MR Morphological Characterization of Human Skin Using Phased Array Microcoils at High-Field

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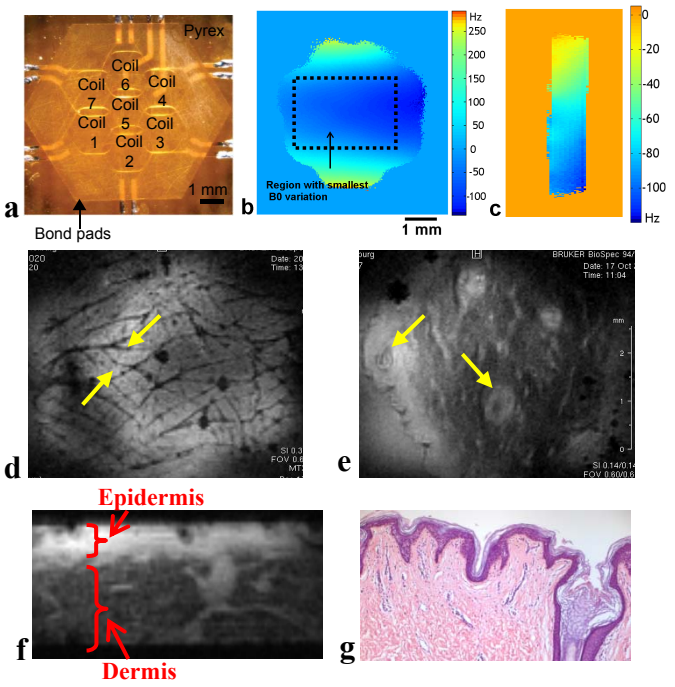
Introduction

There is a growing interest to extend the resolution of conventional MR systems from millimeter to micrometer range in order to resolve small samples structure as for instance the human skin with its cellular and matrix network. One of the current methods of choice for highly-resolved morphological characterization of the human skin is histopathology [1]. If the spatial resolution, contrast and sensitivity are sufficient, MR microscopy can be used as a powerful instrument for *in vivo* investigation of the human skin as an alternative to invasive histopathology sampling. The key obstacle to overcome when imaging the skin is the decrease in signal to noise ratio due to the low sensitivity of MR microscopy as previously reported in [2, 3]. A reason for that is the layered structure of the skin demanding an extremely high resolution over an enhanced FOV. In this context, a home-made microcoil-based MR detector arranged in a phased-array geometry [4] has been developed to alleviate such limitations by combining the advantages of large FOV and high SNR. The presented phased array (planar) microcoil was first characterized in terms of B_0 homogeneity and signal to noise ratio per unit volume (SNR/mm^3). These first feasibility studies allow the acquisition of high-resolution images of healthy human skin.

Material and Methods

Seven helical overlapping coils form the phased array of microcoils, with the arrangement shown in figure (**a**). Each coil element made of electrically insulated gold wire is embedded in SU8. The phased array microcoil is mounted on a PCB, carrying the required circuitry for all seven coils for tuning, matching and active decoupling from the transmit coil. Experiments were performed on a 9.4 T Bruker Biospec animal scanner. The phased array microcoil was used in receive mode, with a circularly polarized ^{1}H coil in transmit mode. The B_0 maps were computed from a 3D double gradient-echo image (TR = 300 ms, TE_1 = 5.7 ms, TE_2 = 13.5 ms, resolution: 35 µm isotropic, acq. time: 40:56 min). For these experiments, coils were loaded with water doped with CuSO4 ($T_1/T_2 \approx 250/205$ ms).

For human skin measurements, a fresh, small axillary skin biopsy sample was inserted into a PMMA container (height = 2 mm) that was filled with nutrient solution to keep the skin in a sustainable environment during measurement. Imaging was performed using a multi-slice GE sequence with: TR = 300 ms, TE= 6.7 ms, flip angle = 60°, resolution 40 ×40 ×200 µm^3 scan time of 4 min 19 s (coronal) and 35 x 35 x 200 µm^3 (axial), scan time 21 min 36 s. The flip angle was estimated based on the T_1 values of epidermis as shown in [2]. The slices were oriented parallel (**d**, **e** - coronal) and perpendicular (**f** - axial) to the surface of the skin. A histological image depicting the layered structure of the skin is shown in figure (**g**). A Hematoxylin Eosin staining was done to emphasize the skin structure.



***a:** Phased-array microcoil design; **b:** B_0 map in coronal and **c:** axial plane; **d:** Example of a axillary skin sample in coronal view; yellow arrows - defined rhombic fields (Areolae cutaneae) on the skin surface; black, round-shaped spots may correspond to the hair location at the surface of the skin; **e:** the white round areas correspond to hair follicles with their sebaceous glands; **f:** MR image of the skin structure including epidermis and dermis in axial view; **g:** Histology cut of normal skin in HE staining (250 x = 10 µm).*

Results/Discussion

B_0 field of phased-array microcoils: The B_0 variation was homogenous in the central part of the coil (framed area in **b**) with frequency shifts not exceeding 100 Hz). A maximal value of 250 Hz was observed close to the feeding wires of channel number 6 and 2.

Characterization of human skin: The coronal view shows the outer layer of the skin with its defined rhombic field structure appearing as dark contrast (**d**) and the cross sections of hair follicles with their sebaceous glands as brighter contrast (see yellow arrows, **e**).

The outer skin is principally built of three layers, epidermis, dermis and subcutis. The axial slice (**f**) reveals the expected layered structure of the skin. The white layer corresponds to the epidermis, because of the higher water content, with a measured thickness of 347.1 ± 26.6 µm. The grey innerlayer including the arrector pili muscles attached to hair follicles corresponds to the demis. The reduced coil sensitivity perpendicular to the skin surface did not provide sufficient SNR for detecting the subcutis structure. The corresponding histological image of healthy human skin shown in (**g**) for comparison confirms the results obtained by MRI.

Conclusion

In this work we demonstrate that MR microscopy can be performed using phased array microcoils that provide a sufficient homogenous B_0 variation and allow to delineate the skin substructure within a reasonable short scan time. This approach enabled high-resolution imaging of *ex vivo* human healthy skin biopsies with a very good contrast between skin layers and a resolution comparable to histology. The presented results make this approach very suited for the characterization and early detection of skin structural changes. Specifically, future studies will focus on the investigation of a chronically relapsing suppurative inflammation of skin called *Akne inversa* where epithelial sinuses penetrate into the dermis, leading to fibrosis of the tissue with time.

References/Acknowledgements: [1] Kanitakis J, Eur J Dermatol. 2002; 12(4): 390-401. [2] Sharma R, Skin Res Technol. 2010;16: 339-353. [3] Canuto HC, et *al.* NMR Biomed. 2011, *in press*. [4] Gruschke O, et *al.* In: Transducers, Beijing, China 2011. This work was supported by the European Union (FP6-NEST-2004: Micro-MR).