Dynamic cardiac MR temperature imaging with the Proton Resonance Frequency technique: a study on the feasibility and accuracy

B. Quesson[1], B. Denis de Senneville[1], G. Herigault[2], P. Jaïs[3], C. Moonen[1]

[1]Imagerie Moleculaire et Fonctionnelle, Bordeaux, France, [2]Philips systèmes Médicaux, Toulouse, France, [3]hopital cardiologique du haut lévèque, Bordeaux, France

Purpose/Introduction

Heart arrhythmia can be treated with local hyperthermia using a radiofrequency ablation catheter positioned in contact with the internal heart wall. Ablation duration and effectiveness is highly dependent on the local tissue heating. However, at present time, no quantitative thermal imaging is available treatment monitoring. This preliminary study aims at optimizing a MR protocol for cardiac temperature imaging (using the Proton Resonance Frequency (PRF) shift [1]) and estimating the precision of the technique.

Subjects and Methods

Healthy volunteers (n=3) were positioned in a 1.5T scanner (Philips Intera) with a 5 elements cardiac coil positioned around the thorax. Breath hold balanced FFE scout images were acquired. A single slice was then positioned in the short axis of the left myocardium for thermometry. The phase sensitive MR imaging sequence was a combination of a transient field echo and a segmented EPI technique (TFEPI) to acquire a complete image within 1 to 4 cardiac cycles. Since PRF technique is sensitive to motion, cardiac triggering was used and respiratory motion was compensated using a navigator (pencil beam) positioned on the liver/lung interface. An optimal EPI factor of 5 was empirically determined to limit image distortions. To reduce the influence of cardiac motion, acquisition was performed during the end-diastolic period and the TFE factor was adjusted such that the TFE shot duration remained in the range of 10-20% of the RR cardiac interval. A rectangular FOV (65%) was used with a matrix of 128, resulting in a pixel size in the order of 2.2 mm. Slice thickness was set to 7 mm and echo time/TFE repetition time was fixed to 10/20 ms. In addition, blood signal was suppressed before each TFE train using a double inversion-recovery module. Several dynamics were acquired over a period of time of at least 2 minutes to estimate the temporal stability of cardiac MR thermometry. Each individual image was processed offline to calculate apparent temperature changes from phase difference. The stability of MR thermometry was estimated in each pixel from the calculation of temperature standard deviation over time. Additional image processing was performed to correct for possible remaining displacements between successive dynamics by applying an image registration algorithm (optical flow) on magnitude images. This method uses a subset of images (the first 30% dynamics) to correct for erroneous temperature variations due to local displacements and susceptibility related effects [2].

Results

Figure (a) displays a magnitude image of the short axis of the heart for one of the volunteers after optimization of the acquisition protocol. Figures (b) and (c) display standard deviation maps of the temperature obtained without (b) motion correction, and with (c) the motion correction algorithm described above.

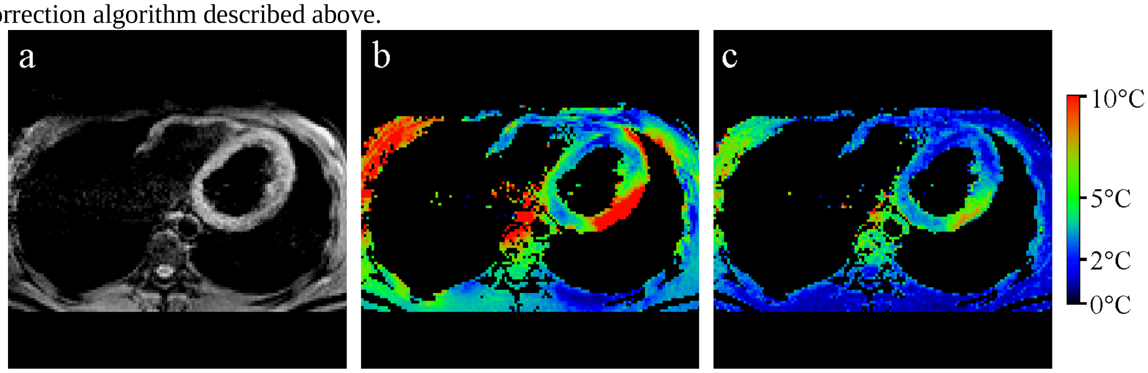

Image quality observed on magnitude images was high enough to obtain accurate phase measurements in most of the pixels located on the myocardium. The quality of blood signal suppression allowed a clear delineation of the myocardium. A large number of the pixels in image (b) exhibit a temperature standard deviation above 5°C. After motion correction, most of these pixels display a standard deviation below 5°C, except in a very small region close to heart/lung interface.

Discussion

This preliminary study demonstrates that rapid dynamic MR temperature maps can be obtained on the left myocardium with the use of a fast and phase sensitive imaging sequence associated with respiration and cardiac synchronisation. Although our optimized protocol provides magnitude image of sufficient quality for an accurate phase measurement, additional processing may improve temperature stability by correcting for residual motion artefacts. The temporal resolution and accuracy of our technique may be well suited for precise monitoring of temperature evolution in typical radiofrequency ablation procedures (several minutes).

Ref

1-Ishihara Y et al [1995],Magn Reson Med,34:814-823

2-de Senneville B et al [2004] International Conference On Image Processing, Singapore