MR Microscopy of Diseased Human Skin Using Phased-Array of Microcoils at 9.4 T: First Results

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Purpose

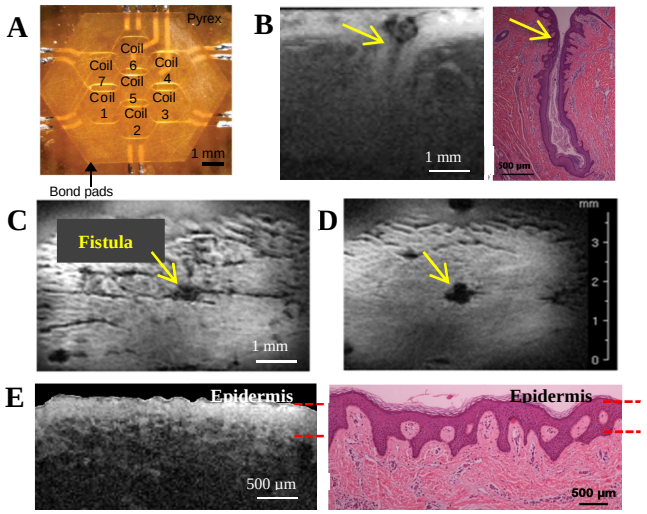
The examination of the skin structure is fundamental for accurate disease diagnostics as well as for the evaluation of the efficiency of applied therapeutic strategies. Currently, invasive surgical procedures, such as skin biopsies, followed by histopathology [1] are necessary to establish the diagnosis. MR imaging of the skin as non-invasive alternative to biopsy is very challenging as dedicated approaches are required to overcome the low sensitivity and contrast of standard MR investigations applied at microscale. The geometry of the skin with layers of large lateral dimensions and micrometre thickness demands extremely high resolution (approx. 10 µm voxel size) combined with large imaging matrix size.

In our work, a home-made MR detector arranged in a phased-array geometry [2] has been developed to overcome these challenges. Based on previous findings about coil performance and its feasibility to perform high-resolution imaging of healthy human skin [3], we present first MR results on structural differentiation of diseased skin (Acne inversa) from healthy skin biopsies with direct comparison to histopathological sampling.

Methods

The presented microcoil device (diameter = 5.5 mm) consists of seven small overlapping gold coil elements each connected to the individual receiver channels of the MR system (**A**). 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 conventional horizontal 9.4 T Bruker BioSpec 94/20 USR system (Bruker BioSpin, Ettlingen, Germany). The phased array microcoil was used in receive mode together with a linearly polarized ^{1}H coil in transmit mode.

For human skin measurements (both Acne inversa-diseased and healthy skin), a small part of a fresh skin biopsy was inserted into a hydrophilic PMMA container (height = 3 mm) sealed on one side with adhesive PCR tape. The epidermis was placed with direct contact to the bottom of the container. The skin was covered with nutrient solution to keep the sample in a sustainable environment during measurement. The imaging slices were oriented parallel (**C**, **D** - coronal) and perpendicular (**B**, **E** - axial) to the surface of the skin. Imaging was performed using a multi-slice gradient echo (GE) sequence with: TR = 300 ms, TE = 6.7 ms, flip angle = 60°, NEX = 50, four slices, resolution 35×35×170 µm³ and a scan time of 21 min 30 s (axial, **B**) and NEX = 14, four slices, 40×40×140 µm³ scan time 11 min 28 s (coronal, **C**, **D**). High-resolution axial images of the healthy skin (**E**) were acquired with TR = 300 ms, TE = 7.24 ms, flip angle = 70°, NEX = 80, four slices, resolution 30×30×100 µm³, scan time 26 min 24 s. The flip angle was estimated based on the T_1 values of epidermis as shown in [4]. Histology (Hematoxylin Eosin staining) was subsequently performed after the MR measurements to identify structural abnormalities of the diseased skin compared to the corresponding healthy situation.



A *Phased-array microcoil design;* **B** *Axial slice of an axillary Acne inversa skin sample depicting the typical epithelial sinus penetrating the dermis and epidermis (GE sequence, resolution 35×35×170 µm³, T_{scan} = 21 min 30 s); corresponding histological image depicting the location of fistula through the skin;* **C, D** *Coronal view of the same axillary Acne inversa skin sample clearly depicting the epithelial sinus through consecutive slices parallel to the surface of the skin (GE sequence, resolution 40×40×140 µm³, T_{scan} = 11 min 28 s);* **E** *High-resolution MR image of healthy skin revealing the epidermis and dermis in axial view (GE sequence, resolution 30×30×100 µm³, T_{scan} = 26 min26 s); corresponding immunohistochemical investigation (HE staining) of the same skin sample validating the MRI results.*

Results/Discussion

Acne inversa is a chronically relapsing suppurative inflammation of the skin where epithelial sinuses penetrate into the dermis, leading to fibrosis of the tissue over time. The axial slice (**B**) of the diseased skin reveals the expected layered structure of the skin with the typical inflammation site penetrating through the epidermis. The corresponding histological image depicts a similar shape and dimension of the fistula as the MRI. The coronal view through epidermis (**C**) shows the epithelial sinus crossing the skin surface through the 520 µm package of four consecutive slices of 140 µm thickness each, enabling accurate spatial location of the fistula (**D**). A high-resolution image of a healthy skin biopsy is shown in (**E**) for comparison. The brighter outer layer corresponds to the epidermis, because of the higher water content followed by the grey inner layer of dermis. The corresponding histological images of both affected and healthy human skin shown in (**B**, **E**) confirm the results obtained with MRI.

Conclusion

The here presented results demonstrate the ability of MR microscopy to delineate the skin layers with contrast and resolutions comparable to histology and to accurately identify the typical location of the inflammatory sites in the Acne inversa disorder. This methodological approach is therefore suitable for the characterization and early detection of structural changes of the skin. Next steps will take advantage of the phased-array configuration of the presented microcoil to further accelerate the MR acquisition using parallel imaging that will enable faster and accurate screening of representative changes of diseased skin morphology. At longer term, with the introduction of MR microscopy into the skin cell biology workflow, a simplification of the current diagnostic procedure is expected with a better understanding of normal and pathological skin structure and physiology.

References/Acknowledgements: [1] Kanitakis J, Eur J Dermatol. 2002; 12(4): 390-401. [2] Gruschke OG et al, Lab Chip. 2012; 12(3): 495-502. [3] Göbel K et al, In: Proc ISMRM, Melbourne, Australia, 2012, p. 2380. [4] Sharma R, Skin Res Technol. 2010; 16: 339-353.

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