Autofocusing Motion Correction with 3D Image-based Navigators for Abdominal Imaging

Jieying Luo[1], Nii Okai Addy[1], R. Reeve Ingle[1], Joseph Y. Cheng[1], Bob S. Hu[2], and Dwight G. Nishimura[1]
[1]Electrical Engineering, Stanford University, Stanford, California, United States, [2]Palo Alto Medical Foundation, Palo Alto, California, United States

Target Audience: MR physicists interested in image reconstruction, motion correction and/or abdominal imaging.

Purpose: Respiratory motion is a major challenge in free-breathing magnetic resonance (MR) abdominal imaging. Techniques such as respiratory gating or breath-hold imaging have been widely used to address respiratory motion, with the drawbacks of long scan time or limited volume coverage. Recently, autofocusing nonrigid motion correction techniques [1] based on butterfly navigators or 2D/3D image-based navigators (iNAVs) have been developed and applied in pediatric body imaging [2] and coronary MR angiography [3][4], demonstrating promising retrospective nonrigid motion correction. In this work, we developed an autofocusing motion correction method based on 3D iNAVs for free-breathing abdominal imaging.

Methods: A free-breathing alternating-TR balanced steady state free precession sequence with a 3D cones acquisition [5] was used for abdominal imaging at 1.5 T. The sequence was cardiac-gated for consistent blood inflow. In every heartbeat, a 3D iNAV with a 28×28×14 cm^3 FOV and 5.2 mm isotropic resolution was acquired after the 3D cones data acquisition. These 3D iNAVs served as low-resolution images containing nonrigid motion information of the whole volume (Fig. 1). To decrease possible motion during the 3D iNAV acquisition, the duration of 3D iNAVs was significantly reduced from 1584 ms for a fully sampled 3D cones trajectory to 176 ms by the use of a variable-density trajectory and iterative reconstruction with ESPIRiT [6].

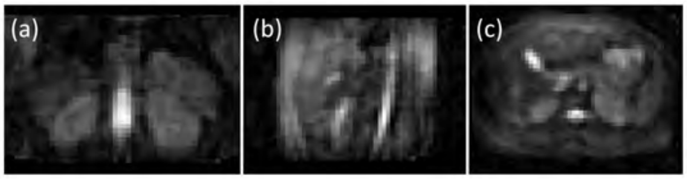

Figure 1. *Representative cross-section views of 3D iNAVs. (a) Coronal view. (b) Sagittal view. (c) Axial view.*

The autofocusing motion correction method has three steps. First, a set of motion trajectory candidates are estimated from 3D iNAVs. Next, a bank of motion-corrected images are generated by image reconstruction with linear phase compensation for every motion candidate. Lastly, a gradient-entropy focusing metric [1] is used to select the best-focused pixels from the bank of motion-corrected images.

To build the set of motion trajectory candidates, the 3D iNAVs were divided into 9 regions of interests (ROIs) (Fig. 2(a)). For each ROI, 3D translational transforms in SI, AP and RL directions were performed to estimate the motion trajectory. Representative motion trajectories are shown in Fig. 2(b), displaying different motion patterns at different locations of the imaging volume. The ROI located at the posterior chest wall (blue) is almost static, while the center ROI has large scales of SI and AP motions (green). The ROI located at the anterior chest wall (red) is dominated by the AP motion. Because the center ROI (ROI 5) has the largest SI motion, scaled versions of ROI 5's motion trajectories were also included in the motion candidates to capture localized motions. 5 SI, 5 AP and 3 RL scale factors uniformly spanning [75%, 125%] were used for ROI 5. In total, 9 motion trajectories directly estimated from ROIs and 74 scaled versions of ROI 5's motion trajectory served as the motion candidates.

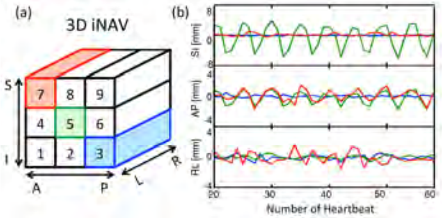

Figure 2. *(a) ROI divisions (3 (SI) x 3 (AP) x 1 (RL)). Representative motion trajectories in SI, AP and RL directions from ROI 3 (blue), ROI 5 (green) and ROI 7 (red) are shown in (b).*

Figure 3. *Motion map of one axial slice. Magenta scale denotes the selected ROI index, and green scale denotes selected SI scale of ROI 5.*

Results: The results of volunteer abdominal scan are shown in Fig. 3-4. As displayed in the motion map (Fig. 3), the center region selected several scaled versions of ROI 5 and the outer region selected other ROIs. Figure 4 shows the reformatted maximum-intensity-projection (MIP) images reconstructed with no motion correction (Fig. 4(a)(c)) and with autofocusing motion correction (Fig. 4(b)(d)). Autofocusing method significantly improves the image quality of the whole imaging volume. As demonstrated in Fig. 4(b)(d), the small branches of portal vein is better visualized (solid arrow), the sharpness of the hepatic vein is improved, and the splenic artery (arrowhead) is recovered from motion blurring. Static structures such as the spinal arteries maintain sharpness after motion correction owing to the nonrigid and localized property of the autofocusing method.

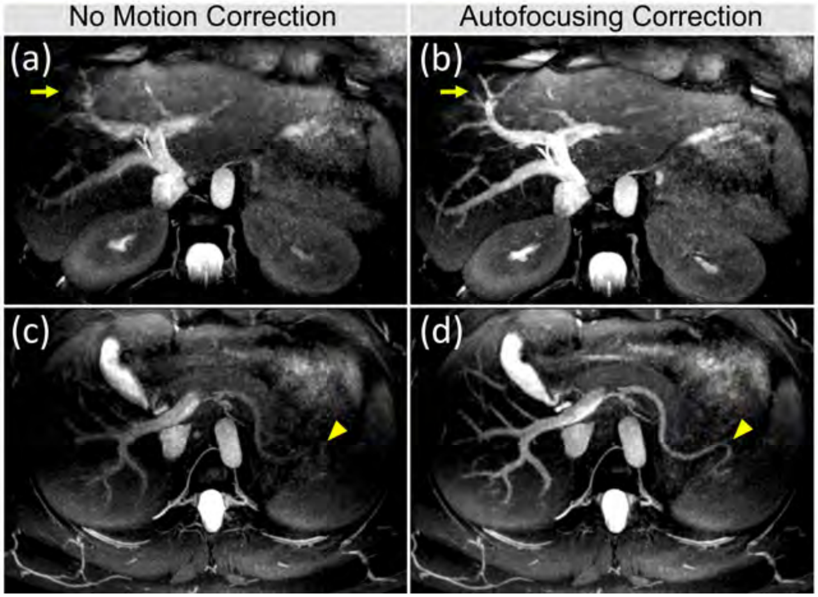

Figure 4. *Reformatted MIP images reconstructed with (a) (c) no motion correction and (b) (d) autofocusing motion correction. Autofocusing method significantly improves the visualization of portal vein (solid arrow), hepatic vein and splenic artery (arrowhead).*

Conclusion: An autofocusing nonrigid motion correction method based on motion trajectories estimated from 3D iNAVs was developed and demonstrated in free-breathing abdominal imaging.

References: **[1]** McGee KP, *et al.*, MRM 11:174–181, 2000; **[2]** Cheng JY, *et al.*, MRM 68:1785–1797, 2012; **[3]** Ingle RR, *et al.*, MRM 72:347–361, 2013; **[4]** Ingle RR, *et al.*, Proc. 21st ISMRM, p. 189, 2013; **[5]** Wu HH, *et al.*, MRM 69: 1083–1093, 2012; **[6]** Addy NO, *et al.*, SCMR 16 (Suppl 1), pp. 380, 2014.