Simple Method for Attenuation of Streaking Artifacts from Peripheral Intensity Accumulation

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Introduction: Radial sampling of k-space has become quite popular in the last years of MRI research, particularly in the context of compressed sensing and ultra-short TE imaging (UTE). While first studies validated its benefit for clinical applications, most notably due to lower sensitivity to motion [1,2], the use of radial sampling for daily routine examinations remains difficult. In many cases images are contaminated by mild or severe streaking artifacts that arise even if the number of acquired views fulfills the sampling requirement for the prescribed field-of-view (FOV). When coinciding with the region of interest, the streaks can render images non-diagnostic and can cause severe problems for automatic post-processing procedures like segmentation (see figure 1a for an example). Often, the streaking artifacts arise from high signal peaks in the periphery of the object that spill parts of their intensity throughout the image, which can be explained with the point-spread-function (PSF) model for radial trajectories. This happens particularly with surface coils that have focussed off-center sensitivity because the elements receive high signal strength while fat-suppression techniques often fail in peripheral areas. In addition, gradient non-linearities can cause severe intensity distortion in these areas [3]. It can be clearly seen in the single-channel reconstruction 2a that streaks in the image center originate from a signal spot in the neck area, which is close to the upper receive element of the spine coil. Therefore, it has been suggested in [3] to disable coil elements that significantly contaminate the image with streakings, which, however, leads to SNR loss in the local areas covered by the discarded elements. Alternatively, it has been proposed in [4] to replace the sum-of-squares channel combination by a sensitivity-weighted combination, which showed to reduce artifacts but requires knowledge of complex-valued coil profiles. Here, we describe another simple approach to attenuate the streaking artifacts.

Theory: According to the PSF description of the imaging process, streaking artifacts arise beyond Nyquist distance from a source point that depends on the number of acquired views. As evident in figure 2, in uncombined coil images the artifacts often fall into areas where the individual coil does not deliver relevant object information, i.e. the streaks appear outside of the sensitivity support of the receive element. Therefore, the idea is to restrict the contribution of each coil to the sum-of-squares image to those areas where the coil element is known to have sufficient sensitivity, which prevents inclusion of spurious long-distance streaks. The support of each coil is identified from an artifact-free Cartesian low-resolution large-volume scan, which is acquired prior to the radial scan and interpolated to the imaging plane. Because such a calibration scan is required anyway for intensity normalization of surface coil arrays ("pre-scan normalize"), the procedure does not add scan time. Binary acceptance masks are then derived using a thresholding procedure where a threshold of 10% of the maximum coil sensitivity was used. To prevent sharp transitions, the mask is dilated several times and smoothed towards the rejection area. Finally, the coil images are multiplied with the acceptance masks and combined by calculating the sum-of-squares.

Methods: To demonstrate the approach, a radial 3D dual-gradient-echo UTE sequence has been employed where fully sampled spokes from the second echo were used in this work (192 pixels base resolution, 300 mm FOV, 25000 views, TE = 2.46 ms, TR = 3.78 ms). The gradient-echo based Cartesian calibration scan used an isotropic resolution of 64 pixels at 500 mm FOV size and was mapped to the orientation of the radial scan using trilinear interpolation. Experiments were conducted with a 3T MR system (MAGNETOM Verio, Siemens AG, Erlangen) where written informed consent was obtained from all volunteers. A combination of head, neck, and spine coil elements was used for signal reception.

Results: The uncorrected combined image 1a shows severe artifacts close to the cerebellum. Single channel reconstructions 2a and 2b illustrate that these artifacts are largely caused by long-distance streaks originating from signal spots in the neck area. Figure 3 describes the correction procedure for the channel shown in image 2b, which includes estimation of the spatial coil sensitivity, generation of an acceptance mask, and application of the mask. Figure 1b shows the corrected combined image after applying the procedure to all channels before the sum-of-squares combination. It can be seen that the approach leads to clear reduction of the artifacts, making the image usable for segmentation applications. However, slight residual streaking artifacts remain visible because the method can not remove artifacts that overlap with the support of the coil elements.

Conclusion: This work presents a method for suppression of streaking artifacts by constraining the contribution of each receive channel to the area of known coil support. The method is simple and fast, does not require user interaction, and does not prolong the scan time. While it does not guarantee complete elimination of all visible streaking artifacts, the method yields significant improvement of the image quality at negligible costs.

References:
1. Azevedo RM et al, AJR 197:650-657, 2011
2. Chandarana H et al, Invest Radiol 46:648-653, 2011
3. Xue Y et al, MRM Early View, 2011
4. Kholmovski EG et al, ISMRM 15:1902, 2007

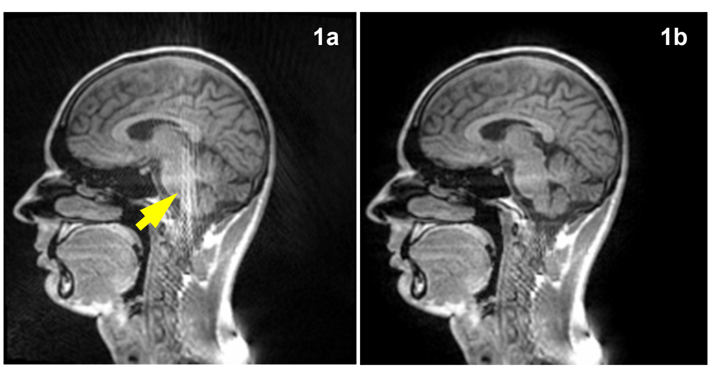

Fig 1: (Left) Uncorrected brain scan shows spurious streaking artifacts, which are reduced after applying the proposed method (right).

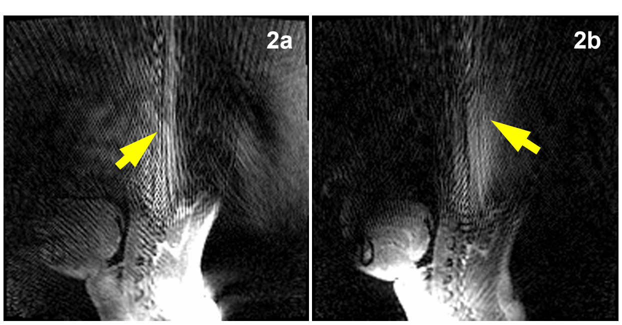

Fig 2: Single-channel reconstructions show that the streakings originate from high-intensity peaks in the neck region.

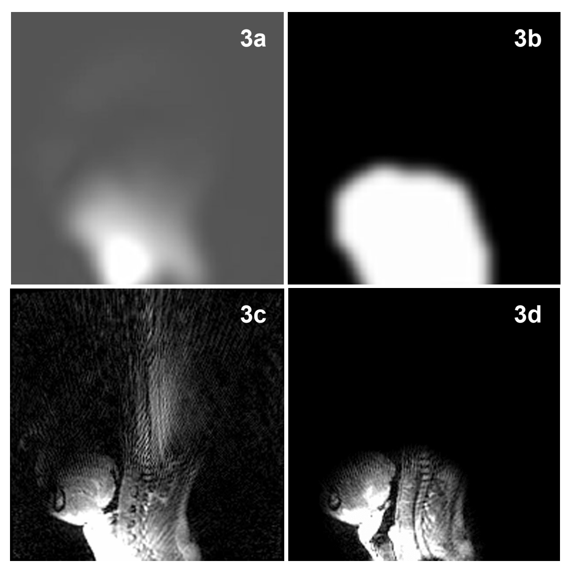

Fig 3: Illustration of processing applied to each cannel before coil combination: (a) interpolation of sensitivity map from available pre-scan, (b) generation of acceptance mask, (d) multiplication of single-channel reconstruction (c) with acceptance mask (b).