Correlation of MRI and externally visible findings by external fiducial markers

Bridgette Webb[1], Andreas Petrovic[1], and Eva Scheurer[1,2]
[1]*Ludwig Boltzmann Institute for Clinical Forensic Imaging, Graz, Styria, Austria,* [2]*Institute of Forensic Medicine, Medical University Graz, Graz, Styria, Austria*

Target Audience: Clinicians, forensic experts and radiologists interested in correlating externally visible findings with internal findings in MRI.

Purpose: Accurate detection of traumatic lesions in subcutaneous fatty tissue is important in the forensic evaluation of injuries. Due to its proven objective utility in assessing soft tissue injuries, the use of MRI is especially advantageous in the forensic examination of living victims[1]. A lack of anatomical landmarks in subcutaneous soft tissue and the problem of external clinical fiducial markers inducing artifacts in the superficial tissue layers make the correlation of externally visible findings with MRI difficult. Strand-shaped markers were previously used to register histology and MR images in the prostate[2]. The present study investigated similarly shaped external markers to visualize and correlate internal and external characteristics of subcutaneous hematomas.

Methods: Ten volunteers (median age 26.3y, range 25.1-33.9y) with at least one visible hematoma on their upper leg were included in the study. Following preliminary investigation of marker size and the visibility of various soaking-agents (contrast agents/oils), wool (100% cotton, black) soaked in corn oil was selected. Markers were secured over the hematoma using a transparent medical patch, and photographs of the region of interest were taken pre- and post-scan. Participants were scanned using a CPC 4-channel coil (Noras GmbH, Germany) and one of two available 3T-scanners (TimTrio & Skyra, Siemens AG, Germany) (Tab.1). A photograph of the hematoma with markers in place was used as a 'base image' (BI) to which all other images were registered. Markers allowed the manual identification of matching control points in photographs and oblique MR images, which were used to extract a transformation matrix. Applying an affine transformation, MR images were registered to the BI (workflow, Fig. 1). The position of a selected transversal slice was overlaid onto the oblique MR images. Along the line marking this position, the coordinates of three points (line-marker intersections) were recorded in both the photograph and the registered oblique MRI scan. Using the differences between the coordinates of these locations, the root-mean-square error (RMSE) was calculated for each volunteer. Finally, an overall RMSE was used to assess how accurately the MR scans were registered to the photographs across the cohort.

Table 1: Sequence parameters for MR image acquisition.

	TIRM	TSE2D	TSE-PDw
Orientation	Obl.	Obl.	Trans.
TE (ms)	12	10	12
TR (ms)	7000	1540	3290
Slice Thickness	1.5 mm	1.5 mm	1.5 mm
In-plane Resolution	0.52 mm	0.52 mm	0.52 mm
Flip Angle	-	150°	136°
Fat Suppression	TI200	SPAIR	SPAIR

Figure 1: Interactive registration workflow.

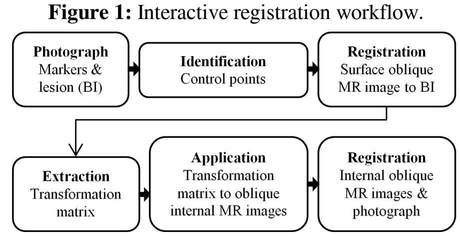
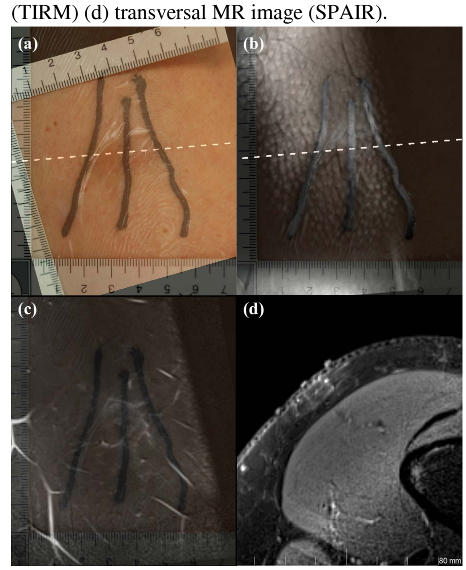


Figure 2: (a) photographs (BI) (b) registered surface MR image (TIRM) (c) registered internal MR image (TIRM) (d) transversal MR image (SPAIR).

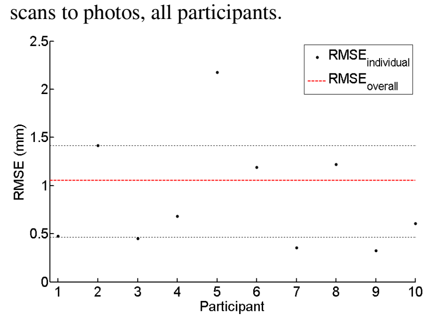


Results: Oblique fat-suppression sequences (TIRM/SPAIR) visualized the configuration of the markers at the surface and the internal characteristics of the subcutaneous hematomas (tissue damage). Marker positions, essential to the registration, were best seen using the TIRM sequence. The TSE2D sequence (SPAIR), however, provided more information regarding internal damage. The visualization of the internal and external characteristics of the subcutaneous hematomas was possible for all volunteers (Fig. 2). The overall RMSE of the registration of oblique MR images to photographs was 1.05 mm (95% CI [0.46; 1.42]) (Fig. 3).

Discussion: IR fat-suppression (TIRM/SPAIR), optimized to suppress the signal of normal adipose tissue[3], resulted in good contrast between lesions and surrounding fatty tissue. The fat signal from the markers was, however, not fully suppressed. The spectroscopic peak accounting for the corn oil fat signal was noticeably broader than that observed for normal adipose tissue. This residual fat signal may explain the visibility of the markers. A transversal TSE-PDw (SPAIR fat-suppression) sequence clearly visualized the internal characteristics of the subcutaneous hematomas. Fulfilling requirements for precise photography and the acquisition of oblique MR images exactly parallel to the skin surface was challenging for larger lesions and those located on irregular surfaces. In view of these challenges and the diameter of the markers (approx. 2mm), the registration achieved is considered sufficiently accurate for the forensic visualization of hematomas in subcutaneous soft tissue.

Conclusion: Registration of photographs and MR images was achieved using the proposed markers and sequences. This enabled a sufficiently accurate co-visualization of both internal characteristics (depth and extent of tissue damage) and external characteristics (size, color and contours of the bruise), important in the forensic assessment of soft tissue injuries. These markers may also have applications in the investigation of a range of lesions in both skin (e.g. tumors), and subcutaneous fatty tissue.

Figure 3: RMSE of the registration of MRI scans to photos, all participants.



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