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Comparative study on developmental stages of the clavicle by postmortem MRI and CT imaging ☆

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ABSTRACT

Objectives: The developmental stages of the clavicles are important for forensic age estimation purposes in adolescents. This study compares the 4-stage system to evaluate the ossification of the medial end of the clavicle as visualized by magnetic resonance imaging (MRI) and computed tomography (CT). As several forensic institutes routinely perform CT scans, the large amount of available data may serve as reference sample for MRI in specific cases.
Material and methods: This prospective study included an MRI and CT scan of 47 autopsy cases performed prior to medico-legal autopsy (age range 12.9–27.5 years). All images were scored in blind trials using a 4-stage system by a trained observer.
Results: Intra-observer agreements were substantial within (MRI: $K=0.685$, CT: $K=0.611$) and between modalities ($K=0.644$, $p<0.001$). No systematic differences were found between stages as assessed by CT and MRI. The mean and minimum ages by each stage (2–4) were in accordance to previous published results. At younger than 18, no subjects were assessed as a stage 4.
Conclusion: Age estimation from the clavicle using either CT or MRI performs concordantly. In lack of MRI reference studies, CT data may be used.

1. Introduction

In the past 10 years, publications regarding forensic imaging have increased dramatically [1]. This reflects the increasing number of forensic institutes with an associated radiological facility including a computed tomography (CT) and/or a magnetic resonance imaging (MRI) scanner [2,3]. Most forensic publications regard postmortem imaging as compared to autopsy results, i.e. the Virtopsy project [4–8]. Among previous comparing studies on postmortem MRI and CT are neuroimaging [9], heart examinations [7] chest traumas [5] and hemorrhages [10,11]. For postmortem imaging, the amount of radiation is of no importance. Despite its ability to visualize heart infarctions [12] and bone lesions [13] the use of MRI for forensic purposes is less frequent as compared to CT, probably reflecting limited access, time constraints, expensive costs and the complexity of MR technology [1]. However, being a non-ionizing method gives MRI additional advantages for clinical forensic purposes. Although MRI has been shown applicable for visualizing hemorrhages in strangulation victims [14,15], it is mostly investigated for the purpose of assessing a likely chronological age of young individuals lacking relevant documents from their country of origin. MRI can visualize the epiphyseal fusion of bones in the knee, ankle, left-hand and clavicle [16–20]. However, to serve as a method for assessing a likely chronological age in the examinee, large reference studies must be performed [21].

In order to assess the legal age limit of 18 and 21, it is recommended to perform a radiological examination of the developmental stages of the clavicles. While the use of CT and conventional radiography (CR) are well studied [22–28], only few studies are available for MRI [29–31]. Although CT and CR of the clavicles have shown concordant results in 97 of 99 stage assessments, it is recommended to obtain reference samples from the same modality as used [25]. As this may serve well as a theoretical argument, it is a time-consuming process as larger reference samples needs to be prospectively collected before the method is implemented [29,32]. As more institutes routinely perform CT and/or MRI scans prior to autopsy [4,22,33] data can be continuously collected and may serve as reference samples. To our knowledge, no previous study has compared developmental stages of the clavicle by CT and MRI. Adding to the knowledge on postmortem imaging modalities, the aim of this study was to compare the 4-stage assessment of clavicle ossification as visualized by MRI and CT.

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Table 1
The technical parameters for the MRI and CT images.

Modality	Technical parameters
MRI	TE: 7.29 ms, TR: 26.44 ms, FOV: 180 mm, Scan Time: 6.04 min, Flip angle: 25, Matrix: 256, slice thickness: 1.5 mm.
CT	kV: 120, mAs: 140, FOV: 150 mm, Kernel B40f, slice thickness 1.0 mm.

MRI = magnetic resonance imaging; CT = computed tomography; TE = time to echo; TR = time to repeat and FOV = field of view.

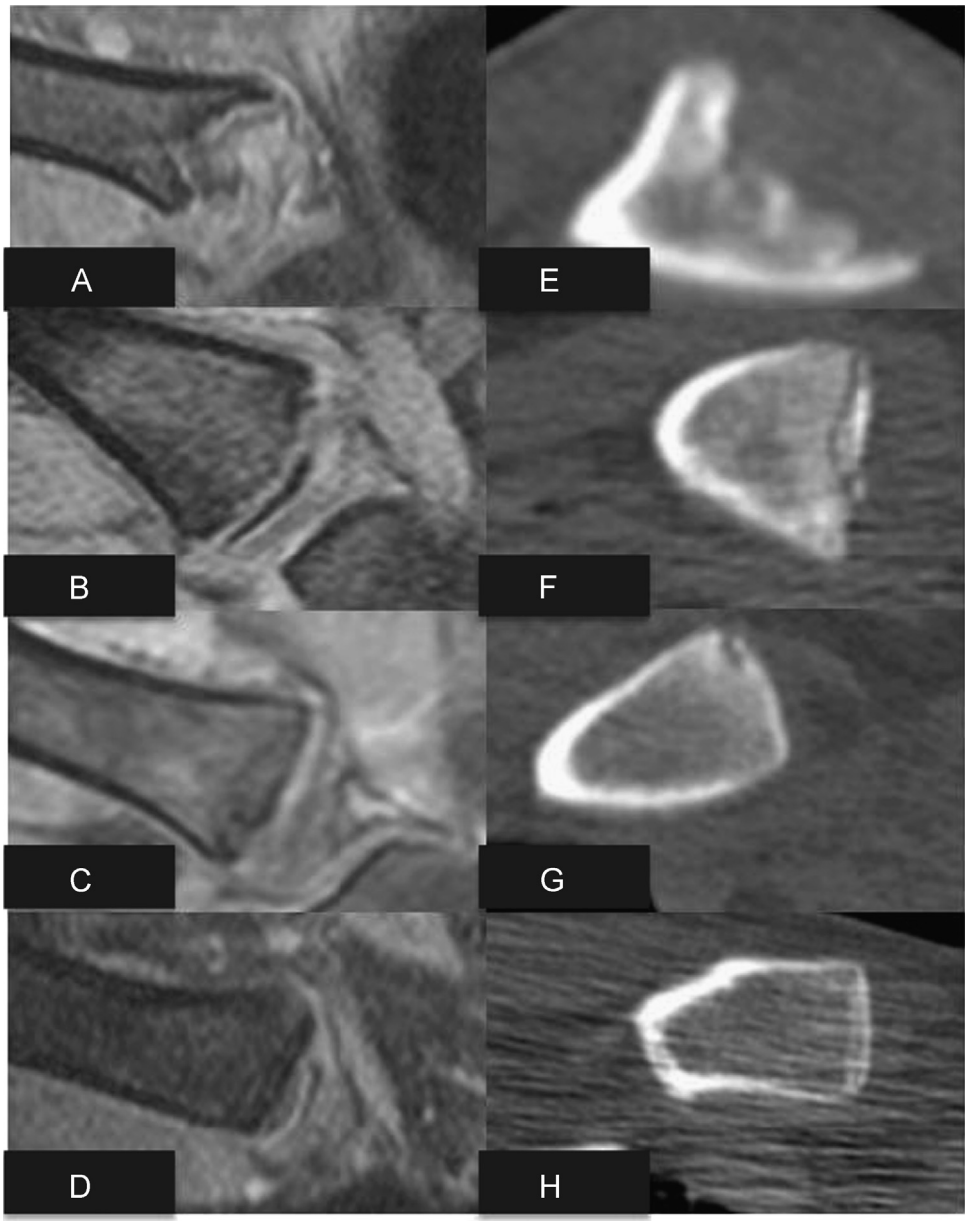

Fig. 1. Images representing developmental stages 1–4 of clavicle development as seen in the same individual by MRI (A–D) and CT (E–H). MRI is visualized in the coronal plane, CT in the transversal plane.

2. Material and methods

2.1. Data collection

This prospective study included 47 autopsy cases between 12.9 years and 27.5 years. The mean age for the male sample ($n=35$) was 22.3 years (range 17.0–27.5). Females ($n=12$) were slightly younger (mean age 21.0 years, range 12.9–27.4). MRI and CT scans were performed in the supine position prior to the medico-legal autopsy as part of the routine investigation. Subjects which were severely decomposed or had trauma to the chest area were excluded. Ethnic origin was not taken into account.

2.2. MRI and CT scanners

MRI images were collected on a 1.0T Siemens Harmony® scanner, Siemens AG, Germany with standard software using a 3D T2 weighted gradient Echo sequence. Slice thickness was 1.5 mm. Images were analyzed using multi planar reconstruction (MPR),