Multimodal non-rigid motion artifact correction with concurrent ultrasound

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Introduction: Motion artifact correction is one of the important issues in magnetic resonance (MR) imaging [1]. As MR imaging has limited temporal resolution, any motion of the patient would result in motion artifacts in the image. There have been a lot of efforts to correct or reduce motion artifacts such as gating, fast acquisition, navigator echo, etc. Although these conventional techniques are utilized in clinic, they have several disadvantages including vulnerability to non-rigid/non-periodic motion, low signal-to-noise ratio (SNR), low scan efficiencies, and others [2]. Hence, application of these methods is limited to some specific cases. Recently, as a treatment for those problems of conventional motion correction methods, Ultrasound-guided MR (USgMR) is getting attention [2,3]. In previous works on USgMR motion artifact correction, gating and navigating were performed using the positional information measured from US [2,3]. However, the previous works are fundamentally based on conventional gating and navigator schemes. Therefore, they have limited performance as the other conventional methods have. This abstract introduces a novel USgMR motion artifact correction method, which is not employing gating or navigating scheme, and presents its effectiveness by *in vivo* experiment.

Methods: The implemented USgMR experiment system seen from axial view is shown on figure 1. It consists of 3T Siemens Tim Trio MR scanner, US device and the right-arm of a human subject. A standard clinical portable US device (LogicScan 128EXT-1Z, Telemed) and an extra-wide (170mm) linear US probe (L3.5/170/96Z, Prosonic) were employed. All the devices and cables operated inside MR room were shielded in order to suppress the RF interference between MR and other devices including US [4]. US and MR were operated simultaneously for acquiring image data. The FOVs of US and MR were set to be overlapped in 2D plane as illustrated in figure 1. US image frames were acquired with frequency of 2MHz. A laptop computer was operated outside the MR scanning room for receiving US image frames. MR data was obtained by commercial clinical radial pulse sequence with parameters of TR=50ms, TE=7ms, number of view=256, FOV=128x128mm^2, flip angle=25˚, datapoints per a radial spoke=256, and acquisition matrix=256x256. The subject, a male with an age of 27, grasped and released his fists during the scanning, which introduced non-periodic and non-rigid motions of inner muscles. Only a single set of k-space data was acquired without any gating or navigator echoes. Spatio-temporal registration between US frames and MR data were performed after extracting motion information from US frames as shown in figure 2a-b. Motion information was extracted by block-matching algorithm (BMA) with hierarchical scheme [5]. The extracted motion information was realigned in order to compensate the motion with respect to the reference point of time. During the filtered back-projection (FBP) reconstruction of MR image, the pixels on the area covered by US FOV were repositioned according to the motion information extracted from US frames at each back-projection of a radial spoke.

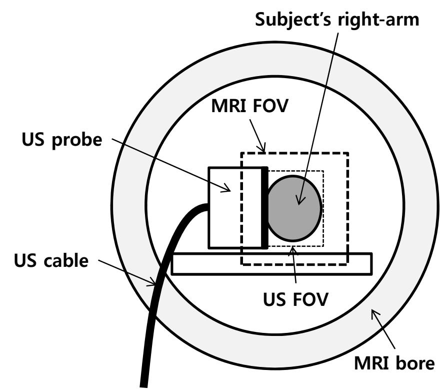

Figure 1. USgMR experiment setup

Results: The results of the experiment are shown in figure 2. Image (f) shows the result of the proposed USgMR motion correction technique which was highly effective at retrieving original structures from motion-corrupted data (the image reconstructed without correction is shown in (e)). Those structures indicated by ellipses show significant improvements in comparison with the uncorrected image (e).

Conclusion/Discussion: Non-rigid and non-periodic motion was corrected by our proposed method without any gating or navigator echoes. Generally, conventional motion correction techniques only consider rigid or periodic motion. In contrast, our proposed method can compensate any arbitrary motion in US FOV since US can capture any arbitrary motion information regardless of rigidity or periodicity. Further improvements can be made by incorporating iterative reconstruction methods to reduce streak artifacts, investigating global compensation scheme, and increasing FOV of US.

One substantial advantage of USgMR motion correction technique is that pulse sequence is not interrupted by navigator echoes or any other k-space signals [2]. Furthermore, our implemented technique does not need any gating or navigating, so the k-space is filled continuously. This implies that the total imaging time can be substantially reduced even with motion artifact correction while conventional techniques usually lengthen imaging time.

Additionally, when the correction is performed with respect to every point of time during the scanning, we can have MR images corrected regarding to each moment. This means that *real-motion MR* is possible by sequencing the corrected images by time. The main difference between conventional gated dynamic cine MR imaging and real-motion MR is that the conventional method is based on gating and therefore it does not show the real instantaneous motion but only the averaged one for many periods, while real-motion MR can exhibit real instantaneous motion captured by US.

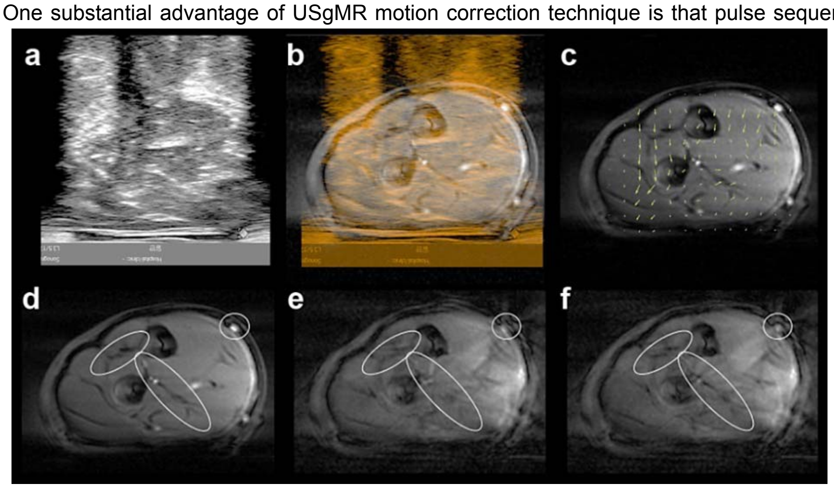

Figure 2. Experimental results. (a) cross-sectional US image frame of the subject's right-arm, (b) superimposed image of US and MR, (c) estimated motion vectors, (d) MR image acquired without motion, (e) motion-distorted uncorrected MR image, (f) the corrected image. Three distinct features that are severely distorted in the uncorrected image (e), but substantially recovered in the corrected image (f) are indicated by ellipses.

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