MRI compatibility study of a pneumatically actuated robotic system for transperineal prostate needle placement

S. Song[1], N. Cho[1], J. Tokuda[2], N. Hata[2], C. Tempany[2], G. Fichtinger[3], I. Iordachita[1]

[1] ERC-LCSR, The Johns Hopkins University, Baltimore, MD, US
[2] NCIGT, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, US
[3] Queen's University, School of Computing, Kingston, Canada

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Purpose

Transrectal ultrasound (TRUS) guidance is the most commonly used needle navigation method for prostate biopsy and brachytherapy. However, TRUS-guided biopsy has a poor cancer detection rate [1]. In order for greater detection rate, magnetic resonance imaging (MRI) has been used, since MRI has high sensitivity for detecting prostate tumor, high spatial resolution, and multi-planar volumetric imaging capabilities [2]. With the enhanced MRI targeting capability, a number of robotic assistants have also been introduced to increase the needle placement accuracy [3, 4, 5]. However, due to the strong magnetic field and physical limitation of the confined in-bore workspace and access, such robot developments have not been successfully implemented in clinic. To overcome such problems, we have developed a pneumatically actuated robotic system that can operate inside high-field MRI bore for the prostate intervention [6]. As a preliminary evaluation of the robot development, a MRI compatibility study has been conducted with three widely used MRI scanners.

Methods

In order to determine the effects of the robotic system on the MRI imaging, in other words, to quantify MRI compatibility, signal-to-noise-ratio (SNR) was obtained using National Electrical Manufacturers Association (NEMA) standard method [7]. Tests were performed on three 3T MRI scanners: Philips Achieva (Philips Medical Systems), GE Excite HD (GE Healthcare), and Siemens Magnetom Verio (Siemens AG). Two widely used T1 and T2 weighted imaging sequences with parameters that are used for usual patient prostate scanning, were used for the compatibility study. Each set of experiments consisted of the phantom being imaged alone (baseline) and subsequently imaged under following four configurations: 1) Baseline. 2) System in place: Image the phantom after placing the robot. The phantom and robot position approximate prostate and robot position in a clinical procedure. The controller is located in the scanner room but is powered off. 3) System powered: Image the phantom after powering the controller on but piezo servo valves are not enabled. 4) Servoing: piezo servo valves are servoing. Often, MRI scanner room is equipped with electromagnetic noise filtered patch panel. This allows an AC-DC power converter for the controller to be located outside the scanner room to minimize electromagnetic noise. However, at Siemens scanner room, patch panel was unavailable so that the converter was located inside the scanner room. Ten (five for a few scan sequences) axial image slices close to the center of the spherical phantom were obtained for each configuration for each imaging sequence. Fig. 1 shows a MRI compatibility study (SNR test) setup.

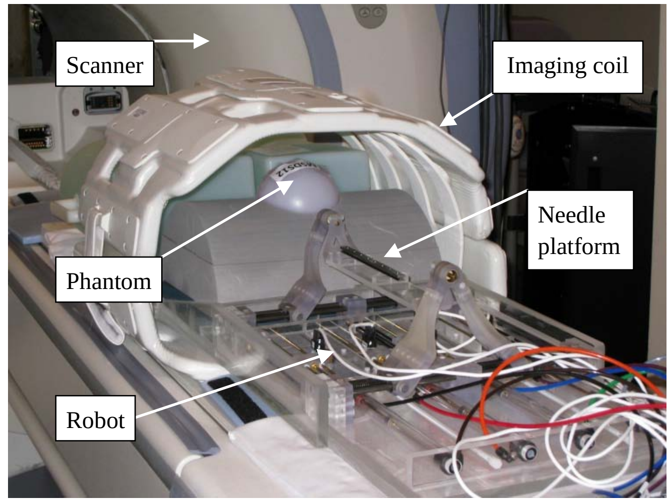

Fig. 1 MRI compatibility study (SNR test) setup using a phantom in GE scanner

Results

Average SNR values were computed from the phantom MRI images obtained at each scanner/configuration. To normalize the values among the three scanners, a percentile value (when baseline SNR value is 100%) was calculated. Fig. 2 shows the plot of SNR results. Overall, all three scanner SNR results show a typical reduction pattern i.e. gradual decrease from baseline to servoing configuration, which can be found in similar study [4]. Philips and GE scanner SNR tests resulted in similar values: less than 5%, 10% and 15% reduction at physical presence, providing controller power, and servoing configuration, respectively. The Siemens scanner SNR result, however, shows greater SNR value decrease, approximately from 110% (it is not unusual to find a SNR value greater than baseline value) to 75%. For all scanners and configurations, two imaging sequence T1 and T2 resulted in very similar SNR values.

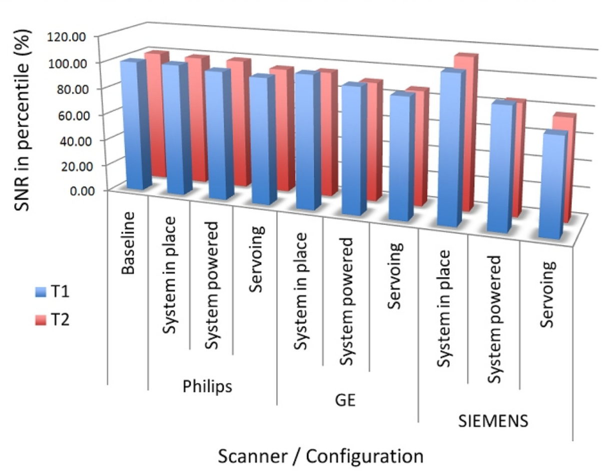

Fig. 2 MRI compatibility study (SNR test) results in percentile

Conclusion

In order to evaluate the MRI compatibility of recently developed pneumatically actuated robotic system for transperineal prostate needle placement, a series of SNR tests were conducted and the results suggest that with the designated system setup i.e. powered through patch panel, the robotic system causes insignificant image quality degrading. In other words, an adequate degree of MRI compatibility was observed. The greater SNR reduction in the Siemens scanner test result leads to another test on a patch panel equipped Siemens scanner in order to confirm whether the reduction was caused by the power converter being inside, or the scanner has a different MRI compatibility characteristic against the robot system. This will conclude a scanner-independent MRI compatibility specification of the robotic system.

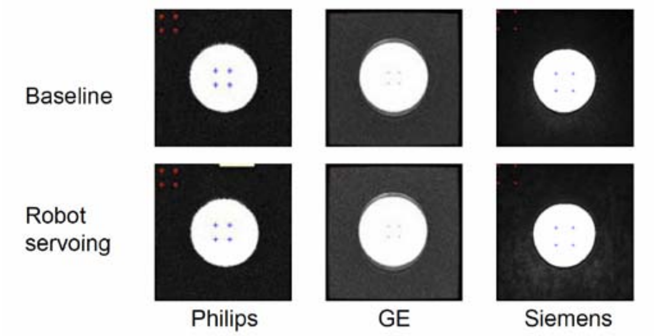

Fig. 3 Representative T1 phantom images

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