Musculoskeletal MR-Imaging in fracture dating

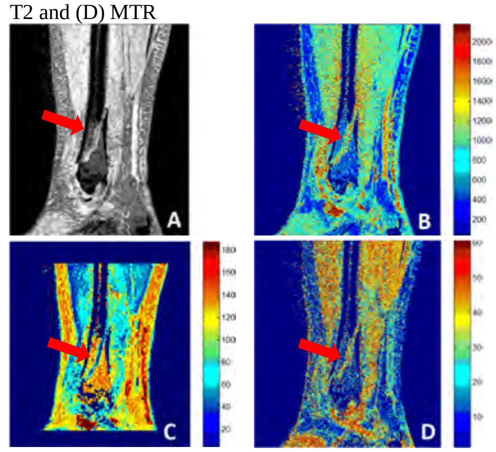
Katharina Baron[1], Bernhard Neumayer[1], Thomas Widek[1], Sylvia Scheicher[1], Eva Maria Hassler[2], Fritz Schick[3], and Eva Scheurer[1]
[1]*Ludwig Boltzmann Institute for Clinical-Forensic Imaging (LBI-CFI), Graz, Styria, Austria,* [2]*Department of Radiology, Medical University of Graz, Styria, Austria,* [3]*Diagnostic and Interventional Radiology, Eberhard-Karls-University Tübingen, Baden-Württemberg, Germany*

Target Audience: This study is important for radiologists and forensic experts assessing hard and soft tissue injuries after a fracture event.

Purpose: Historically, the healing of bone fractures has been divided into five phases based on histological and radiological investigations: (1) fracture event, (2) haemorrhage inflammation, (3) soft callus formation, (4) hard callus formation and (5) bone remodelling.[1-5]

The determination of the time frame of fracture healing is of special interest in the field of clinical forensic examinations of child abuse, but can also be applied to the reconstruction of accidents and medical investigations of bone healing. To date, fracture dating is performed using radiographic methods and only allows qualitative results, strongly depending on the experience of the examiner.[6] Moreover; a considerable radiation dose is associated with this approach. Magnetic resonance imaging, in contrast, allows the investigation of bone as well as surrounding soft tissue structures, without any exposure to radiation. As a novel approach, this ongoing study aims to investigate the possible usage of quantitative MR imaging for bone fracture dating by systematically investigating time-resolved changes in quantitative MR characteristics after a fracture.

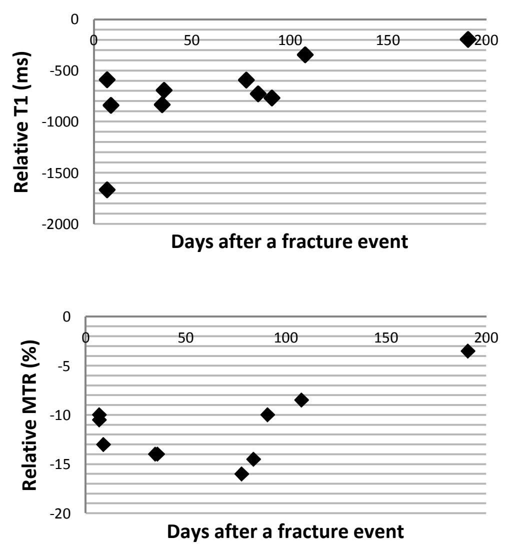
Figure 1: (A) T1w image of metatarsal bone 7 days after fracture event; Quantitative maps for (B) T1, (C) T2 and (D) MTR



Methods: Currently, 18 MR scans of 10 subjects (♀:6 ♂:4; aged 19–67 y; median: 35 y, scanned 1 to 5 times over a period of up to 191 days after fracture event), were acquired on a 3 Tesla MR scanner (TimTrio, Siemens AG, Germany). All subjects were treated conservatively for a fracture in either a long- or collar-bone. 8 MR sequences were applied for the determination of both, quantitative as well as qualitative parameters, of which four MR sequences were applied for morphological analysis: T1w VIBE WE (TE/TR=4.9ms/9.47ms, THK=1.5, RES=0.5x0.5), PDw SPACE SPAIR (TE/TR=32ms/1200ms, THK=0.6, α=120, RES=0.5x0.5), T2w TSE FatSat (TE/TR=76ms/3870ms, THK=2, α=150, RES=0.5x0.5), and T1w TSE (TE/TR=10ms/655ms, THK=2, α=140, RES=0.5x0.5). Furthermore, for the acquisition of the quantitative parameters T1, T2, and magnetization transfer ration (MTR), four sequences were applied: FLASH 3D (TE/TR=4.45ms/11ms, THK=1.5, RES=320x320, 2 measurements: α1=4, α2=19), MSE (τ/TR:10.6/3800ms, 18 echoes, THK=1.5, RES=160x160), Flash 3D (TE/TR=4.27ms/26ms, THK=1.5, RES=320x320, α=8, 2 measurements: with and without MT saturation). Quantitative MR characteristics were determined using MatLab (R2014a, ©MathWork Inc.; Figure 1) and changes were evaluated with respect to the temporal fracture healing progress. Changes of the quantitative parameters were investigated by evaluating the difference between a reference area of intact bone (at least 9 pixel per area) and the fractured area ($Value_{Bone}$ - $Value_{Fracture}$).

Results & Discussion: The preliminary evaluation of 10 MR scans (♀:2 ♂:2 aged 23–33, median 23.5 y, 1 to 5 MR scans over a period of 191 days after fracture event) showed clear changes for all quantitative parameters over time. An increase of T1 (Figure 2) over time compared to intact bone was found, which is most probably caused by an entrance of larger molecules and proteins into the injured area during to the healing processes. It is, however, interesting to note that T1 values seem to monotonously return to the reference value while T2 values of the fracture (not shown) remain roughly constant. Additionally, MTR values (Figure 2) are only slightly increased during the phase of inflammatory response (~1 week) and reach their maximum after 11 weeks; the fracture values then start to return to their reference values. These preliminary results denote that the three different quantitative parameters T1, T2, and MTR show different behaviour for a fracture area over time. Provided that the discovered characteristics are confirmed for a larger number of volunteers this will allow for the application of these characteristics for an improved, objective assessment of the age of a fracture.

Figure 2: Relative T1 and T2 values of bone - fracture over a time period of 191 days.



Conclusion: A first very promising trend in time-dependent changes of quantitative MR parameters could be shown already in a small number of evaluated scans. The evaluation and incorporation of additional data from a greater number of subjects, will allow for a more accurate determination of the correlation of quantitative MR characteristics with single fracture healing phases. These results will form the basis for a more accurate fracture dating in forensics as well as better assessment of bone healing processes in a clinical perspective.

Reference: **1.** Brighton, C. T. The biology of fracture repair. *Instr Course Lect* **33**, 60-82 (1984). **2.** Willenegger, H., Perren, S. M. & Schenk, R. [Primary and secondary healing of bone fractures]. *Chirurg* 42, 241-252 (1971).**3.** Brand, R. & Rubin, C. in *The scientific Bases of orthopedics* (ed Albright J.A. and Brand R.A.) (1987). **4.** Gallagher, G. Dating of fractures in infants. *RAD Magazine* 38, 19-20. **5.** Frost, H. M. The biology of fracture healing. An overview for clinicians. Part I. *Clinical orthopaedics and related research*, 283-293 (1989). **6.** Prosser, I. et al. A timetable for the radiologic features of fracture healing in young children. AJR. Am. J. Roentgenol. 198, 1014--1020, doi:10.2214/AJR.11.6734 (2012).