EXCESS HIGH NOISE IN EXERCISE STRESS REAL-TIME CARDIAC CINE IMAGES

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Introduction: Recently proposed treadmill stress cardiac MRI is a promising approach to detect cardiovascular disease utilizing real-time (RT) cine imaging to assess stress-induced cardiac motion abnormalities [1]. However, compared to RT cine at rest, the stress RT cine images show significantly lower SNR (see Figure 1). There are two factors that affect the noise level in RT cines. The first is the noise in the raw data originating from the coil electronic noise, and the second is the "g-factor" of the parallel imaging technique. Both of these should be the same for rest and stress RT cine using the same protocol.

When the motion during the acquisition of k-space is sufficiently small, every temporal frame can be approximated as an instantaneous "snap-shot". However, fast chest wall motion during peak stress introduces inconsistencies in k-space. One effect of this motion will be image distortions, and additionally, the motion may induce a signal variation which behaves statistically like spatial noise. In other words, the motion induced signal perturbation demonstrates randomness even though it is completely deterministic. This is analogous to the deterministic noise introduced by random k-space sampling. As a result, the apparent noise level in stress MRI raw data with rapid heart rate and breathing should be higher than that of the resting RT cine raw data.

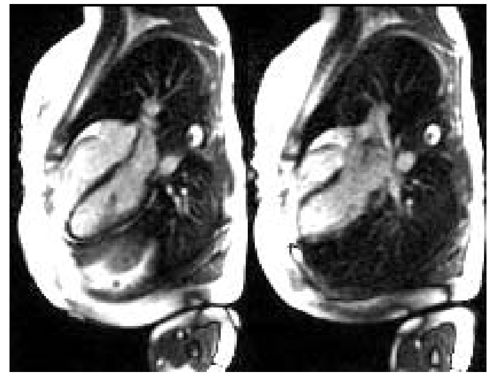

Figure 1. Cine image acquired at peak stress (right) demonstrates lower SNR than cine acquired at rest (left) using identical protocol.

Based on the above analysis, we set up two hypotheses: First, since "snap-shot" is a better approximation at higher temporal resolution, we expect the noise level difference between rest and stress cine raw data to be smaller at high temporal resolution, and larger at low temporal resolution. Second, if this effect is due to motion, then channels with higher temporal signal variation should have higher noise level differences between rest and stress cine raw data.

Methods: These hypotheses were tested in a volunteer imaging study. 7 volunteers were included; both stress and rest RT cines images were acquired in 3 slices, 4-chamber long-axis, 2-chamber long-axis, and mid-ventricular short axis. Stress cine was acquired using TGRAPPA at three temporal resolutions = 63 ms, 47 ms, and 38 ms, corresponding to acceleration rates = 3, 4, and 5 immediately after treadmill stress in a random order. The imaging protocols for rest and stress cine were identical.

All SSFP real-time cine images were acquired on a 1.5T MR scanner (MAGNETOM Avanto, Siemens Healthcare, Germany). Imaging parameters were: 160 × 84 matrix, 10mm slice, flip angle=68^{o}, TE/TR = 0.99/2.26 ms, pixel bandwidth=1360 Hz/pixel, FOV = 380 × 300 mm^2. A 32-channel phase-array coil (RapidMRI, Columbus, OH) was used for data acquisition. A total of 63 cine image series were acquired.

The raw data noise level in each channel was accessed using the MP-Law method based on the random matrix theory. This method uses the singular value spectrum of the data matrix to measure the noise level. It has been shown to be a robust and accurate method applicable to both k-space data and image-space data with and without the parallel imaging.

Results: Figure 2A shows the comparison of the rest and stress raw data noise level for temporal resolution = 47 ms. Figure 2B plots the mean noise level of raw data for all three temporal resolutions. The results show that the noise level in resting cines at three temporal resolutions are the same (within +/-1.5%). The mean noise variance increment in stress RT cine over resting RT cine are 16.6%, 14.2%, and 11.9% for temporal resolution = 63 ms, 47 ms, and 38 ms, respectively. Higher acceleration rate (temporal resolution) does show lower noise increase ($p < 0.0001$). We also found that channel-wise noise increase positively correlated with the temporal signal variation (correlation coefficient 0.4 to 0.6, p-value < 0.0001).

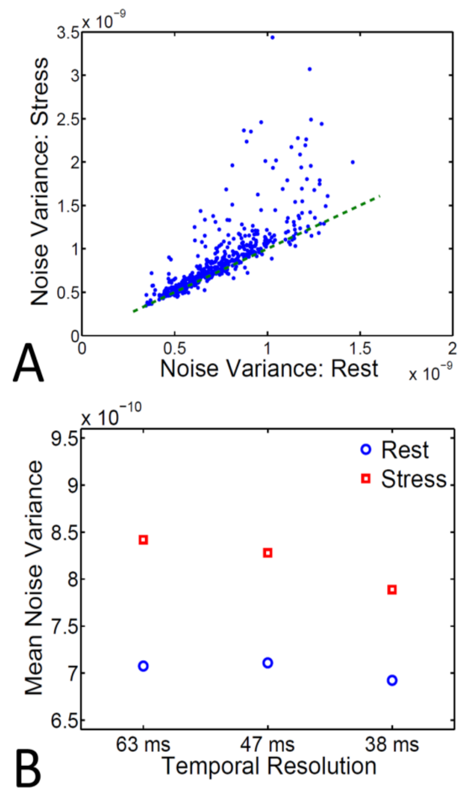

Figure 2. A: The noise variance of each channel of all 63 images series. The green line indicates identity relation y = x. B: the mean noise variance measured in the acquired raw data at all three acceleration rates.

Discussion and Conclusion: In conclusion, the observed excess high noise level in stress RT cine is due to a motion induced noise. It is a deterministic random noise, and can be reduced by increasing the temporal resolution.

References: [1] Jekic M, et al, J Cardiovasc Magn Reson 10 (2008), 3. [2] Ding Y et al, Magn Reson Med 63: 782 (2010)