Circular Tagging with Concentric Data Acquisition: Can we go real-time?

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Purpose

Cardiac tagging is increasingly used for non-invasive imaging of myocardial strain and many different tagging patterns have been implemented. Among these, polar (circular and radial) tagging is advantageous due to its consistency with the structure and motion of the left ventricle and simpler post-processing in the frequency domain (K-space). Quantification of myocardial deformation is potentially of great importance in diagnosis and management of heart failure, but typical acquisition times for tagging are on the order of 15 seconds. It would be desirable to capture the real time response of the heart under stress by accelerating data acquisition. In circular tagging, the information used for strain imaging is concentrated in an annular sub-region in K-space that can be sampled selectively with a set of concentric ring acquisitions [1]. The purpose of this study is to investigate the feasibility of real-time data acquisition for strain imaging through K-space concentric ring sampling. The accuracy of the reconstruction is reported for different K-space sampling patterns and acceleration factors.

Method

MR phantom data were acqired on a 32 channel Siemens TIM Avanto scanner. For ease of implementation and to test the feasibility of the algorithm, we laid down a circular tag pattern on a phantom and generated the concentric rings data format by transposing the raw data from a 2D radial scan. The images were then reconstructed through a modified Filtered Back Projection algorithm using a subset of circles of the acquired data. For reconstruction, we chose a variety of k-space patterns, each with a different number and location of circles in order to examine how far we can go to reduce the required data for robust reconstruction. The selected K-space sampling pattern is illustrated in Figure 1. In one experiment, 21 concentric circles (approximately 11% of the acquired data) were chosen, 4 of which were in the central part of the K-space (to capture the contrast information) and 17 of which spanned the spatial frequency of the circular tagging pattern (i.e. the inverse of the tag spacing).

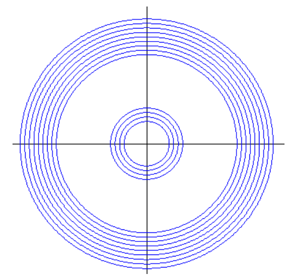

Figure 1. The K-space selected for the final reconstruction including the total number of 21 out of 192 circles.

Results

The reconstructed images are depicted in Figure 2. Figure 2(a) was reconstructed on the MR scanner using the available Siemens algorithms for radial datasets. Figure 2(b) was reconstructed with our proposed algorithm on the whole transposed raw data (192 circles) in order to verify the accuracy and precision. We also used a circular mask in image space to limit our quantification to the region of interest. Figure 2(c) shows the image reconstructed from 30% of the k-space data. The reconstructed image from a 21 circle annulus of k-space (11% of the total data) is illustrated in Figure 2(d). The overall shape and quality of the tag lines have been retained. To assess this quality, the cross-correlation coefficient of our image with the original one are shown in Table 1. Figure 2(e) shows the result for 8% of data acquisition in the k-space where some deviations are seen in tagging pattern.

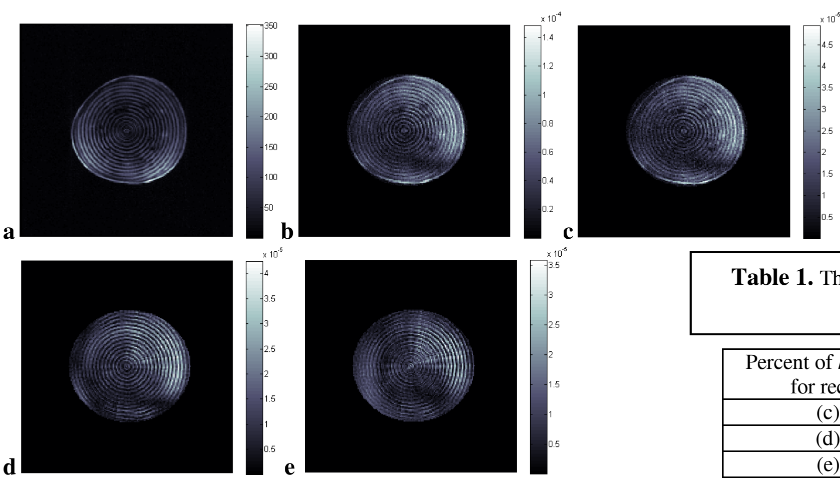

Figure 2. Reconstructed images by MRI scanner (a), applying our proposed algorithm from the entire *k*-space data (b), with acceleration factor of three (c), from only 11% of *k*-space data (d) and finally, the image reconstructed from 8% of k-space (e). As can be seen, in the last image the quality of tag lines has been degraded and the correlation coefficient value reduced as well.

Table 1. The cross-correlation coefficient of reconstructed images with the original one.

Percent of *k*-space data used for reconstruction	Correlation (describes the similarity)
(c) 30%	0.9901
(d) 11%	0.9212
(e) 8.3%	0.8663

Conclusions

We have shown that by acquisition of a small fraction of the K-space data, it is feasible to reconstruct polar tagged images and extract tag line information for strain analysis. The current algorithm speeds up the sampling process by a factor of 8. Considering typical parameters used for concentric k-space scanning, this pattern would result in an acquisition time of 105ms (21x5ms) as each circle could be acquired in a phase encoding step of 5ms. This implies that it may be possible to acquire 9+ frames per second in a real-time manner which is promising for efficient and fast strain imaging.

References

1. Wu HH, Lee JH, Nishimura DG, "MRI Using a Concentric Rings Trajectory," *Magn. Resonance in Medicine*, vol. 59, p.p. 102–112, 2008.