MRI-compatible motion platform for studying the influence of organ motion on body MRI

Joris Nofiele[1], Qing Yuan[1], Quinn Torres[1], Mohammad Kazem[2], Ken Tatebe[1], Ivan Pedrosa[1,3], and Rajiv Chopra[1,3]
[1]*Radiology, University of Texas Southwestern Medical Center, Dallas, Texas, United States,* [2]*Imaging Research, Sunnybrook Research Institute, Toronto, Ontatio, Canada,* [3]*Advanced Imaging Research Center, University of Texas Southwestern Medical Center, Dallas, Texas, United States*

Target Audience: Radiologists, MR-guided radiation therapists

Purpose: Abdominal MRI is commonly degraded due to respiratory motion. Compensation techniques such as respiratory gating, and navigators have been utilized to reduce the influence of motion on diagnostic MRI in clinical practice[1]. Evaluation of these techniques against each other is difficult in patients and/or volunteers due to the difficulty in reproducing the same type of motion between sequences. Furthermore, the ability to control or vary motion parameters such as respiration rate or volume is not easily achieved in subjects. Herein, we report on a custom-built MRI compatible motion platform capable of simulating abdominal organ motion. This technology offers the unique ability to replay true organ motion extracted from an actual human volunteer with very high reproducibility.

Methods: The platform (Fig 1) incorporates two non-magnetic piezoceramic motors (HR4, Nanomotion Ltd, Israel) and an optical encoder (LIA20, Numerik Jena, Germany). Other groups have reported various other types of actuators[2-4]. The motor and encoder cables are passed into the room through a filtered enclosure attached to the penetration panel[5]. Driving electronics and a PC with software in Labview (National Instruments, USA) is used to program the motion of the platform. An anthropomorphic abdominal phantom (Model 057A, CIRS Inc, USA) was used for imaging with conventional torso coils. A 3D rendering of the platform and a photo of the entire setup are shown in Figure 1. The motion platform was operated outside and within the bore of the MRI, and during MR imaging using different pulse sequences to evaluate whether motion was affected by imaging. The impact of the motion platform on the MRI was also assessed by running a spurious noise test on the scanner over a bandwidth of 127.37 MHz to 128.37 MHz. Abdominal organ motion trajectories were extracted from dynamic coronal abdominal images of a healthy volunteer acquired during free-breathing using a k-t BLAST imaging sequence (TR/TE = 2.5/1.3ms, 0.17s/dyn, total scan time = 113s,). All imaging was conducted on a 3T MRI using anterior and posterior coils (Ingenia, Philips Healthcare, Best, Netherlands). Organ motion in the head/foot direction was extracted in MATLAB using a pixel tracking algorithm. Secondly, T2-weighed spin-echo images were acquired (TR/TE = 1000/20, 40, 60, 80, 100ms, FA = 90deg, voxel = 1.2x1.5mm, slice thickness = 4mm, slice gap = 1mm, FOV = 200x300mm) for T2-mapping in the abdominal phantom placed on top of the motion platform under different motion conditions to evaluate the effect of motion on image quality and T2 quantification. T2 maps were calculated for no motion, 10mm sinusoidal motion and kidney motion extracted from the k-t BLAST acquisition.

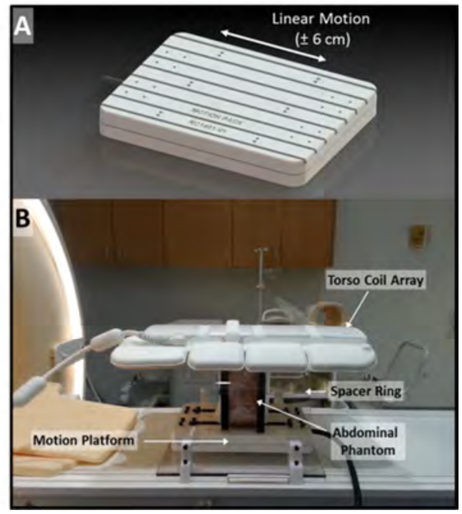

Figure 1: A) Rendering of an MRI-compatible linear motion platform. B) Photo of the platform, phantom and coils used for this study.

Results: The motion of the platform was unaffected by either high RF power (3DFSE) or gradient intensive (single-shot spin-echo echo-planar DWI) imaging sequences when compared to motion outside the MRI or in the bore without scanning (Fig 2). The trajectory tested was that measured for the kidney on k-t BLAST imaging, and the platform reproduced this trajectory with high fidelity (Fig 2). Fig 3 shows the coronal T2-weighted images acquired for no motion, 10mm sinusoidal motion and kidney motion. Differences in the motion artifacts and conspicuity of lesions are apparent under the different conditions. The spurious noise test revealed no perceptible effect related to moving the motion platform within the MRI bore.

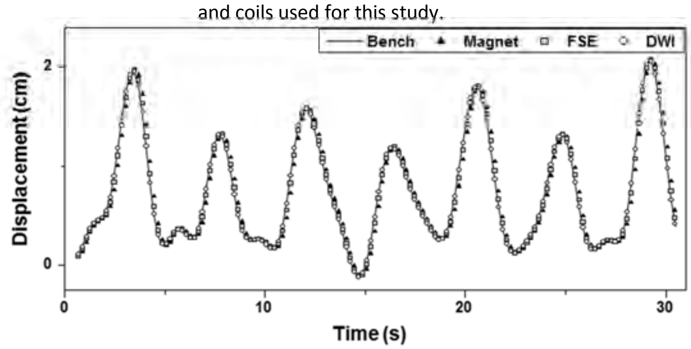

Figure 2: The displacement versus time of the motion platform during playback of a kidney trajectory in different conditions.

Conclusions: An MRI-compatible motion platform has been developed for motion studies in the MRI. The system can operate in the MRI scanner during imaging with no mutual interference, and can reproduce realistic organ motion. This enables investigations into the influence of motion as a research tool for developing robust clinical sequences for body MRI.

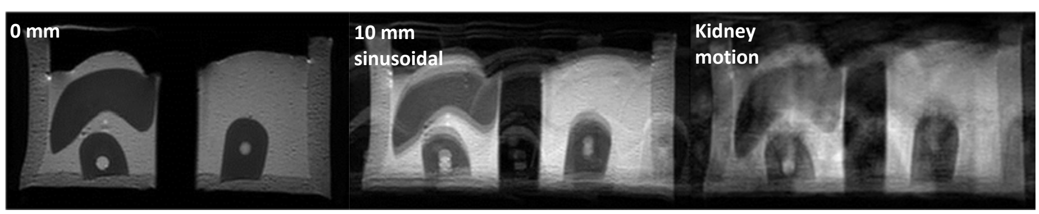

Figure 3: T2W images acquired through the phantom with 0 mm, 10 mm sinusoidal and extracted kidney motion. The degradation in image quality with motion is clear. Kidney motion causes smearing-like artifacts, while sinusoidal motion causes aliasing artifacts.

References:

[1]: Rotenberg D et al. Magn Reson Med. 2013; 69(3):734-48
[2]: Fischer GS et al. Conf Proc IEEE Eng Med boil Soc. 2011; 6687-90
[3]: Yiallouras C et al. Int J Comput Assist Radiol Surg. 2014; 9(4): 745-53
[4]: Elbannan KM et al. Conf Proc IEEE Eng Med Biol Soc. 2012; 2012:940-3
[5]: Chopra R et al. Med Phys. 2009; 36(5):1867-74