

Complementary Radial Tagging for the Assessment of Left Ventricular Function

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Introduction

Myocardial tagging is a useful magnetic resonance imaging tool to non-invasively assess and quantify myocardial deformation in both research and clinic settings^[1]. We have previously shown that due to the gross annular geometry of left ventricles (LV), radial tags^[2] have advantage for the measurement of LV contraction and myocardial torsion compared with conventional line or grid SPAtial Modulation of Magnetization (SPAMM) tags. T_1 relaxation effect, however causes tags fading and typically results in tags only being detectable during the first ~50% of the cardiac cycle in patients. Complementary SPAMM (CSPAMM) with ramped imaging flip angles provides a way to maintain relatively uniform tag contrast throughout the whole cardiac cycle^{[3][4]}.Herein we combine the CSPAMM technique with radial tag encoding and demonstrate the sequence in simulations, images in phantoms and a normal healthy subject

Methods

A gradient echo pulse sequence was modified to generate radial tags with uniformly spaced spokes that could be circumferentially shifted by adjusting a rotation variable. The pulse sequence for the two complementary radial tagging experiments is shown in Figure 1. Note the subtle shift of the G_x and G_y gradients that accommodate the generation of radial tags along shifted radial paths. The sequence was further modified to support ramped imaging flip angles, which enable near constant tag contrast and facilitate more apparent tag persistence. Variable imaging flip angle (FA) complementary radial tags were used to acquire images in a cardiac motion phantom and in the short axis plane in a healthy human subject with the following parameters: 300x300 mm FOV, 5mm slice thickness, TE/TR=3.75/5.13ms, 30° final flip angle, 192x192-26 acquisition matrix, 8 k_y-lines per segment and ¾ partial Fourier imaging are used for the human study

Results

The pulse sequence diagram is shown in Figure 1. Seven half sinusoid RF pulses are used to generate total of 14 tags in the standard tagging sequence, which results in 28 complementary radial tags. Sinusoid-shaped gradients generate (blue solid line) standard radial tags, while shifted G_x,G_y gradients (red dash line) generate complementary tags. Figure 2 shows the standard radial tag images with constant flip angle and the complementary radial tag images with ramped flip angle in a phantom at early middle and late cardiac phases. Note the apparent radial-circumferential shear deformation. Complementary radial tags increases the apparent contrast of the tags in late phases of the cardiac cycle. Figure 3 shows the standard radial tag images and complementary radial tag images both with ramped flip angle acquired from a healthy human.

Discussion and Conclusion

A new radial tagging sequence was theoretically described, simulated, tested in phantoms and implemented for in vivo imaging. With similar spatial resolution and tag density, radial tag lines may prove more convenient for measuring LV contraction and torsion compared to previous Cartesian coordinate system. In the current complementary radial tagging sequence, the first and last tag lines do not have pre- or post- off -resonance excitation lobes. To compensate for this effect, further modification of the RF and gradient waveform is needed. Also, all the complementary radial tagging techniques double the total data acquisition time, which places limits on the achievable spatial and temporal resolution that can be acquired in a breath hold. Complementary radial tags encode a tagging pattern that enables estimates of circumferential and radial strain. LV torsion and radial-circumferential shear strain with a pattern that is better matched to the LV geometry and may enable more facile assessment of LV regional function.

References

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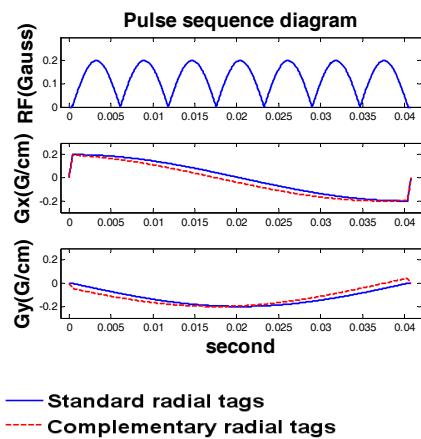


Figure 1 Pulse Sequence Diagram

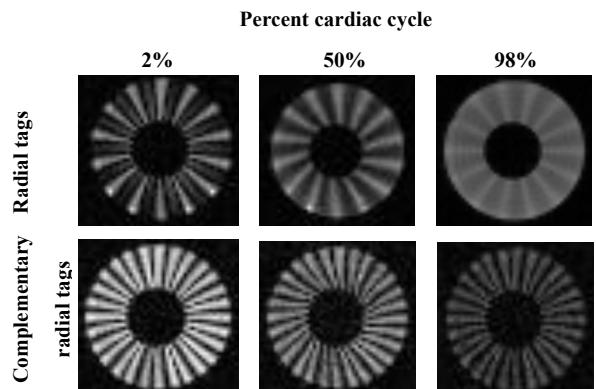


Figure 2 Cardiac motion phantom images

Images are acquired by using standard radial tags (top row) and complementary radial tags (bottom row). Note the improvement in tag contrast in the complementary radial tagging sequence.

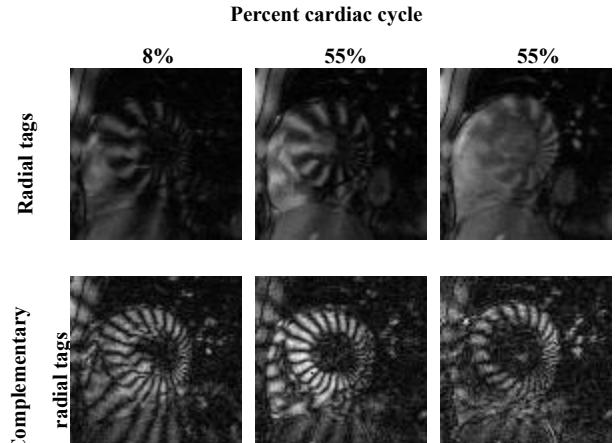


Figure 3 *in vivo* images

Images are acquired from a normal human subject with standard radial tags (top row) and complementary radial tags (bottom row). Note the significantly improved tag contrast in the complementary radial tagging sequence