Optimized MR-guided Biopsy with SSFP and a Hybrid Injection Scheme

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Introduction

MRI has been shown to have a higher sensitivity to breast tumors than mammography and ultrasound (1). For patients with a breast lesion diagnosed on MRI and not visible on other imaging modalities, a MRI-based follow-up procedure is critical. Unlike under other imaging modalities, MR-guided breast biopsy is limited in time by the contrast kinetics of the tumor and surrounding tissues. Cases of the "vanishing target" have been reported at later times during the procedure (2) (3). One example is shown in Fig.1. In these cases, the physician may only have 10-15 minutes to perform the procedure on single or multiple lesions. A prolonged period of lesion enhancement would be preferable in order to provide the means to target and biopsy several lesions. The purpose of this work was to optimize MR-guided biopsy by optimizing the MR sequence and the timing of the contrast injection.

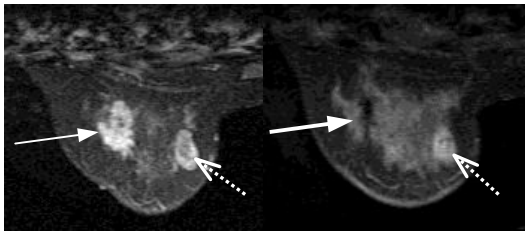

Fig.1 Breast MR images acquired during a wire localization procedure. The cancer (solid arrow) vanished quickly, while the fibroadenoma (dashed arrow) persisted.

Theory and Method

Fully refocused SSFP sequences provide high SNR efficiency when the TR is shorter than the tissue T2 (7). A phantom study was designed to demonstrate the improvement in CNR-efficiency of SSFP over 3pt Dixon GRE (TE/TR = 21/200 ms), which is the current standard sequence for MR-guided core biopsy on our 0.5T GE Signa SP MRI scanner. The phantom consisted of 5 tubes filled with agar gel. One of them had T1/T2 of 590/51 ms as in fibroglandular tissue; others had an initial T1/T2 of 715/60 ms as in suspicious breast lesions (4), then were doped with [40%,60%,80%,100%]*0.45mMol/L of Gd-DTPA, to simulate partial and full doses respectively (a single dose of 0.1mMol/kg results in an initial average concentration of 0.45mMol/L in tumors). SSFP and GRE images of the phantom were acquired with same spatial resolution on a 1.5T scanner (Signa, GE). CNR efficiency was measured and compared with computer simulation.

Using Tofts' model (5) (6), we simulate the lesion-background tissue contrast with the SSFP and the GRE sequences. This is done both for the contrast material given in a conventional bolus and for a hybrid injection, where a fraction of the contrast is given in an initial bolus and the remaining fraction is given evenly spaced through the 30-min procedure. For this simulation, one rapidly vanishing lesion was picked from 46 patient studies of rapid dynamic contrast-enhanced breast MRI acquired at a 1.5T scanner. The signal time courses of tumor and fibroglandular tissue were fit to Tofts' model, and the tumor's visibility during the biopsy is predicted from k and V_I.

Results

Using an SSFP sequence, we defined the minimum dose required as the fraction of dose that will provides the same CNR efficiency currently achieved with our 3pt Dixon GRE sequence using one full dose of Gd-DTPA. Fig.2 demonstrates that the dose needed to obtain this level of contrast can be dramatically reduced with SSFP to as low as 40% at a TR of 4 ms. The remaining 60% can then be used to prolong lesion enhancement.

Fig.3 demonstrates the simulated contrast enhancement curves. Parameters used for this simulation were T1/T2=715/60 and k/V_I=0.5/0.6 for tumor, and T1/T2=590/50 and k/V_I=0.05/0.5 for surrounding fibroglandular tissues. With the conventional imaging methods, this tumor will lose conspicuity after 15min. Better contrast is obtained with the SSFP sequence, with most improvement during the first 10 minutes. Spreading the improvement over 30 minutes with the hybrid injection provides a more stable contrast enhancement throughout the 30-min procedure. A similar method was implemented in CT angiography (9).

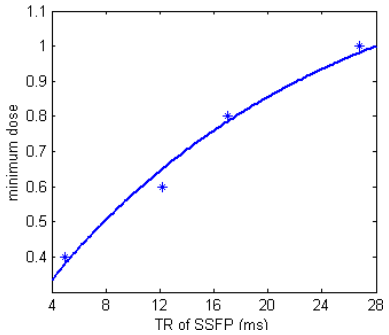

Fig.2 Reduction of contrast material allowed by imaging with a SSFP sequence compared to a GRE sequence. Phantom results are shown by asterisks, simulation results are shown by the solid line.

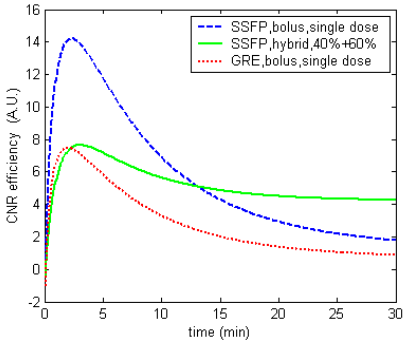

Fig.3 Comparison of contrast time courses of GRE sequence and SSFP sequence. All are constrained to a single dose of Gd-DTPA.

Conclusion and Discussion

In this work we present a technique that combines SSFP imaging with a hybrid injection of contrast material to optimize MR-guided core biopsy. By acquiring pre-contrast T1/T2 and pharmacokinetic parameters in diagnostic MRI as a prior knowledge, the contrast enhancement time course could be individually tailored. Some researchers suggested that the linear dependence of exchange rate on concentration difference might be violated by fibrosis and hydrostatic pressure (8). In these cases, the actual contrast would be higher than the simulation predicted. Nevertheless, using SSFP would still yield higher CNR efficiency, and the hybrid injection could offer options to enhance the contrast over the length of the procedure.

Reference

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