Comparison of different field insensitive saturation pulses for 3T cardiac first pass perfusion

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Introduction

MR imaging during the first pass of an exogenous contrast agent has yielded promising results as a quantitative evaluation in patients with symptoms o coronary artery disease [1]. Quantification or semi-quantification of myocardial perfusion requires spatially homogenous saturation of magnetization across th heart. In particular, variation in flip angle of a saturation preparation will impose a spatially varying difference in contrast which may compromise the accuracy o quantitative or semi-quantitative perfusion and potentially reduce contrast-to-noise (CNR).

The main advantage of 3.0 T field MR is the approximately doubled signal-to-noise (SNR) relative to 1.5 T [2] that could contribute at first-pass myocardia perfusion data. However, higher magnetic field compromises the inhomogeneity of static magnetic field (B0) and radiofrequency magnetic field (B1) [3]. Th accuracy of perfusion measurement depends on initial residual longitudinal magnetization reduced (produced) by a nominal saturation pulse applied in the pre contrast T1 weighted images [4].

The first goal of this study was to determine the most effective out of three different saturation methods in healthy volunteers. In a second step the bes perfoming technique was compared with the standard method (I) in a patient with known history of myocardial infarction. In a second step the comparing norma volunteers and patient with a known history of myocardial disease.

Material and Methods

Sequence Design:

A single shot first pass perfusion sequence using a Turbo FLASH readout has been modified on a clinical 3.0T scanner (Siemens MAGNETOM Trio Siemens, Erlangen, Germany) to support three different saturation methods: (I) standard single non-selective saturation recovery pulse, (II) three repeated non selective saturation composite pulses with crusher gradients to improve the effectiveness of the saturation pulse [6] and (III) a adiabatic BIR4 pulse that provide improved insensitivity to both B_1 and B_0 [4]. Typical imaging parameters have been: TR= 171ms, TE= 1.2 ms, flip angle = 12 degrees, bandwidth of 975 Hz/pixe matrix =123 x 83, FOV of 360 x 243, GRAPPA Factor = 2, three slices per heart beat, typically 50 heartbeats.

Volunteer Study:

Pre-contrast images were obtained using the three saturation methods to compare the saturation performance of each technique. For first pass perfusion imaging Gd-DTPA (0.075 mmol/kg, Magnevist, Schering AG, Berlin, Germany) was injected at a rate of 4.0 ml/sec followed by saline flush (20ml at a rate of 4.0m/s).The volunteers were studied three times at different days to acquire first pass perfusion images without contrast load from previous studies. The slice position in different studies was visually reproduced.

Patient Study:

A patient with a known history of myocardial infarction was scanned using method (I) and method (III) and first pass perfusion images were obtained.

Data Analysis

A plot profile of the myocardial was obtained to quantify the field inhomogeneity within the heart and normalized values were obtained. The obtained first pass images have been segmented 16 segments in the short-axis plane according to the segmentation model of the left ventricle as described by the American Heart Association and signal intensity (SI) curves were plotted for each segment. Signal-to-noise (SNR) and contrast-to-noise (CNR) was calculated. SNR was measured at the value of peak myocardial SI and divided by the standard deviation (SD) of noise. CNR was calculated by subtracting the baseline signal of each segment from the maximum signal and dividing the difference by the SD of noise [7, 8].

The images obtained from healthy volunteers and patient have been evaluated qualitatively by an experienced reader: after blinding and randomizing the perfusion images using the described three methods: The "Overall image quality" was graded on a scale as follows: presence and severity of artifacts (rim artifacts) were recorded for each cine perfusion sequence; the severity was rated on a 3-point scale representing 0 = no artifact, 1 = mild artifact, not compromisin the diagnostic value; and 2 = severe artifact. The presence and severity of background noise was recorded for each cine sequence; the severity was rated on a 3-point scale representing 1 = low, 2 = medium and 3 = high noise level. Image quality was also rated on a 4-point scale with 1 = poor, non diagnostic; 2 = fair, diagnosis may be impaired; 3 = good and 4 = excellent based on SNR and CNR.

Results:

Mean values of plotted profiles of the heart during the pre-contrast images demonstrated for volunteers during each saturation methods were significant lower at methods (II) and (III) comparing to (I), by applying a student t test ($p<0.05$). Table 1 demonstrates normalized values of histogram for each pulse obtained from pre contrast images of healthy volunteers.

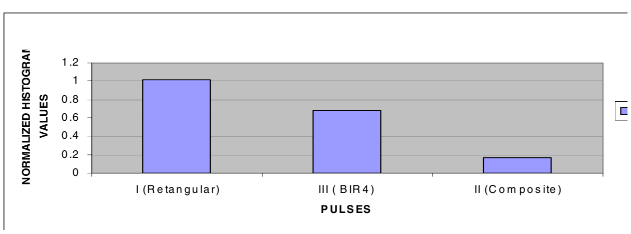
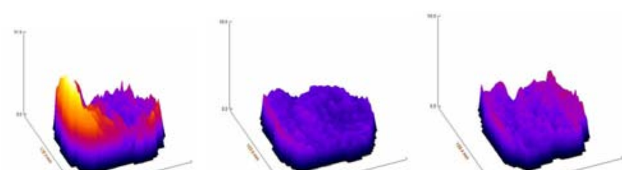


Figure 1 illustrates the surface plots of short axis images of myocardium, using three saturation methods prior to contrast injection and respective images. Saturation methods II (train of 90 degrees pulse) and III (BIR4 adiabatic pulse) presents lower surface profiles values.



Pulse (I) single non-selective saturation recovery pulse

Pulse (II) train of 90 degree pulses pulse-composite

Pulse (III) BIR4 adiabatic pulse

Image Quality

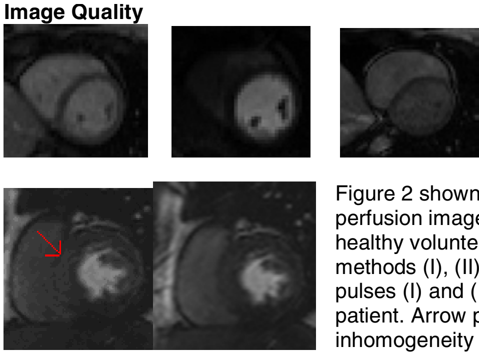


Figure 2 shown short axis perfusion images of a healthy volunteer after methods (I), (II), (III) and pulses (I) and (III) in a patient. Arrow points inhomogeneity within the myocardium.

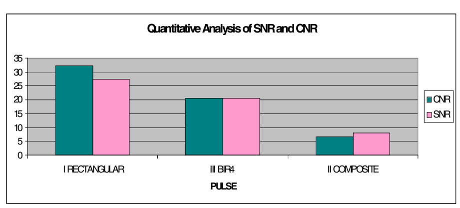


Table 2 represents quantitative values of CNR and SNR for each pulse method. Method II presented lower CNR and SNR comparing to methods I and II.

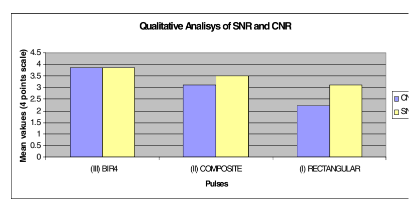


Table 3 reports improvements in both SNR and CNR by using method III (BIR4 adiabatic pulse) and II (train of 9 degree pulses –composite) by qualitative analysis.

Conclusion:

The performance of method II (repeated non-selective saturation composite pulses) and method III (BIR4 adiabatic pulse) to minimize detrimental field inhomogeneity at 3T are comparable and generate a more reliable saturation of the magnetization than method (I). The potential increase of the accuracy of the (semi) quantitative analysis of the first-pass perfusion images need to be demonstrated.