MR microscopy of human skin vasculature in vivo at 3 Tesla using a small copper surface coil

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Introduction

Observation of the cutaneous vessel tree by MRI might help to identify pathologies such as vasculitis at an early stage or follow the effects of treatment in a longitudinal study due to the non-invasiveness of the method. Resolving skin vessels with diameters <1mm requires very high spatial resolution. Due to the a priori unknown orientation of these vessels, isotropic voxels are the best choice [1]. To ensure sufficient SNR at small voxel volumes such as (100 µm)³=1 nl, highly sensitive, small surface coils must be used [2] to keep measurement time short enough to avoid strong motion artifacts.

Materials and Methods

Measurements were done on a 3T Bruker Medspec S300 (Bruker BioSpin, DE) using a transmit/receive surface coil (d=1.5 cm) (Rapid Biomedical, DE), on one healthy subject (f, 26y). A band-aid containing chili extracts (ABC Wärme-Pflaster, Beiersdorf AG, DE) for improvement of blood circulation was attached to the region of interest 2hrs before measurement. A blood-pool contrast agent (Vasovist®, Schering, DE) was applied 5min before the first measurement. Three identical acquisitions with the following 3D GE sequence were performed on the upper side of the thigh, 10 cm above the right knee: TR/TE=32.5/10ms, FOV=(17x11x17)mm³, MA=170x110x170, read-out BW=8kHz, flip angle=Ernst angle for the dermis, resulting in a scan time of 10min 7s. Read-out and slice selection directions were parallel to the skin's surface, so fold-over artifacts expected to arise in the direction perpendicular to the surface should not occur due to the sensitivity profile of the small surface coil. The FOV was chosen to be a compromise between acquisition time, image information, avoiding fold-over artifacts and gradient limitations. Because of the low read-out BW a chemical shift of ~9 voxels/0.9mm between water and fat is expected. Images were interpolated to an isotropic voxel size of (75µm)³ by zero-filling in order to improve accuracy for realignment and segmentation. The 3 datasets were realigned using SPM8b (The Wellcome Trust Center for Neuroimaging, UCL, U.K.) and averaged. Vessels were manually segmented using MRIcro (Chris Rorden, SC, U.S.A.) and 3D-rendered using MATLAB 7.4.0 (The MathWorks, MA, U.S.A.).

Results

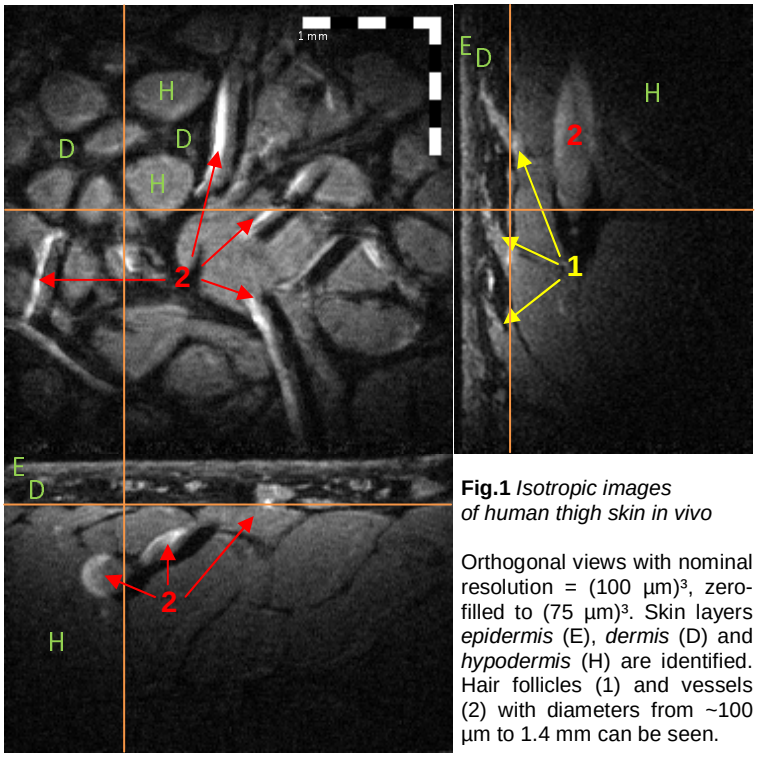

Fig.1 *Isotropic images of human thigh skin in vivo*

Orthogonal views with nominal resolution = (100 µm)³, zero-filled to (75 µm)³. Skin layers *epidermis* (E), *dermis* (D) and *hypodermis* (H) are identified. Hair follicles (1) and vessels (2) with diameters from ~100 µm to 1.4 mm can be seen.

The images obtained are shown in Fig. 1, the 3D rendering of the extracted vessel tree is shown in Fig. 2. Please note that the vessels' shadow-like appearance is due to the chemical shift between water and fat. As expected from dermatology textbooks, a layer of vessels parallel to the surface of the skin at the boundary between dermis and epidermis, the *deep vascular plexus*, was found. Vessel diameters in this region vary between 100 and 250 µm. Even smaller, more superficial vessels close to the border of epidermis and dermis forming the *superficial vascular plexus* can also be seen (not shown here), although with weaker contrast due to partial volume effects. For the same reason, vessel diameters in this region cannot be extracted reliably. The thicknesses of epidermis and dermis were measured to be 300 µm and 1.4 mm, respectively.

Fig. 2 *3D rendering of the segmented vessel tree,* extracted manually from the data set shown in Fig. 1. The largest vessel (d=1.4 mm) can be seen in both sections perpendicular to the skin surface in Fig. 1.
Note that the majority of the smaller vessels lie in the *deep vascular plexus* at the boundary of dermis and hypodermis (also in Fig. 1, bottom left)

Conclusions, Discussion, and Perspectives

We have shown, that using small surface coils and dedicated sequences, imaging of the human skin in vivo with an isotropic resolution of (100 µm)³ is feasible at reasonable scan times with normal conducting surface coils at 3 T. Small cutaneous and subcutaneous vessels are well delineated and SNR is sufficient for manual segmentation. At such high spatial resolutions, subject motion is one of the limiting factors for good image quality. Using rather short sequences (~10 min) limits motion and realigning images from individual scans cancels out movement that occurred between two scans. Averaging of these n realigned images improves SNR by $\sqrt{n}$. Also special care has to be taken for subject fixation, without exerting too high pressure on the skin which would squeeze the skin's small vessels. The strong chemical shift artifact can be turned into an advantage for this purpose, because it improves the visibility of the vascular system embedded in adipose tissue. For automatic segmentation of the vessel tree from the MRI data, sophisticated algorithms will have to be developed, based on morphologic filtering such as [3], or water-fat separation using [4]. The architecture of the vessel tree should be analyzed, possibly giving parameters helping to differentiate between healthy and pathologic appearance of cutaneous vasculature. The use of coil arrays will provide a larger FOV in direction of the skin surface and will also improve penetration depth. Imaging at even higher field strengths, e.g. 7T will further increase SNR allowing for even higher spatial resolution, first test are in progress.

References

[1] Laistler et al. 2007, Proc. ISMRM **15**, 326
[2] Darrasse et al. 2003, Biochimie **85**, pp. 915-937
[3] Frangi et al. 1998, MICCAI'98, Lect Notes in Comp Sci **1496**, pp. 130-137
[4] Ma JF. 2008, JMRI 27, pp. 881-890