

### A111 Staging Clavicular Development on Magnetic Resonance Imaging (MRI): Pitfalls and Recommendations for Age Estimation

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**Learning Overview:** After attending this presentation, attendees will be aware of the pitfalls of staging clavicular development on Magnetic Resonance Imaging (MRI) for age estimation and how to take those pitfalls into account to estimate age in a proper manner.

**Impact on the Forensic Science Community:** This presentation will impact the forensic science community by elaborating on the emerging field of radiation-free age estimation by means of MRI. It will be demonstrated that even experienced researchers are prone to the pitfalls of assessing clavicle MRI, which affects stage allocation for age estimation.

**Background:** In age estimation, a particularly challenging region of interest is the sternal end of the clavicle, which is studied when the age threshold of 18 years is of importance. Few studies have applied MRI of this region in the living, which may be due to the prevalence of motion artifacts and shape variants, impeding an assessment of clavicular development.<sup>1-5</sup>

Regarding early and late clavicular development, two ambiguities have been pointed out in the literature. First, Hillewig et al. highlighted that the physal scar was hard to discern on MRI.<sup>1</sup> This was confirmed in a larger study sample, while the physal scar had not disappeared in any of Schmidt et al.'s participants.<sup>2,3</sup> Second, the fully mature stage resembles the earliest stage, in which the epiphysis has not yet begun mineralization. Therefore, those two stages may be confused and wrongfully allocated.<sup>2</sup> It should be noted that this problem was not encountered by Schmidt et al.; they stated that discerning early from late clavicular development should be based solely on the sternal end's shape, not on the hand/wrist status.<sup>3</sup>

Regarding physal bridging, substages proved to be useful in determining whether the age thresholds of 18 and 21 years old had been reached.<sup>3,5</sup> However, none of these studies reported the corresponding probabilities to having reached those age thresholds associated with the different substages.

**Purpose:** To elaborate on these pitfalls and this staging technique and to propose recommendations for a proper use of clavicle MRI for forensic age estimation.

**Materials and Methods:** Three Tesla MRIs were conducted on both clavicles in 524 healthy Caucasian volunteers (277 females, 247 males) between 14 and 30 years of age. Two observers assessed the images independently, applying the most elaborate staging technique that has been described in the literature.<sup>6,7</sup> Consequently, a Bayesian model for age estimation used the data and its performance was tested.<sup>8</sup> Two aspects of age estimation were studied using the model: (1) point prediction of age and its uncertainty; and (2) the ability to discern minors from adults.

**Hypotheses:** (1) early (stage 1) and late development (stages 4 and 5) of the clavicle's sternal end should be disregarded for age estimation; (2) substages before bridging of the physal plate has started (stage 2) disturb the chronology of stages. Therefore, they should be considered jointly as one stage and incorporated accordingly into the model for age estimation; and (3) conversely, substages of the bridging physal plate (stage 3) can successfully be incorporated into a Bayesian model for age estimation, rendering acceptable point predictions of age and diagnostic indices to discern minors from adults.

**Preliminary Results:** Weighted kappas of 0.77 for intra-observer agreement and 0.64 for inter-observer agreement indicated large discrepancies between observations. These were mainly caused by interchangeably allocating stage 1 and stage 4 or 5. When one observer allocated stage 1, the other observer allocated stage 4 or 5 in 12% (3/26) of cases; vice versa occurred in 30% (16/53) of cases. This confirmed hypothesis 1.

Considering age distributions within substages of stages 2 and 3, the chronology was disturbed, since bridging did not wait until the epiphysis had widened. Moreover, mean ages within substages of stage 2 did not increase consecutively. This confirmed hypothesis 2. By contrast, the mean ages in substages of stage 3 did increase consecutively, even when substages of stage 3a were considered. This confirmed hypothesis 3.

Performance of the Bayesian model for age estimation was not yet assessed at the time this presentation was submitted.

#### Reference(s):

1. Hillewig E., De Tobel J., Cuche O., Vandemaele P., Piette M., Verstraete K. Magnetic Resonance Imaging of the Medial Extremity of the Clavicle in Forensic Bone Age Determination: A New Four-Minute Approach. *European Radiology*. 2011 Apr;21(4):757-67.
2. Hillewig E., Degroote J., Van der Paelt T., Visscher A., Vandemaele P., Lutin B., et al. Magnetic Resonance Imaging of the Sternal Extremity of the Clavicle in Forensic Age Estimation: Towards More Sound Age Estimates. *International Journal of Legal Medicine*. 2013 May;127(3):677-89.
3. Schmidt S., Ottow C., Pfeiffer H., Heindel W., Vieth V., Schmeling A., et al. Magnetic Resonance Imaging-Based Evaluation of Ossification of the Medial Clavicular Epiphysis in Forensic Age Assessment. *International Journal Of Legal Medicine*. 2017 Nov;131(6):1665-73.
4. Tangmose S., Jensen K.E., Villa C., Lynnerup N. Forensic Age Estimation From the Clavicle Using 1.0T MRI-Preliminary Results. *Forensic Science International*. 2014 Jan;234:7-12.



5. Vieth V., Schulz R., Brinkmeier P., Dvorak J., Schmeling A. Age Estimation in U-20 Football Players Using 3.0 Tesla MRI of the Clavicle. *Forensic Science International*. 2014 May 21;241c:118-22.
6. Kellinghaus M., Schulz R., Vieth V., Schmidt S., Pfeiffer H., Schmeling A. Enhanced Possibilities to Make Statements on the Ossification Status of the Medial Clavicular Epiphysis Using an Amplified Staging Scheme in Evaluating Thin-Slice CT Scans. *International Journal of Legal Medicine*. 2010 Jul;124(4):321-5.
7. Wittschieber D., Schmidt S., Vieth V., Schulz R., Püschel K., Pfeiffer H., et al. Subclassification of Clavicular Substage 3a Is Useful for Diagnosing the Age of 17 Years. *Rechtsmedizin*. 2014 2014/12/01;24(6):485-8.
8. Fieuws S., Willems G., Larsen-Tangmose S., Lynnerup N., Boldsen J., Thevissen P. Obtaining Appropriate Interval Estimates for Age When Multiple Indicators Are Used: Evaluation of an Ad-Hoc Procedure. *International Journal of Legal Medicine*. 2016 Mar;130(2):489-99.

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### **Age Estimation, Clavicle, Magnetic Resonance Imaging**