Hybrid Radial-Cartesian MRI

J. K. Mendes[1], J. A. Roberts[1], and D. L. Parker[1]

[1]UCAIR, University of Utah, Salt Lake City, Utah, United States

INTRODUCTION

Spatial resolution in radial imaging is determined by the readout resolution. Streak artifacts and reduced signal to noise accompany undersampling in the angular direction rather than a reduction in resolution or field of view. In many radial imaging applications a level of streak artifact due to undersampling is acceptable in diagnostic images and undersampling can be used to achieve higher spatial or temporal resolution (1,2). Radial imaging also offers some degree of reduced sensitivity to motion primarily through averaging of oversampled data near the center of k-space (3). However, several Cartesian based MRI techniques have been employed to remove certain motion artifacts by correcting errors due to in-plane displacement, in-plane rotation, through plane motion and image phase due to motion (4). This work presents a new MR technique that combines the resolution and undersampling characteristics of radial imaging with the motion correction techniques of Cartesian trajectories.

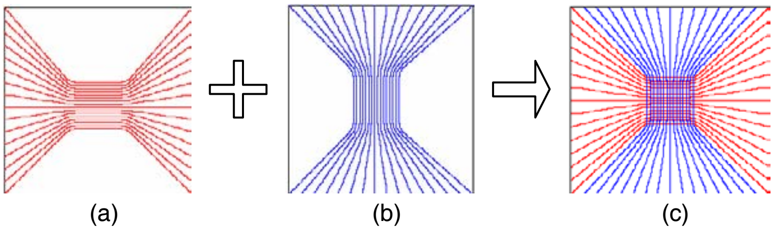


Figure 1. In the first section (a), ½N_θ views of data are acquired with the center of k-space forming parallel rectilinear lines. The second set (b) of ½ N_θ views are acquired with the center perpendicular to the first set. The N_θ lines are combined to form the complete k-space.

METHODS

The k-space trajectories of the new method are shown in Figure 1 and the gradient waveforms for a single readout are shown in Figure 2. A typical Cartesian acquisition is modified such that data is acquired near the edge of k-space in a radial fashion and rectilinearly near the center of k-space. Data is sampled isotropically in the readout direction but is divergent in the phase encode direction to cover to the corners of k-space. As shown, for 2D acquisition, the sequence must be applied once in the horizontal and once in the vertical directions for complete k-space coverage. Re-gridding techniques are applied in the phase directions before reconstruction.

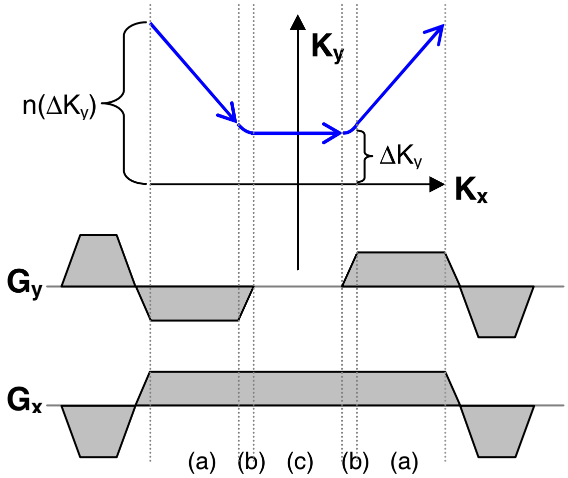
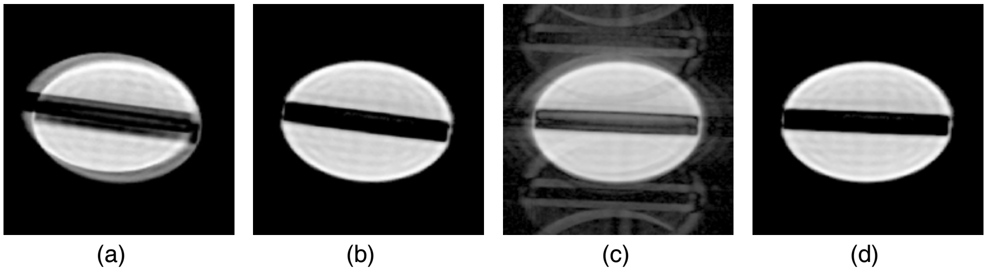


Figure 2. K-space trajectory of a single view. Radial acquisition (a), transition (b) [gradient ramp time limited] and Cartesian data acquisition (c). The constant 'n' is the ratio of N_{read} to N_θ.

RESULTS

A FLASH sequence was modified to acquire 2D data in the modified trajectories shown in Figure 1. The sequence was tested on a Siemens Magnetom Trio scanner. Images shown below were acquired with N_{read}=256 and N_θ=128 and a resolution of 1mm x 1mm. The data was acquired in two segments (64 views per segment/section). Motion between segments and motion during the segment were investigated. The phantom was moved 5~7 mm in a random direction. Images with motion and with correction are shown in Figure 3.

Figure 3. (a) Motion artifact caused by motion between data segments and (b) corrected data using oversampled data in the center of k-space. (c) Motion artifact due to motion between views within a segment/section and (d) the corrected image.



DISCUSSION

The sequence presented has similarities to both radial and Cartesian acquisition. The potential advantages of these unique attributes were investigated by simulation and phantom experiments. The results show that this technique produces images similar to those acquired with radial trajectories, with only small differences in the undersampling artifacts. The finite gradient ramp time during the transition period (Fig 2(b)) creates additional small pockets (above those created by undersampling) in k-space where no data points are sampled. These sampling holes are outside the central Cartesian rectangle of k-space and represent small inhomogeneities in sampling density that appear to be adequately handled by regridding. The response of this MR sequence to off resonance effects has not yet been investigated. This MR technique can be extended to 3D imaging with volume Cartesian coverage in the k-space center. The center of k-space would be oversampled in three perpendicular directions, but the total number of acquired views remains unchanged from a normal radial 3D image.

CONCLUSION

This MR technique retains the resolution and undersampling characteristics of radial imaging with the motion correction capability of Cartesian trajectories.

REFERENCES

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