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Fast Field-Cycling MRI: Demonstration of New Technology for T1-Dispersion Contrast

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PURPOSE

We have designed and constructed two prototype human-scale scanners which use Fast Field-Cycling (FFC) to measure the variation of tissues' spin-lattice relaxation time (T1) as a function of magnetic field strength ("T1-dispersion"), in the range 0.001 T to 0.1 T. T1-dispersion is shown to be sensitive to disease state.

METHOD AND MATERIALS

In an FFC-MRI scanner the magnetic field B0 is switched between three levels during the scan. Initially B0 is set at a high level in order to polarize the spins. It is then switched to a low value for a time of the order of T1, so that the spins evolve. B0 is then switched back to a high value, gradients are applied and NMR signals detected. By repeating the pulse sequence at different "evolution" B0 values, T1-dispersion can be measured and employed as a contrast generator. Detection always occurs at the same field, so no retuning of radiofrequency coils is needed.
The FFC-MRI scanner used was designed and constructed in-house, using commercially-available and home-built modules. The whole-body magnet uses a double coaxial design, in which the polarization and detection B0 fields are generated by a Halbach-ring permanent magnet (59 mT). This field is opposed by an inner "offset" resistive magnet in order to generate the lower, evolution B0 values. The evolution field is controlled by changing the current in the offset coil; switching between field levels can be done in ca. 30 ms.
Measurements were made on healthy volunteers and on surgically-excised tissues from patients undergoing joint-replacement surgery (normal and osteoarthritic (OA) joints) and resection of breast and musculoskeletal tumours. Full ethical approval was granted, and patient consent was obtained.

RESULTS

Measurements on healthy volunteers show that good quality FFC-MRI images can be obtained. The figure shows inversion-recovery calculated-T1 FFC-MRI images of a volunteer's brain, at 49 mT and 59 mT evolution B0 values; total acquisition time was 28 min.

T1-dispersion plots (T1 versus evolution B0) showed significant differences between normal and diseased tissues, in both OA and in cancer.

CONCLUSION

This work shows that FFC-MRI is a new imaging modality which can, for the first time, use T1-dispersion as an endogenous MR contrast mechanism which is invisible in conventional MR. Early results show sensitivity of T1-dispersion to disease state.

CLINICAL RELEVANCE/APPLICATION

Study shows relevance to osteoarthritis and cancer.