic age estimation, at the Institute for Radiology of the Charité University Hospital in Berlin between August 2003 and November 2004. In all cases the examination was authorized by a legal order of a judge under Section 81 of the Code of Criminal Procedure (StPO) allowing X-ray examinations without medical indication.

The computed tomographic examinations were performed with a Toshiba Asteion (Single-Slice CT; rotation time 1 s; 120 kV; 130 mA; pitch 1.5; collimation 1 mm, kernel FC30 (bone kernel), matrix 512×512, and scan length 4 cm).

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Table 1 Ossification stages of the medial clavicular epiphyses, separately for both sides, and for different CT slice thicknesses

Subject	Sex	Left				Right			
		1 mm	3 mm	5 mm	7 mm	1 mm	3 mm	5 mm	7 mm
P.D.	m	2	3	3	3	2	2	3	3
N.K.	f	4	4	4	5	5	5	5	5
E.M.	m	3	3	5	5	3	3	5	5
N.H.	m	2	2	2	3	2	2	2	2
A.O.	m	2	2	2	3	3	3	3	3

From the data acquired from 1-mm-thick slices (no overlap), images with a slice thickness of 3, 5 and 7 mm were reconstructed (reconstruction interval 1 mm) for the present study. We determined the respective ossification stage for each reconstructed slice thickness, separately for both sides, using the classification of stages drawn up by Schmeling et al. [10]:

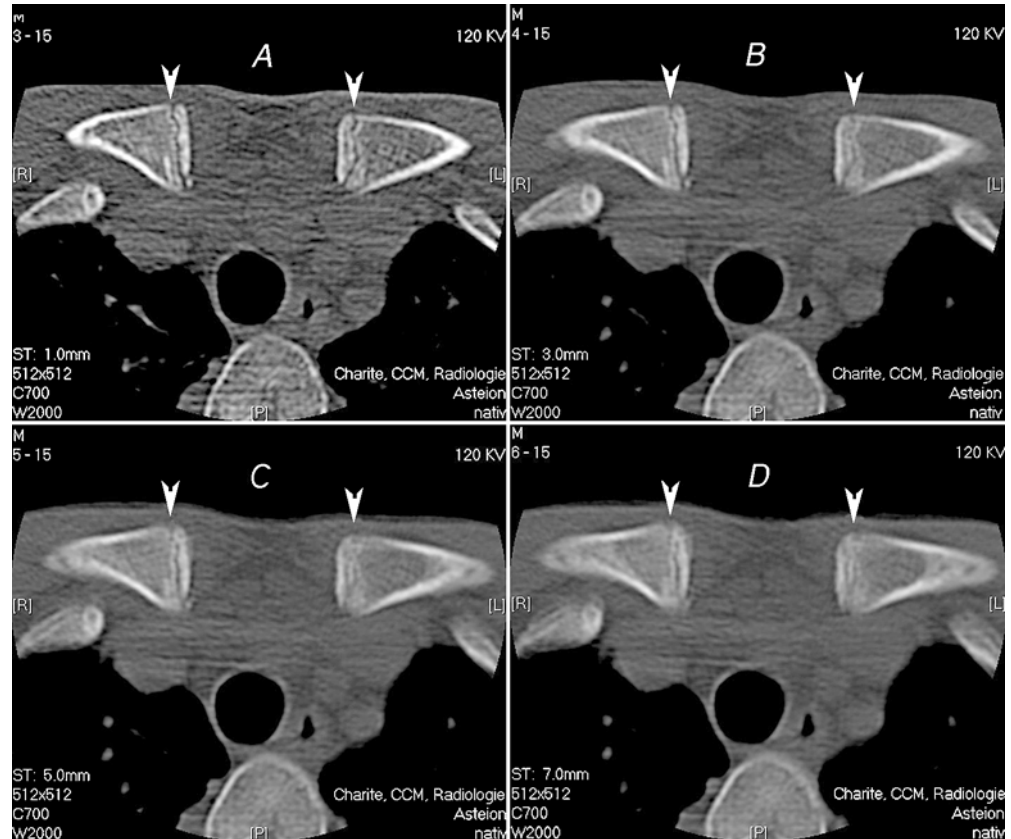
- Stage 1: ossification centre not ossified,
- Stage 2: ossification centre ossified, epiphysial plate not ossified,
- Stage 3: epiphysial plate partly ossified,
- Stage 4: epiphysial plate fully ossified, epiphysial scar visible and
- Stage 5: epiphysial plate fully ossified, epiphysial scar no longer visible.

The effective radiation dose was computed using CT-Expo V. 1.3 software (copyright Georg Stamm and Hans Dieter Nagel, Hanover–Hamburg 2001–2003).

Results

All 80 images of the medial epiphysial plates of the clavicle were suitable for evaluation, i.e. we were able to determine the ossification stage for all slice thicknesses. We diagnosed different ossification stages, depending on the slice thickness, in the case of seven clavicular epiphysial plates belonging to five subjects. Table 1 shows the slice-thickness-dependent ossification stages of the five subjects. Depending on the slice thickness, the ossification status was identified as stages 2 or 3 in four cases, as stages 3 or 5 in two cases and as stages 4 or 5 in one case. In one case, the diagnoses were different for slice thicknesses of 1 and 3 mm; in three cases the diagnoses were different for slice thicknesses of 3 and 5 mm; and in three cases the diagnoses were different for slice thicknesses of 5 and 7 mm. Figure 1 shows the slice-thickness-dependent changes in the ossification stage diagnosed on the basis of CT scans belonging to a suspect (P.D.).

Fig. 1 Left and right medial clavicular epiphyses after reconstruction of CT data with a slice thickness of 1, 3, 5 and 7 mm, respectively, belonging to the suspect identified by the initials P.D. **a** Stage 2 ossification on both sides, with 1-mm slice thickness. With increasing slice thickness (3 mm, **b**), the ossification stage appears to differ between sides (right 2, left 3). Further increase in slice thickness to 5 mm (**c**) and 7 mm (**d**) results in identification of stage 3 ossification on both sides. Arrows indicate the medial clavicular epiphyses



Taking into account the specific examination strategy used in this study, the effective radiation dose computed was 0.5 mSv for a patient weighing 70 kg.

Discussion

Computed tomography studies of the time frame for ossification of the medial epiphysial plate of the clavicle were published by Kreitner et al. [3, 4] and Schulz et al. [11]. Following up on their study published in 1997, Kreitner et al. [4] analysed a total of 380 CT scans of patients aged between 0 and 30 years. Slice thickness was 8 mm in 202 cases, 5 mm in 88 cases, 4 mm in 54 cases and 1, 2 or 3 mm in 36 cases. Without any further explanation, Kreitner et al. [4] recommend a slice thickness of 3 mm for age estimation practice.

Schulz et al. [11] examined 629 chest CT scans of patients aged between 15 and 30 years and evaluated the medial epiphysial plate of the clavicles. The slice thickness of the scans suitable for evaluation was as follows: 7 mm in 546 cases, 5 mm in 2 cases, 3 mm in 4 cases, 2 mm in 1 case and 1 mm in 3 cases. While the identified age intervals for stages 2–4 corresponded with the data published by Kreitner et al. [3, 4] and Schmeling et al. [10], the minimal age for stage 5 was noted 4 years earlier in men and 5 years earlier in women compared with the results of the conventional X-ray study of Schmeling et al. [10]. Schulz et al. [11] raised the question on whether CT scans with a slice thickness of greater than 1 mm can cause a misinterpretation of clavicle ossification status and recommended examining the influence of slice thickness on the age intervals of ossification stages in additional studies.

The present study found that the ossification status of the epiphysial plates of the clavicle was determined differently depending on the slice thickness of the CT scans in 7 out of 80 cases. Such differences concerned stages 2 and 3 in four cases, stages 3 and 5 in two cases, and stages 4 and 5 in one case. This dependency on slice thickness was caused by the partial volume effect: increasing slice thickness results in decreasing spatial resolution along the longitudinal axis, which apparently partly or fully masks fine anatomical structures such as the cartilaginous epiphysial plate or the epiphysial scar.

The effective radiation dose computed for our examination strategy, with a slice thickness of 1 mm, lies within the range given in literature [2, 8].

Conclusions

The slice thickness of CT scans has a crucial impact on the evaluation of clavicle ossification status. In the present

study, even slice thicknesses of 1 and 3 mm led to different ossification stages being identified in one case; the determination of the ossification stage also differed for slice thicknesses of 3 and 5 mm in three cases and for slice thicknesses of 5 and 7 mm in another three cases. In all cases where differences in identifying stages occurred, increased slice thickness resulted in assessing higher ossification stages. In age estimation practice, this means that the estimated age of the person under examination would have been higher than the actual age. In terms of criminal law, this would have put the person concerned at a disadvantage. Therefore, we recommend that a slice thickness of 1 mm should be used for CT examinations of the clavicle to evaluate the ossification stage for forensic age estimation purposes, to ensure maximum accuracy and diagnostic reliability.

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