Progress in Multimodality Imaging: Truly Simultaneous Ultrasound and Magnetic Resonance Imaging

R. Chopra[1], L. Curiel[1], and K. Hynynen[1]
[1]Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

INTRODUCTION

MRI is used widely for both diagnostic and therapeutic planning applications because of its multi-planar imaging capability, high signal to noise ratio, and sensitivity to subtle changes in soft tissue morphology and function. Ultrasound imaging, on the other hand, has important advantages including high temporal resolution, high sensitivity to acoustic scatterers such as calcifications and gas bubbles, excellent visualization and measurement of blood flow, low cost, and portability. The benefits of combining these modalities through image registration have been shown for intra-operative neurosurgical applications [1] and breast biopsy guidance [2]. By performing imaging with both modalities simultaneously a number of issues such as spatial and temporal registration between data sets can be simplified or resolved. Some work has been reported concerning the integration of US and MR imaging systems [3-5], however no integrated systems capable of simultaneous imaging have been developed to date. This goal of this study was to explore the feasibility of performing simultaneous MR and ultrasound imaging using an MRI compatible ultrasound imaging system.

METHODS

A. Integrated US & MR Imaging System: The MRI-compatible ultrasound imaging system designed in this study incorporated a mechanically-scanned transducer (5 MHz, focal length=50 mm, 20-mm diameter, bandwidth 50%). Linear scanning was accomplished with a custom-designed MRI compatible motion system incorporating piezo-ceramic motors and optical encoders. Apart from the transducer and linear stage, all of the electronics controlling the motors, encoders and the transducer were kept outside the magnet room. Cables containing RF signals for ultrasound imaging, and the motor and encoder signals passed through a filtered penetration panel prior to entering the MRI. All ultrasound imaging experiments were performed in a closed-bore clinical 1.5T MR imager (Signa, GE Healthcare, USA).

B. Simultaneous Imaging: Two approaches were investigated to perform simultaneous imaging with both modalities. The first approach was to filter the transmitted and received RF signal to the ultrasound transducer with a low-pass filter. The second approach was to synchronize the two systems such that ultrasound imaging was only performed during the time between the frequency encoding gradient and the subsequent RF pulse for the MR imaging (Figure 1). The MRI-compatibility of the scanning system enabled movement of the transducer at any point in the imaging process without causing significant interference. In order to compare the different acquisition schemes a test phantom was imaged with both modalities and the SNR was measured in a region of interest.

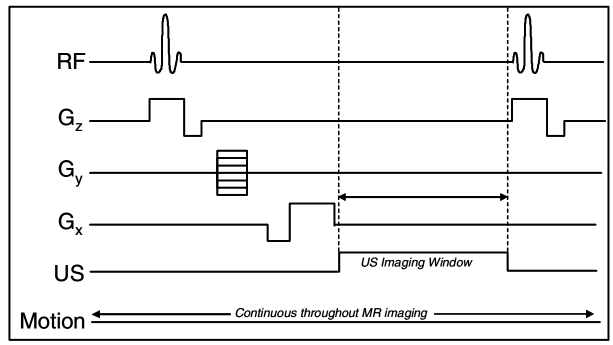

Figure 1: Method for synchronized US and MRI

C. Simultaneus imaging in vivo: Simultaneous images were acquired of a rabbit kidney *in vivo* to demonstrate the feasibility of this system. A New Zealand White rabbit (female, 3.5kg) was anesthetized, shaved and depilated on the abdomen. The rabbit was laid on a platform in the lateral decubitus position such that its kidney was over an acoustic window, and in contact with a water bath. The ultrasound transducer was scanned from below the animal to acquire a 2D image of the kidney. MR imaging was performed in the same orientation using an integrated surface coil embedded around the acoustic window. MR images were acquired using a fast spin echo image with the following parameters (512x512, TE/TR=15.00/180, FOV=16cm, Slice=3mm, ETL=1). The ultrasound images were acquired with a step size of 1mm.

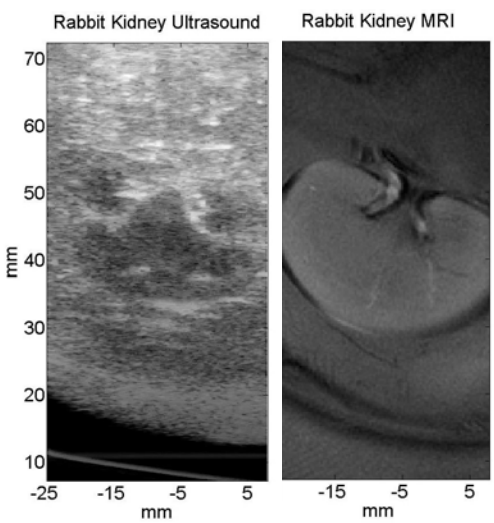

Figure 2: Simultaneous US and MR imaging of a rabbit kidney

RESULTS

Table 1 shows the SNR measured in the MR and US baseline images as well as for the different acquisition schemes. Asynchronous operation of both modalities resulted in significant interference, and a degradation in SNR. Both the filtering and synchronized acquisition schemes maintained an acceptable SNR in each modality. The simultaneous ultrasound and MR images acquired in the rabbit kidney are shown in Figure 2. The registration between the two imaging planes can be seen clearly from the similar structures visible in both images. These images were acquired using the synchronized imaging method.

Table 1: SNR Measured using various acquisition schemes

	SNR (MRI)	*SNR (US)*
MRI Baseline	*22 ± 7*	*–*
US Baseline	*–*	*22 ± 9*
Asynchronous	*7 ± 7*	*21 ± 8*
Filtered	*22 ± 7*	*26 ± 13*
Synchronized	*21 ± 7*	*21 ± 9*

SUMMARY

Simultaneous imaging with both ultrasound and MRI could provide complementary diagnostic information in a naturally co-registered fashion, opening up a number of clinical applications ranging from cardiology to oncology. This study demonstrated the capability to perform ultrasound imaging in a clinical MR imager using an MRI-compatible ultrasound imaging system. Electrical interference between the two imaging systems was observed, and two acquisition schemes were successful in eliminating it. The feasibility of performing simultaneous ultrasound and MR imaging was also demonstrated *in vivo* in a rabbit model. The main benefits of using these modalities simultaneously include the ability to co-register imaging information without tissue distortion, reduced exam times, and the ability to capitalize on the strengths of each modality in a truly simultaneous fashion. These benefits could have broad number of applications in medicine.

REFERENCES

[1] R. M. Comeau et al, *Med. Phys.,* vol. 27, pp. 787-800, 2000.
[2] C. A. Piron et al, *IEEE Trans. Med. Imaging,* vol. 22, pp. 1100-1110, 2003.
[3] D. A. Sebok et al, *Invest. Radiol.,* vol. 26, pp. 353-357, 1991.
[4] J. M. Rubin et al, *Acad. Radiol.,* vol. 7, pp. 1116-1122, 2000.
[5] M. Gunther et al, *Magn. Reson. Med.,* vol. 52, pp. 27-32, 2004.