IDEAL fat-water separation for the detection and characterization of subcutaneous hemorrhage

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Target Audience - Forensic Radiologists, researchers interested in fat-water separation and its application.

Introduction - In forensic medicine the morphological characterization of subcutaneous (s.c.) hemorrhage caused by violent events is highly desired, as detailed knowledge of the origin, appearance, and the age of the injury helps to reconstruct the sequence of events, and serves as evidence in court. However, in contrast to intracranial hemorrhage[1] these injuries are clinically not relevant and, thus, are not very well investigated in MRI. A recent study evaluated s.c. hemorrhage and its changing appearance with time based on signal intensities and contrast values[2]. The aim of this study was to use IDEAL[3] fat water separation to delineate s.c. hemorrhagic lesions with good contrast. Furthermore, the change of water content was investigated with respect to the estimation of the age of the hemorrhage.

Methods - In 20 healthy volunteers own venous blood (4 ml) was injected into the s.c. fatty tissue of the thigh to create an artificial hematoma. Imaging was performed prior to injection (baseline) and directly, 3h, 24h, 3d, 1w, and 2w afterwards. Images were acquired on a 3T scanner (Tim Trio Siemens, Erlangen, Germany) in supine position using one element of the CPC coil (Noras, Höchberg, Germany). For accurate repositioning the distance of the injection position from the patella was recorded. The protocol included GRE imaging with echo times adjusted for the IDEAL reconstruction (TR=50ms, TE=4.72/5.54/6.36ms, α=20°, slice 1.5mm, res 0.6mm). After the exclusion of 9 subjects for technical reasons (e.g. artefacts) data analysis was performed for 11 volunteers (6 f, 5 m, age 18-33, mean 25, informed written consent). The IDEAL reconstruction was implemented in MATLAB[3]. For quantitative analysis 3 ROIs were placed in the reconstructed water-only slices one each in the fatty tissue, muscle and hematoma, respectively. These ROIs were then applied to the water fraction images. Since the hematomas were difficult to segment thresholding was applied to exclude fat-only pixels. The threshold was calculated by taking the mean plus 3 times the SD of the ROI of the pure fatty tissue. The time course of the mean water fractions for each individual and tissue were displayed, and a one-way ANOVA was performed to check if water fractions changed with time. Additionally, for the hematoma ROIs an exponential model $WF(t)=A\cdot\exp(-t/\tau)+B$ was fitted to the water fraction data averaged over all volunteers.

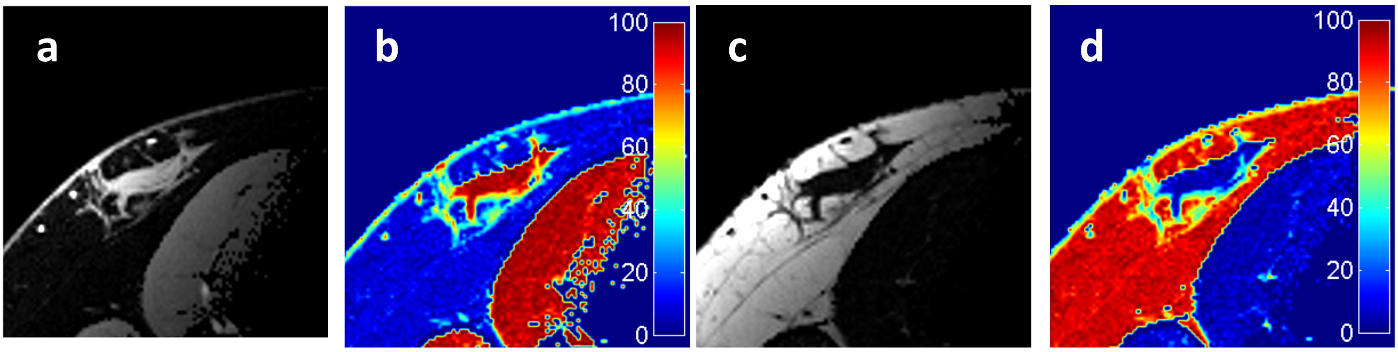

Fig. 1: Representative slice of a fresh artificial hematoma. (a) water-only image, (b) water fraction, (c) fat-only image, and (d) fat fraction. Fractions are scaled in %. Especially in the water image the contrast is high, and fine details of the hematoma are well visible.

Results - Fig. 1 displays the water and fat images for a representative slice of a fresh artificial hematoma, as well as the calculated fractions. The water image (a) provides an excellent contrast for all volunteers showing the compact core and diffuse rim of the hematoma with high signal intensity, also compared to muscle tissue. The fat image (c) also provides a strong contrast, but the internal details of the hemorrhage representing the lobulation of the fatty tissue are not clearly visible. The water (b) and fat (d) fraction images, respectively, give a reliable estimate of the water and fat distribution in the tissues. The average water fraction for all ROIs in fat was 8% (SD 1%) and 96% (2%) in muscle tissue. Statistically, there was no significant change of these values over time ($p=0.84$ for fat, $p=0.57$ for muscle). However, the values for the hematoma regions changed significantly ($p<0.01$) over time. The complete data (one outlier excluded), mean values and the fitted exponential model (A=21%, B=34%, τ=64h) are given in Fig. 2. A quick decrease of the water fraction from 56% to 35% after one week was observed, resulting in a value already close to the baseline values before injection (32%).

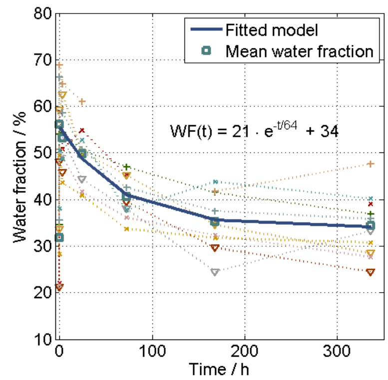

Fig. 2: Time course of the mean water fraction in the hematoma. Dotted curves correspond to the volunteers, bold squares stand for the mean values, the solid line for the exponential model.

Discussion & Conclusion The detection, delineation and characterization of s.c. hemorrhage is important in forensic imaging. We found that IDEAL fat-water imaging is optimally suited for achieving this aim by producing images with excellent contrast of these diffuse lesions and quantitative fraction images virtually free of spurious coil sensitivity variations. A significant decrease of the water fraction was observed with ongoing resorption of the hematoma which is consistent with our observations in PDw TSE scans[2] (data not shown). As shown, this resorption process seems to be mono-exponential. This systematic relationship might help to estimate the age of s.c. hematomas. However, variability is quite large, presumably because of considerable inter-individual variation, but also due to the evaluation process (drawing of ROI, repositioning) even though these influences were minimized. The application of IDEAL fat-water imaging can considerably improve forensic imaging practice by allowing an optimized detection and delineation of subcutaneous bruises, and by providing information on the age of hematomas.

References - 1. Bradley, Jr, WG, 1993. *Radiology*. 189:15-26. 2. Hassler et al, 2012. *Proc ESMRMB*. 364. 3. Reeder SB, 2004. *Magn Reson Med*. 51:35-45.