Impact of Image Registration on Cardiac Perfusion Interpretation

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Introduction

Cardiac perfusion MRI is used to characterize the abnormal distribution of myocardial blood flow using the infusion of paramagnetic contrast agents. Typically images are acquired over 45-60 seconds and routinely suffer from inter-frame mis-registration due to respiratory and other sources of physiologic motion. Quantitative analysis of perfusion images involves estimating signal intensity-time curves from desired regions of interest. It is well understood that automatic computation of these curves and further quantification from them requires the time-series images to be spatially aligned prior to data analysis. Several techniques for performing semi-automatic image registration have been proposed [1-3].

However, most large-scale perfusion studies reported in the literature comparing MR perfusion with SPECT studies have relied upon qualitative visual assessment by inspecting image movie loops. It is commonly believed that image registration is only necessary if quantification is the end-result, and thus is often ignored for visual assessment of perfusion. The goal of this study is to show that image registration is vital for qualitative analysis of perfusion as well by measuring the improvement in "quality" of visual reading and thus increasing the confidence of diagnosis.

Methods

Acquisition: Thirteen patients with coronary artery disease were scanned on a 1.5T Signa CV/i MRI scanner (GE Healthcare, Waukesha, WI) under IRB approved protocols after obtaining informed consent. First-pass perfusion imaging was performed using a 2D Fast-GRE EPI (TR/TE=6.8/1.5ms; Flip 20^{o}; thickness 8 mm, spacing 5 mm) saturation recovery sequence and 8 to 9 short-axis slices were imaged every 2 heartbeats. Contrast administration (0.1 mmol/kg Gd-DTPA) and imaging were started at the same time, resulting in the acquisition of 5-6 baseline images, followed by 30-40 images depicting the arrival and wash-out of first pass contrast. Following the administration of an additional 0.1 mmol/kg (cumulative 0.2 mmol/kg Gd-DTPA dose) delayed enhancement (MDE) images matching the perfusion slices were acquired about 15-20 minutes after the injection of contrast using an inversion time of 200-225 msec.

Processing: The resulting images were transferred to a PC for off-line analysis. Multi-slice cine animation loops were created for all studies after suitably zooming and adjusting the images for brightness and contrast (Cinetool, GE Healthcare). Next, the images from all thirteen subjects were registered using the automatic rigid-body registration technique described in [2]. The average time for registering one full dataset was 20 seconds. The resulting 26 perfusion movie loops (registered and unregistered data) were blinded and randomized for visual assessment of perfusion defects.

Reading: Two experienced readers independently reviewed the perfusion images and labeled segments as normal or containing perfusion abnormality using subjective criteria. The 17-segment AHA model was used for data collection. The readers also assigned a motion quality score ranging from 0 to 3 (0=non-diagnostic exam due to motion; 1=fair to poor image registration, not very confident; 2=good image registration, somewhat confident; 3= excellent image registration). Further, to separate the effects of image artifacts and noise from motion, the reviewers also scored the exams on image quality alone without consideration of motion on a similar scale of 0 to 3.

Results

The average motion quality of the exams before automatic image registration was 1.5 +/-0.4 and it increased to 2.4 +/-0.4 after registration ($p = 0.0004$). Figure 1 shows the motion quality results before and after registration from all subjects. The average image quality was 1.8 +/-0.2 both before and after image registration (no statistical differences, $p=1.0$). In 9 of the 13 cases, both registered and non-registered interpretations matched and correlated with MDE findings. In the remaining 4 cases, the segments marked with perfusion defects from registered data differed from those marked from unregistered data. These datasets were then compared to the corresponding MDE data. Good agreement was found between the registered interpretations and the MDE results. Figure 2a shows one perfusion image from a sequence of images that was read as normal without registration but was marked with abnormal perfusion segments in the antero-septal mid-cavity segments (arrow) with image registration. The corresponding MDE is shown in Figure 2b, and the hyper-enhanced zone (arrow) agrees with the post-registration results.

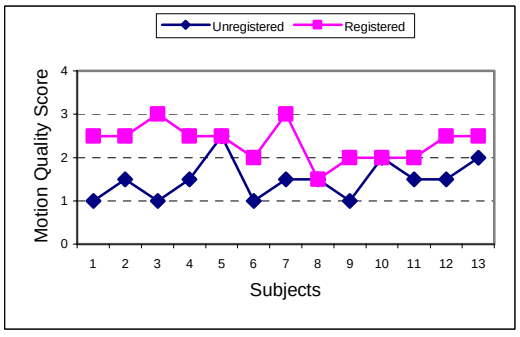

Fig. 1

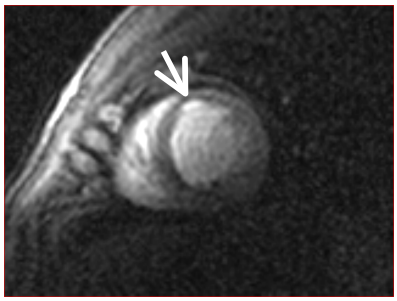

Fig. 2a

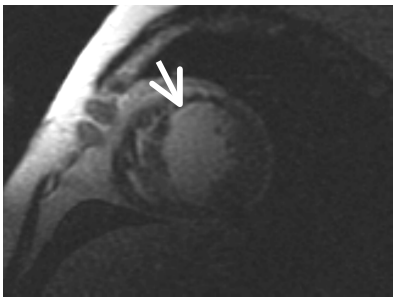

Fig. 2b

Conclusion

We have demonstrated the utility of image registration for the interpretation of cardiac MR perfusion studies. Image registration has clear benefits for both qualitative as well as quantitative perfusion analysis and helps increase the confidence and efficiency of diagnostic interpretation of the first pass perfusion studies. This limited study has demonstrated that qualitative assessment of perfusion defects using spatially unregistered images increases the likelihood of incorrect diagnosis. Robust image registration techniques have important implications for patient comfort and overall exam success by enabling the perfusion study to be conducted during free-breathing or the interpretation of images acquired during a failed breath hold.

References

[1] Dornier C et al., *JMRI*, 18 (2):160-168, 2003 [2] Gupta et al., *MRM*, 49:506-514, 2003 [3] Bidaut LM, *JMRI*, 13:648-655, 2001