Improved TSE imaging of the heart with motion-tracking

J. Keegan[1], P. Gatehouse[1], S. Prasad[1], D. Firmin[1,2]

[1]CMR Unit, Royal Brompton Hospital, London, United Kingdom, [2]Imperial College of Science Technology and Medicine, London, United Kingdom

Introduction

The addition of a slice-selective 180^0 pulse (STIR) approximately 170ms before a dark-blood prepared T2-weighted TSE imaging segment (1) provides effective suppression of epicardial fat and sensitivity to the prolonged T1 and T2 of infarct-associated myocardial edema (2). The efficacy of this technique relies on the heart being in the same position during the preparation phases (both dark-blood and STIR) as it is during imaging. The slice thickness of the dark-blood and STIR selective preparation pulses is generally twice that of the imaging slice in order to compensate for some cardiac mis-registration and for imperfect slice profiles. However, despite this, poor image quality is often obtained, particularly in the highly mobile basal short axis imaging plane and particularly in subjects with a fast heart rate. Although increasing the slice thickness to 15 - 20mm (2) reduces the effects of mis-registration, it increases the unwanted signal from slow moving blood and reduces the sensitivity for detecting focal areas of edema. We have developed a motion-tracked TSE sequence which provides good quality images in the basal planes without the need for an increased slice thickness.

Methods

Using the method of Kozerke et al. (3), a cine sequence with a labelling pre-pulse (selective and non-selective 90^0 pulse pair) was implemented on a Siemens Sonata 1.5Tesla scanner. Interleaved horizontal (hla) and vertical (vla) long axis image planes were acquired during a breath-hold, with the labelling being performed perpendicular to the hla plane, just below the level of the valves. The resulting images show the motion of the labelled slice through the cardiac cycle in both planes. A TSE sequence was modified to allow selective positioning of the dark-blood and STIR 180^0 preparation pulses. STIR T2-weighted TSE imaging (slice thickness 7mm, TE = 60ms, acquisition window = 110ms) was performed in the basal plane of healthy volunteers according to our standard imaging protocol. The imaging was then repeated using the same parameters, but with the position and orientation of the dark-blood and STIR preparation pulses being determined from the interleaved labelled hla and vla scans. For optimal basal left ventricular imaging the labelled vla scan was positioned through the left ventricle, whereas for optimal basal right ventricular imaging, it was positioned through the right ventricle.

Results

Figure 1 shows the positioning of the selective dark-blood and STIR 180^0 preparations ((a) and (b) respectively) and of the TSE imaging segment (c). The positions are determined from the labelled hla and vla cine datasets and for clarity, have been superimposed on standard cine images at the appropriate times in the cardiac cycle. In this example, the inversion pulse positions were optimised for the left ventricle. Figure 2 shows images of a basal short axis plane both without (a) and with (b) motion-tracking of the left ventricle. The image quality of the tracked left ventricle is clearly superior to that of the untracked image, where mis-registration of the preparation and imaging slices has resulted in considerable and patchy signal loss. A second example is shown in Figure 3(a) where this time, the motion of the right ventricle has been tracked. In this example, the untracked image is non-diagnostic while tracking has resulted in good image quality for both ventricles. Note that in both of these examples, as the STIR 180^0 pulse in the tracked image has been positioned in a plane determined by the motion of the basal short axis slice (Figure 1(b)), the degree of fat suppression seen in the imaged slice (Figure 1(c)) varies across the image but should be optimal for those regions moving with the ventricle of interest.

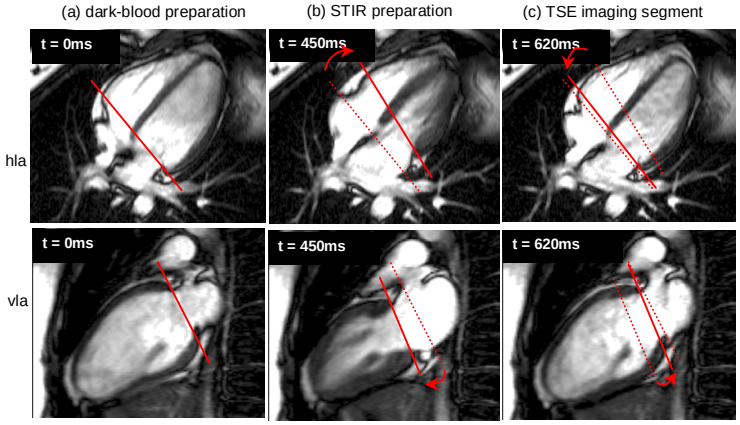

Figure 1: hla (top) and vla (bottom) images showing the positions (solid lines) of (a) the dark-blood preparation (t = 0ms), (b) the STIR preparation (t = 450ms, TI = 170ms) and (c) the TSE imaging segment (start at t = 620ms, duration 110ms) in a subject with an R-R interval of 850ms. The timing of the imaging segment was chosen for optimal dark-blood suppression and for minimal motion throughout the TSE readout period.

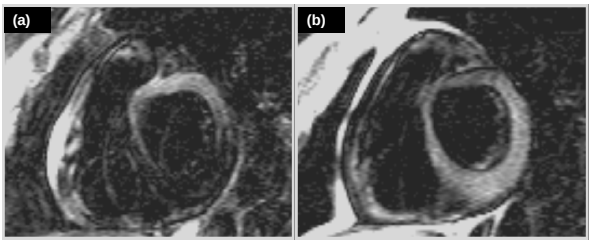

Figure 2: STIR T2-weighted TSE images both without (a) and with (b) motion tracking of the left ventricle

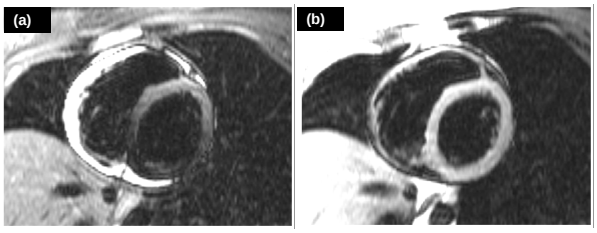

Figure 3: STIR T2-weighted TSE images both without (a) and with (b) motion tracking of the right ventricle.

Conclusion

Motion-tracking techniques improve the quality of TSE imaging of the heart. We have demonstrated this in the basal short axis plane where motion throughout the cardiac cycle has been determined in two perpendicular planes in a single labelled breath-hold acquisition. Although we have labelled only a single plane, replacing the selective 90^0 pulse in the labelling sequence with a COMB excitation allows multiple planes to be labelled simultaneously. In the examples shown here, the selective preparation pulses in the TSE sequence are positioned manually on the labelled images but alternatively, the time-dependent motion of the imaging plane could be determined automatically (3) and input to the sequence. This technique could also allow motion tracking of the slice throughout the 180^0 pulses of the TSE imaging segment which would be particularly beneficial in patients with a fast heart rate and a reduced period of diastasis.

References

(1) Simonetti O et al., Radiology 1996
(2) Abdel-Aty et al., Circulation 2004
(3). Kozerke et al., Magn Reson Med 1999