Cartilage destruction in small joints by rheumatoid arthritis: assessment of fat-suppressed three-dimensional gradient-echo MR pulse sequences in vitro

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Abstract Purpose. To assess the accuracy of different MR sequences for the detection of articular cartilage abnormalities in rheumatoid arthritis.

Design and patients. Ten metacarpophalangeal joints and 10 metatarsophalangeal joints (specimens from arthritis patients undergoing ablative joint surgery) were examined with a fat-suppressed (FS) 3D FLASH, a FS 3D FISP, a FS 2D fast spin-echo T2-weighted, and a 2D FS spin-echo T1-weighted sequence. Each cartilage lesion and each cortical lesion was graded from 0 to 4 (modified Outerbridge staging system). Subsequently, the results of each sequence were compared with the macroscopic findings and statistically tested against each other.

Results. The study shows that 3D gradient-echo techniques were best for imaging and grading of cartilage lesions in arthritis of the small joints of the hands and feet. Using 3D techniques, all grade 2, grade 3, and grade 4 lesions of cartilage or cortical bone were detected.

Conclusion. FS 3D gradient-echo techniques were best for the detection and grading of hyaline cartilage and subchondral bone lesions in rheumatoid arthritis. MRI has a great potential as an objective method of evaluating cartilage damage and bone erosions in rheumatoid arthritis.

Key words Cartilage, MR · Magnetic resonance imaging (MRI), technology · Rheumatoid arthritis, diagnostic · Joints, MRI

Introduction

Rheumatoid arthritis is a chronic symmetric polyarthritis with characteristic involvement of the metacarpophalangeal and metatarsophalangeal joints. Persistent inflammation results in a variety of typical deformities, which can be attributed to a number of pathologic processes including cartilage destruction, weakening of ligaments and tendons, and destruction of joint capsules. Since cartilage plays a crucial role in maintaining normal joint function, and because of the frequent occurrence of cartilage lesions in rheumatoid arthritis, the development of an accurate noninvasive method for chondral evaluation may be important in arthritis imaging. A multitude of MR pulse sequences has been proposed for imaging articular cartilage abnormalities. These include T1-weighted [1], proton-density-weighted [2], and T2-weighted spin-echo sequences [3], inversion recovery sequences [4], magnetization transfer contrast sequences [5], fat suppressed two- or three-dimensional gradient recalled echo sequences [6], and three-dimensional spoiled gradient recalled echo sequences with short TE and small flip angle [7]. Their reported sensitivity for detecting lesions of cartilage ranged from a low of 31% [8] to a high of between 81% [9] and 100% [8]. Nearly all these studies were undertaken in knee joints and not in the small joints of the hand and feet [7–10]. Cartilage destruction caused by rheumatoid arthritis has not been examined. Small joints need MRI techniques that provide greater spatial resolution for detecting very small cartilage lesions.

In an attempt to identify which sequence is most appropriate, we optimized four different types in an in vitro
pilot study. They were subsequently compared in the assessment of arthritic cartilage lesions and subchondral cortical lesions in 20 typically affected small joints of the hands and feet.

**Materials and methods**

Metacarpophalangeal (MCP) and metatarsophalangeal (MTP) joints were obtained from patients undergoing joint surgery and joint replacement.

Pilot study

We imaged three formalin-fixed human MCP joints with a 1.5 T MRI system (Siemens Magnetom Vision, Siemens, Erlangen, Germany) using 3 mm sagittal sections with 0.5 mm intersection gaps (small-loop coil, diameter 50 mm).

Optimization of the gradient echo sequences

FLASH (fast low-angle shot, SPGR) (TR=48 ms), and FISP (fast imaging with steady-state precession, SSFP) (TR=45 ms) was achieved by varying the flip angles of both gradient echo techniques (30°, 40°, 60°, 90°), and combining each flip angle with two different echo delay times (TE=11 or 12 ms, 20 or 21 ms). Both sequences were studied with a spectral fat suppression technique. This gave a total of eight different imaging parameters for each gradient-echo technique. The signal intensities of cartilage, bone marrow, and background noise were measured and compared. Contrast-to-noise (C/N) ratios for cartilage versus bone marrow were calculated as the signal intensity of cartilage minus the signal intensity of bone marrow divided by the standard deviation of noise. In addition, images were evaluated by three of the authors with regard to their demonstration of the internal structure of cartilage. The signal intensity and the C/N ratios are given in Fig. 1.

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**Fig. 1**

A Signal intensity (S/N ratio) of cartilage in different FLASH and FISP sequences (n=3 joints). B Contrast-to-noise (C/N) ratios for cartilage versus bone marrow in FLASH and FISP sequences with different flip angles and echo times. (TE echo time, FS fat saturation; n=3 joints)