

Automatic Coil Selection for Streaking Artifact Reduction in Radial MRI

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Introduction: Radial acquisition has become increasingly popular in MRI, as images can be acquired with significantly less data than conventional Cartesian imaging, permitting reduced scan time and/or enhanced temporal resolution. However, one drawback of radial imaging is the potential for streaking artifacts, which can become worse when imaging gradients become non-linear, as they do at the periphery of large FOV images [1]. In these regions, images are often distorted, causing signal to become highly concentrated, and streaking artifacts arising from these regions cannot be completely removed even when Nyquist criterion is fulfilled. Unlike Cartesian imaging, signal from regions outside the prescribed FOV cannot be digitally filtered out to avoid the streaking. When multiple-coil arrays are used for signal reception, coils which lie near the FOV edges can detect the highly concentrated signal and cause significant streaking. While those coils can be excluded by visual inspection during image reconstruction, the process is inefficient and impractical in large studies. In this abstract, we describe an algorithm which can automatically identify those coils whose images contain streaking artifacts and by excluding these coils, we demonstrate marked improvements in image quality.

Theory and Methods: In our proposed methodology, we seek to identify those coils whose images contain abnormally high levels of streaking. To evaluate the streaking artifacts for each coil, the individual coil images (I_{orig}) are first reconstructed. A low-pass filter is then applied to the same k-space data to generate separate low-resolution images. Due to the low-pass filtering, streaks are nearly absent in this latter set of images. We used these low-resolution images as reference images (I_{ref}) to quantify the streaking artifact level of the original images. A streaking artifact ratio was defined as the normalized image intensity difference between the original and reference images.

$$R_{streak} = \frac{\text{mean}(\text{abs}(I_{orig} - I_{ref}))}{\text{mean}(I_{ref})} \quad (1)$$

For each image, an empirically determined R_{streak} threshold of 1.7 was used to determine whether or not a particular coil is to be included in the reconstruction.

The proposed methodology was evaluated in subjects undergoing radial DCE-MRI protocol. The data were coronally acquired on a 1.5T Siemens MRI scanner with spine and chest array coils. A 3D hybrid radial sequence was used with the following parameters: FOV=300mm, slice thickness=8mm, 192x192 in-plane resolution, TR/TE=3.2/1.6 ms, flip angle 25°, 32 slices. Over-sampling (2x) was performed in the read-out direction. Both the original and low-resolution images (filtered by a 64-point FWHM Hanning filter) were reconstructed using 300 views. For comparison, a coil sensitivity-weighting method proposed by Kholmovski et al. [2] for streak reduction was also implemented and evaluated. In this method, the sensitivity map for each coil is first calculated by dividing a low-resolution coil image by the combined coil image. The magnitude signals from the different receive coils are then weighted by the coil sensitivity prior to combining the coils.

Results: Three individual coil images (out of 6) from an in vivo exam are shown in Fig. 1. In the image of the first coil (most inferiorly located), the weakening of the gradients causes the signal to be highly concentrated. As a result, streaks from that region dominate the entire image. In contrast, streaking is negligible in the images from the other two coils. As expected, the first coil had a much higher R_{streak} value than the other coils. Figure 2 shows the reconstructed images using all coils, sensitivity-weighting, and our automatic coil-selection methodology. While including all coils yields unacceptable levels of streaking, high image quality is achieved by removing the undesired coils using our methodology. The sensitivity-weighting method does help attenuate the streaks, but when the streaking intensity is very high, the sensitivity factor does not sufficiently remove the artifacts. Figure 3a compares the ratio of the mean signal to the standard deviation (s.d.) measured within a high signal intensity region (blood within the heart) and Figure 3b shows the mean signal in the lung where signal is expected to be low. Streaking artifacts cause tissue signal intensities to become much more inhomogeneous, lowering the overall signal/s.d. ratio. In the low signal intensity region, the streaks drastically increase the average signal when all coils are used. With selective coil elimination, the lung signal approaches that of background noise.

Discussion and Conclusion: In the proposed automatic coil selection methodology, low resolution reference images were used to quantify the streak levels. While low-pass filtering also reduces the high spatial frequency content (with the difference being reflected in the difference image), its contribution to R_{streak} is much lower than that of the high intensity streaks which we wish to eliminate (see Fig. 1), and thus the method is effective regardless of the object's high frequency content. In our methodology, coils were determined on a slice-by-slice basis according to the R_{streak} value for each slice. This method optimizes the SNR for each slice while eliminating the streaking artifacts. Such optimization is not possible if the imaging coils were pre-selected prior to data acquisition. In conclusion, our proposed methodology is shown to be effective in removing streaking artifacts and significantly improving the image quality. It is expected that accuracy of quantitative radial MRI imaging, such as DCE-MRI, can be improved with these strategies.

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Reference: 1. Du et al. MRM 2004; 51:1071-1076. 2. Kholmovski et al. ISMRM 2007. (Abstract 01902)

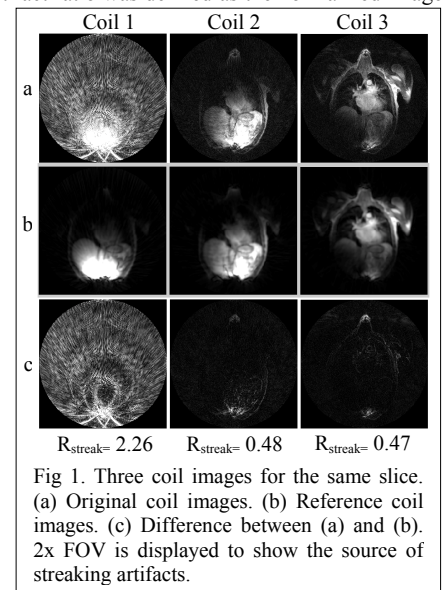


Fig 1. Three coil images for the same slice. (a) Original coil images. (b) Reference coil images. (c) Difference between (a) and (b). 2x FOV is displayed to show the source of streaking artifacts.

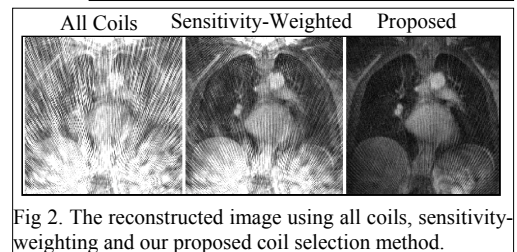


Fig 2. The reconstructed image using all coils, sensitivity-weighting and our proposed coil selection method.

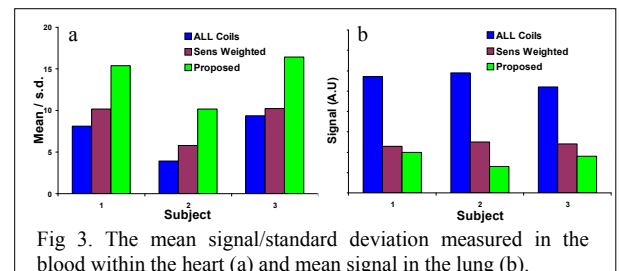


Fig 3. The mean signal/standard deviation measured in the blood within the heart (a) and mean signal in the lung (b).