Quantitative in vivo diffusion imaging of cartilage using double echo steady-state free precession

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Author(s) Bieri, Oliver; Ganter, Carl; Scheffler, Klaus
Author(s) at UniBasel Bieri, Oliver ;
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Single-shot echo-planar imaging techniques are commonly used for diffusion-weighted imaging (DWI) but offer rather poor spatial resolution and field-of-view coverage for species with short T(2) . In contrast, steady-state free precession (SSFP) has shown promising results for DWI of the musculoskeletal system, but quantification is generally hampered by its prominent sensitivity on relaxation times. In this work, a new and truly diffusion-weighted (that is relaxation time independent) SSFP DWI technique is introduced using a double-echo steady-state approach. Within this framework (and this is in contrast to common SSFP DWI techniques using SSFP-Echo) both primary echo paths of nonbalanced SSFP are acquired, namely the FID and the Echo. Simulations and in vitro measurements reveal that the ratio of the Echo/FID signal ratios of two double-echo steady-state scans acquired with and without diffusion sensitizing dephasing moments provides a highly relaxation independent quantity for diffusion quantification. As a result, relaxation-independent high-resolution (0.4 x 0.4 - 0.6 x 0.6 mm(2) in-plane resolution) quantitative in vivo SSFP DWI is demonstrated for human articular cartilage using diffusion-weighted double-echo steady-state scans in the knee and ankle joint at 3.0 T. The derived diffusion coefficients for cartilage (D approximately 1.0-1.5 mum(2) /ms) and synovial fluid (D approximately 2.6 mum(2) /ms) are in agreement with previous work. Magn Reson Med, 2011. (c) 2011 Wiley Periodicals, Inc.
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