Implementation of an interactive real-time MRI acquisition and display for improving efficiency and accuracy of MR-guided breast interventions

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INTRODUCTION

MRI can be an important tool in the early detection of breast lesions and may provide improved capability for imaging-guided interventions (IGI) and therapies (IGT). During an MR-guided breast intervention, placement of a needle or probe requires accurate localization of the target. An unsuccessful needle placement can occur if the target moves from its original position during the insertion or the patient moves after the planning images were acquired, between the acquisition of roadmap images and the needle insertion. To allow rapid identification of these errors, avoid unnecessary trauma to the patient, and minimize scanner time, a real-time MR acquisition and display was implemented to allow the physician to monitor both the progress of the insertion and the procedure itself, such as core needle biopsy or tumor ablation. Flexibility was added to adjust the scan plane in real-time and make tradeoffs between update display rate and image quality.

METHODS

A breast image volume is conventionally acquired and loaded into a Graphical User Interface (GUI) developed using the OpenGL Graphics API[1] for target selection and trajectory manipulation occur (**Fig 1a**). The mechanical insertion of the needle/probe is facilitated by a true 3D breast interventional device (**Fig 1b**) that provides circumferential access to the breast, allowing a trajectory from any coronal angle [2]. This flexibility allows superior access to the target while in the magnet bore, allowing MR imaging during the procedure. When the real-time option is selected, a double oblique imaging plane that includes the calculated trajectory and target is automatically selected using the three-point localization method [3]. Interactive control of the real-time acquisition is achieved using messages passed to the pulse sequence control program by XML-RPC [4]. Adjustments to the position or angle of the imaging plane can be made in real-time to continuously track the needle tip position, the target, or both by changing real-time variables within the pulse sequence. Our initial implementation uses a two-dimensional SPGR pulse sequence which samples radial k-space lines incremented angularly using the Golden Angle method [5]. This allows an arbitrary number of consecutive projections to be grouped while still maintaining uniform sample spacing, giving the user interactive control over the desired amount view sharing (**Fig 2**) without pausing the scan to adjust parameters. A wider window improves SNR and reduces streak artifact but reduces temporal resolution and leads to blurring in the case of motion. Interactive control provides the user the ability to adjust these parameters in real-time. The image updates appear in the same graphical display in which the trajectory planning was performed.

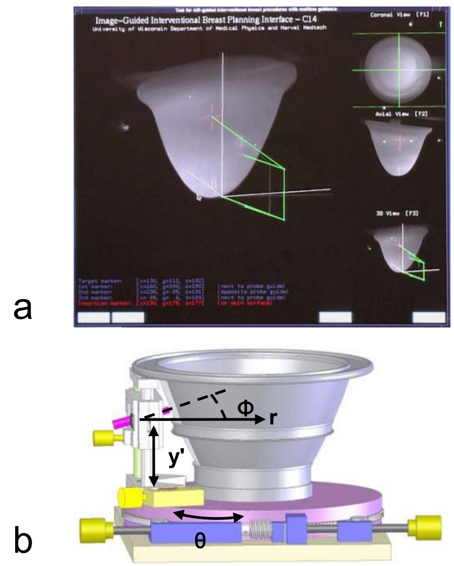

Fig 1. (a) Graphical user interface for lesion targeting and trajectory planning. The 3D volume can be rotated freely and orthographic maximum intensity projections MIP are displayed (right column) to facilitate trajectory planning. The trajectory positioning output generated by the planning algorithm is displayed for localization of the target. Real-time image updates are displayed within this main GUI window. (b) Interventional device that allows circumferential access to the breast. Four degrees of freedom are represented.

RESULTS

Rapid, real-time reconstruction and display was implemented (**Fig 3**). Reconstruction times varied depending on the number of projections used. For 128 projection angles, reconstruction took on average 30 msec. The reconstruction time and the time to render the new image combine to be the inherent latency and is less than 200 msec.

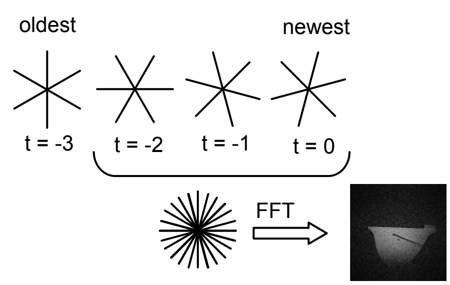

Fig 2. View sharing used in the reconstruction. Unique projection angles from the past are used to provide a high SNR image. Real-time control over the amount of view sharing has been implemented.

DISCUSSION

Rather than depending on the performance of the MR-guided interventional systems, feedback from real-time MR visualization can allow verification of needle placement, ensuring successful localization. Adjustments can be made to the trajectory early to minimize unnecessary trauma to the patient. Future work includes allowing interactive switching between different imaging sequences such as SSFP and SPGR in addition to GRE to increase flexibility in image contrast, as well as more efficient k-space trajectories [6]. Optimization of the real-time rendering in the GUI display window could also minimize the inherent latency.

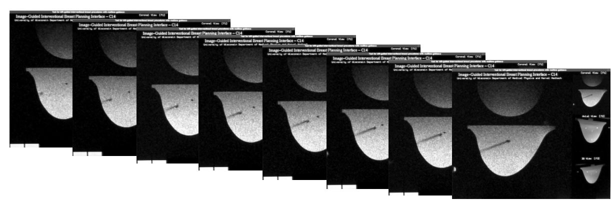

Fig 3. Image updates over time with an update rate of ~300 msec. Needle trajectory is visualized along with the target in the same plane. Adjustments to the imaging plane location can be made in real-time. Image quality is also user controlled and is related inversely to update rate.

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