The new frontier of imaging: the micron

Sirs,

Radiology is starting to explore micron-sized anatomical structures. The technological breakthroughs which allowed to achieve these previously unreachable results in terms of spatial resolution are the introduction of very high-frequency ultrasound (VHFUS) with advanced probes up to 70 MHz and ultra high magnetic fields up to 7 T in magnetic resonance imaging (UHF-MRI). Concerning rheumatologic applications, we focused on the depiction of fine anatomical cartilage alterations both at VHFUS and at UHF-MRI.

A recent feasibility study was performed involving the examination of metacarpophalangeal joint (MPJ) cartilage in ten healthy male volunteers, who were divided into two groups: Group A (five subjects, mean age 32, range 29–33) and Group B (five subjects, mean age 63, range 57–68). We compared the measurements obtained using VHFUS probes (70 MHz). We analysed the MPJ of the second and third finger of the non-dominant hand and then measured the thickness of the cartilage with the flexed finger. Our results show a difference between the average thicknesses obtained in the two groups (Fig. 1a-b). In fact, such difference is in the order of hundreds of microns.

For the MPJ of the second finger, we found a median thickness of 800 micron in group A and 356 micron in group B (p=0.008 – Wilcoxon rank sum test). For the MPJ of the third finger, we found a median thickness of 656 micron in group A and 308 micron in group B (p=0.07 – Wilcoxon rank sum test). These values identify a statistically significant trend that warrants further investigation with a larger sample size. Furthermore, small calcifications of the cartilage profile have been identified in Group B.

These results indicate a promising role of this imaging modality in the early evaluation of cartilage alterations, both in osteoarthritis and other forms of arthritis.

Concerning MRI, medium and high-field MRI (between 1 T and 3 T) has been recognised as the standard imaging technique for cartilage evaluation due to its capability to directly visualise the cartilage with sufficient contrast, assessing its morphological appearance. However, innovations in therapeutic strategies require more detailed information such as quantification of the volume and the analysis of cartilage's biochemical composition, in order to diagnose and manage disease at the earliest stages (1). However, medium and high-field-MRI is unable to precisely evaluate the changes that occur in cartilage physiology prior to morphological changes. Recently, the introduction of the UHF-MRI allowed achieving a significantly higher Signal-to-Noise Ratio and Contrast-to-Noise Ratio, which allows us to reach a very high spatial resolution and to obtain more accurate volume quantification with sophisticated biochemical analysis of cartilage (2-5). We recently optimised a dedicated UHF-MRI protocol to precisely evaluate the morphology, quantify the volume and generate specific highly accurate T2 and T2* maps to perform biochemical analysis of cartilage. This non-invasive technique has the potential to substitute histology in defining early cartilage changes (age-related or disease-specific) with spatial resolution up to 100 micron (Fig. 1c-h, shows the comparison between 1.5 T, 3 T and 7 T). Furthermore, UHF-MRI permits to estimate cartilage content of water, proteoglycan and collagen.

It can be anticipated that Rheumatology will greatly benefit from these advantages in high-resolution imaging: the accurate depiction of micron-sized alterations at the very early stages of disease will improve the therapeutic management of patients, and possibly change the natural history of many rheumatologic diseases.

Future studies should be aimed at evaluating arthritic patients to identify imaging parameters that can be used as early diagnostic signs in different arthritic pathologies. VHFUS and UHF-MRI may be particularly useful when conventional US and MRI examinations are insufficient to obtain an accurate diagnosis and a higher resolution of the joints is required.

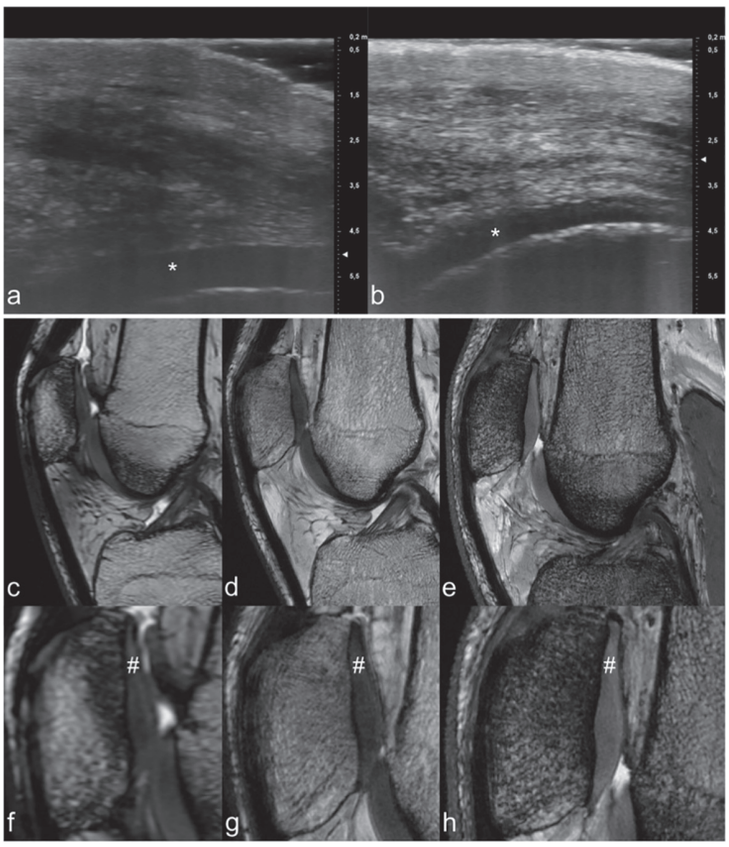

Fig. 1. a-b: A comparison between articular cartilage of metacarpophalangeal joints of the first finger is shown. We can observe the thinned cartilage (*) of a 66-year-old male (**b**) compared to a younger subject 34 years old (**a**). Images **c-e** show the knee cartilage in the same 31-year-old male at medium field MRI 1.5 T (**c**), high field MRI 3 T (**d**), and UHF-MRI 7 T (**e**). Comparing the images acquired at increasing field strength, we can observe an improvement in spatial resolution and image detail.
Images **f-h** focus on the patellar cartilage (#) and show a better definition of the borders and a higher spatial resolution obtained at 7 T, with a pixel size of 130 micron (**h**), in comparison with 1.5 T (**f**) and 3 T MRI (**g**).

G. ARINGHIERI, *Radiologist and Researcher*
S. VITALI, *Radiologist and Researcher*
P. ROSSI, *MD, Radiology Resident*
D. CARAMELLA, *Radiology Professor*

Radiology, Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Italy.

Please address correspondence to:
Dr Giacomo Aringhieri,
Radiodiagnostica 1, Ospedale di Cisanello,
via Paradisa 2, 56124 Pisa, Italy.
E-mail: g.aringhieri@gmail.com

Competing interests: none declared.

Received on October 16, 2017; accepted in revised form on October 27, 2017.

References

1. LINK TM, STAHL R, WOERTLER K: Cartilage imaging: motivation, techniques, current and future significance. *Eur Radiol* 2007; 17: 1135-46.
2. WELSCH GH, JURAS V, SZOMOLANYI P *et al*.: Magnetic resonance imaging of the knee at 3 and 7 Tesla: a comparison using dedicated multi-channel coils and optimised 2D and 3D protocols. *Eur Radiol* 2012; 22: 1852-9.
3. MOSER E: Ultra-high-field magnetic resonance: Why and when? *World J Radiol* 2010; 2: 37-40.
4. STAHL R, KRUG R, KELLEY DA *et al*.: Assessment of cartilage-dedicated sequences at ultra-high-field MRI: comparison of imaging performance and diagnostic confidence between 3.0 and 7.0 T with respect to osteoarthritis-induced changes at the knee joint. *Skeletal Radiol* 2009; 38: 771-83.
5. MATZAT SJ, VAN TIEL J, GOLD GE, OEI EH: Quantitative MRI techniques of cartilage composition. *Quant Imaging Med Surg* 2013; 3: 162-74.