Improved retrospective self-gated human lung imaging using a quasi random sampling scheme

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Introduction

Motion artifacts due to respiration or blood flow degrade image quality in human lung MRI and require some sort of navigation. It was shown that the k-space center signal (DC signal) can be used for respiratory self-gating [1] and high resolution images can be reconstructed retrospectively [2]. In this work, the partition and phase encoding gradients of a 3D FLASH sequence are played out according to two-dimensional quasi-random numbers [3]. In addition the k-space center signal (DC signal) was used for respiratory self-gating, allowing the examination of the human lung under free breathing conditions. It is shown that the quasi-random sampling removes correlations between data acquisition and the periodic respiratory and cardiac motion resulting in ghost artifact reduction and reduced scan time compared to conventional acquired data. Additionally, missing k-space lines due to respiratory gating are uniformly distributed in case of quasi-random sampling enabling a successful iterative GRAPPA reconstruction [4], while conventional sampling yield to a much less uniform sampling of k-space so that the iterative GRAPPA reconstruction is prone to fail.

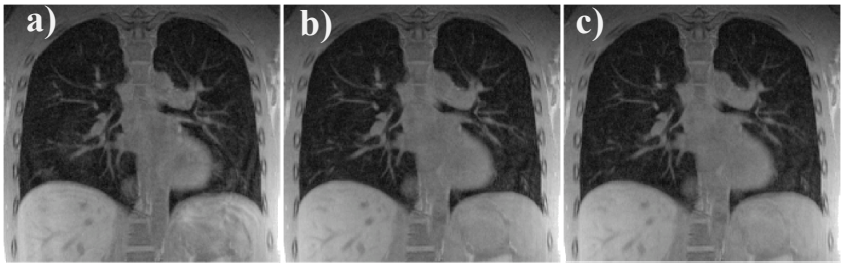

Fig 1: Reconstruction of the self-gated 3D scan without missing lines for a representative slice.(a) Conventional scan, TA = 372s, quasi random scans, TA = 321s (b) and TA = 268s (c)

Materials and methods

Measurements were performed on a 1.5 T clinical MR scanner using a six-channel phased-array body matrix in combination with a spine matrix. The DC signal acquisition was implemented into a 3D FLASH sequence after the actual imaging module. A total of seven full 3D image acquisitions were performed using a conventional sampling scheme as well as the proposed quasi random sampling scheme with identical imaging parameters (TE/TR/α = 1.2ms/3.8ms/7°, matrix: 256x320x44, FOV = 370x450x220mm^3, resolution 1.4x1.4x5 mm^3, acquisition time = 375s). To assess DC signal fluctuations resulting from respiratory motion, all coils were analyzed separately [2] and threshold values in percent of the total signal difference between expiration and inspiration were defined to select data for image reconstruction. Multiple accepted k-space lines were averaged and missing lines, due to data rejection, were reconstructed using iterative GRAPPA.

Results

Figure 1 shows a representative slice of the fully sampled 3D volume using the conventional (a) and the proposed quasi-random sampling scheme (b, c). The total acquisition times (TA) were (a) 375s accepting 50%, (b) 321s accepting 60% and (c) 268s accepting 70% of the acquired data for image reconstruction. Images from quasi random sampling show improved ghost artifact reduction near the heart and the diaphragm compared to the conventional sampling scheme despite reduced scan time and a lower threshold. However slightly increased blurring at small vessels near the diaphragm can be seen (c) when more data is accepted for image reconstruction. Figure 2 top shows the distribution of missing lines in k-space (black) for a conventional scan (left) and a quasi-random scan (right). In both cases, approximately 11.3% of k-spaces lines are missing. In the lower row the corresponding images reconstructed with iterative GRAPPA are displayed. The more uniform distribution of missing lines in k-space in case of quasi-random sampling allows for a more stable iterative GRAPPA reconstruction.

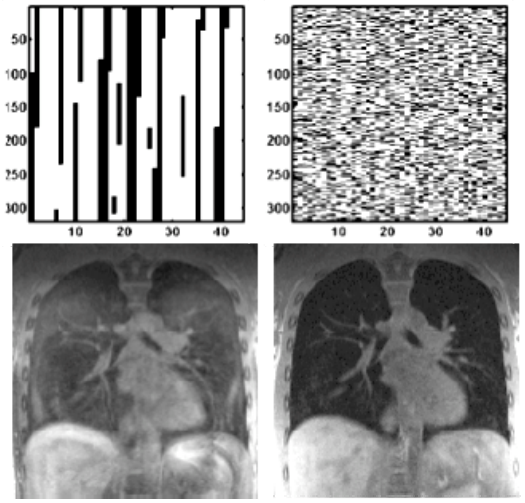

Fig 2: K-space sampling (upper row, white: acquired lines, black: missing lines) and corresponding images reconstructed using iterative GRAPPA (lower row)

Discussion

In this work it is demonstrated that quasi-random sampling in combination with respiratory self-gating reduces artifacts from cardiac and respiratory motion more effectively compared to a conventional sampling scheme. Quasi-random sampling leads to a very uniformly sampled and averaged k-space. Accordingly, the distribution of missing lines in k-space is also very regular, increasing the stability of parallel imaging reconstruction. In summary, retrospective self-gating in combination with quasi-random sampling is a more robust strategy than conventional sampling, allowing for better image quality in shorter scan time.

References

[1] Brau et al., MRM 55:263-270 (2006)
[2] Weick et al., Proc. ISMRM (2009)
[3] Niederreiter H., Bull. Amer. Math. Soc. 84:957-1041 (1978)
[4] Lustig et al., MRM 64:457-471 (2010)

Acknowledgements

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