Validation of Cine-FLASH as a method to image Late Gd Enhancement in mice

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Introduction

Late Gadolinium Enhancement (LGE) cardiovascular magnetic resonance (CMR) imaging is usually performed by a T1-weighted sequence with an inversion recovery (IR) pre-pulse (1). This method is clinically well established to diagnose myocardial infarction (MI) in humans (2). However, few studies have been reported in small animals such as mice (3). Although LGE inversion recovery imaging in mice achieves good contrast from areas of Gd agent uptake, there are several drawbacks. First, the absence of contrast between Gd infarcted areas and blood which is still loaded with Gd, can lead to an under or overestimation of the infarcted area. Second, image blurring and repeatability are strongly related to ECG and respiration trace stability after Gd injection. Third, some anatomical information is lost, due to the null point image acquisition of normal tissues. In order to avoid such limitations, a cine-FLASH (4) has been compared to inversion recovery sequence and it is suggested as a more reliable method of imaging LGE in mice 2 days after MI.

Method

Five C57Bl6 mice underwent permanent left coronary artery ligation. MRI images were obtained with an inversion recovery and cine-FLASH imaging technique at 2 days after MI. After sedation of the animal by isoflurane-oxygen mixture and IP injection of 30µl Gd, images were acquired on a 7 T horizontal-bore MR scanner (Varian, USA), with gradient strength of 1000mT/m and a 39mm RF coil (Rapid, Germany). Imaging parameters included: FOV of 20x25mm², 0.5mm thickness, matrix size of 128x128, 13 slices, flip angle=20°. Cardiac cycle = 120ms, respiration cycle =1300 ms. Double gating was achieved using an external trigger device (SA Instruments, NY, USA). Parameters for the inversion recovery included: TReff =1300ms, TE=1.5ms, 1 average, 1 frame, inversion time (TI) 350ms, 8 phase encoding steps per cardiac cycle, temporal resolution 7min. Parameters for the cine-FLASH included: TR=15ms, TE=1ms, 4 averages, 8 frames, temporal resolution 15min.

Results

Fig1A reports a short axis view of an inversion recovery image where significant contrast is achieved between infarcted and normal myocardium. The drawback is the absence of contrast between blood in the left ventricular cavity and infarcted tissue. Fig1B shows a cine-FLASH image which is spatially correspondent to Fig1A. The contrast between infarcted wall (enhanced by Gd), healthy myocardium and blood is well enhanced. Only three mice out of five were imaged with the IR LGE sequence due to double gating instability. IR and cine images revealed a 5% accuracy in the enhanced wall area throughout the myocardium volume. Fig2 reports the SNR obtained from IR and cine-FLASH images. The IR data are related to three of the five mice scanned, while cine-FLASH data are related to all five mice. IR infarcted tissue SNR is 309±50, blood SNR 311±100, healthy tissue 0. Cine-FLASH infarcted tissue SNR is 372±20, blood SNR 545±40, healthy tissue 221±20. The contrast for IR acquisitions of infarcted area and blood is 2±111, while between infarcted and healthy tissue is 309±50. The cine-FLASH contrast between infarcted myocardium and blood is 173±45 and between infarcted and healthy tissue is 151±28.

Discussion

The data reported show that LGE works sufficiently well in mice 2 days post ligation. Images were obtained with the inversion recovery (IR) and cine-FLASH to differentiate infarcted from normal myocardium. However, two out of five mice failed to be imaged by IR due to ECG and respiration instability. Despite such instability, cine-FLASH achieved good images from all five animals. Hence, cine-FLASH represented a more flexible and reliable technique when compare to IR. Cine-FLASH also reported more accurate SNR values and better contrast between infarcted myocardium, normal myocardium and blood. These achievements were established by cine-FLASH when the TE was shortened to 1ms. The here implemented steady–state technique was able to accurately detect T1 differences between blood (still loaded with Gd) and Gd enhancemed myocardium and to maintain a lower but still detectable signal from healthy tissues. Such a scenario is not achievable from clinical system due to the lower gradient strength and therefore longer TE (≈5ms) used. On the other hand, high contrast between healthy and infarcted myocardium was obtained by IR technique although it was difficult to distinguish between infarcted tissues and blood still loaded with Gd. In addition, anatomical information was partly lost due to the null point of healthy tissues.

Conclusion

Cine-FLASH appears to be a reliable method for the study of LGE of myocardium in mice after MI. The technique overcomes issues such as tissue differentiation and monitoring discrepancies, and no anatomical information was lost. On the contrary, IR was found to fail in 40% of the mice and although the contrast between infarcted and normal myocardium was maximized, it is difficult to differentiate the border between inflamed tissues and blood.

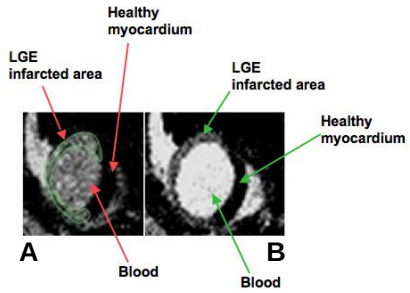

Fig1. A) inversion recovery (IR), B) cine-FLASH, of a mouse 2 days post MI. Although IR is the gold standard technique for LGE imaging, cine-FLASH reports a better way of differentiate between inflamed myocardium, normal myocardium and blood.

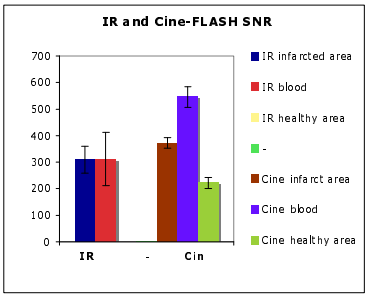

Fig2. Inversion recovery (IR) and cine-FLASH have been used to detect signal from infarcted area, blood and healthy myocardium wall. While the SNR between infarcted area and blood in IR is similar and that of healthy tissue is 0, for cine-FLASH they can be well differentiated.

References

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