Investigation of Background Suppression Strategies in Interactive Fresh Blood Imaging

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INTRODUCTION

In contrast enhanced (CE) MRA, background signal is eliminated by using short TR sequences which saturate the longer T_1 static tissue, leaving only the short T_1 contrast agent within blood vessels to create the angiogram. In non-contrast enhanced (NCE) fresh blood imaging (FBI) [1], two images, usually cardiac gated, are acquired at different phases of the cardiac cycle to generate an intravascular signal difference. The angiogram is created following their subtraction. Effective background suppression relies on the static tissue signal being similar in both images. However TR variations are introduced with the use of different trigger delays for systolic and diastolic acquisition as well as intrinsic beat-beat variation in human heart rate, which results in dissimilar static tissue signal in systole and diastole. This can be overcome by using a long TR but this is not particularly time efficient and may not be practical for regions where other motion such as respiration can introduce artefacts.

The aim of this work is to investigate several alternative background suppression strategies as a part of the development of a rapid interactive FBI technique using SSFSE. The five strategies for improving background signal elimination in subtraction angiography are: (A) Magnetisation transfer (MT) prep, an off-resonant saturation technique used to reduce tissue signal in intracranial TOF imaging [2], (B) Projection/slice dephasing gradients used in 2D thick-slab projection phase contrast angiography [3], (C) Inversion recovery (IR) prep pulses, used routinely in 3D-FBI to eliminate fat signal, (D) Variable systolic refocusing flip train to match tissue signal of the bright blood diastolic acquisition, and last (E) Fixed TR to provide ideal, complete background suppression but may compromise optimal vascular signal [4].

METHODS

The calf vessels in a healthy volunteer were examined using a clinical 1.5T MRI system (HDx, GE Healthcare, Waukesha, WI) and an 8 channel phased array coil. SSFSE parameters were TE=33.8ms (41.4ms for projection dephaser method); resolution = 256x256; flip=130°; ZIP512; FOV=30-35cm; slice=3-4cm; NEX=0.523; receiver bandwidth=83.33kHz; min TR=1500ms and ECG gating. All sequences, except for Fixed TR case, were triggered such that k-space was acquired at same parts of the cardiac cycle. For each strategy only a single pair of representative consecutive images was subtracted for the comparison. The subtracted images were visually assessed and line profiles obtained through the images to indicate the degree of background suppression.

(A) Magnetisation Transfer. Five 8ms RF pulses at 1200Hz resonance offset, flip=1100° were used to generate a noticeable MT muscle suppression for single slice 2D SSFSE.
(B) Projection Dephaser. The slice refocusing gradient was unbridged from the first refocusing crusher gradient, and reduced appropriately to cause slice dephasing in the range of 0.1-10000cm. Interactive modification of degree of dephasing was enabled to allow real-time image optimisation.
(C) Inversion Recovery. A single 180° RF pulse with inversion delay TI=190ms was chosen following quoted values from 3D FBI literature.
(D) Variable Flip Train. The systole flip train was modulated using an estimated value to match systole and diastole tissue signal. The value was calculated using muscle T_1 and TRs at systole and diastole.
(E) Fixed TR. In order to acquire diastole bright blood every other time only, the TR must be fixed at (n+0.5)*heart period. This assumes that systole is half a cardiac period away. The first acquisition is triggered during systole and then left to run ungated at the fixed TR.

RESULTS

Results from a healthy volunteer (HR~60BPM) leg with all five suppression methods are shown in Figure 1. The systole and diastole trigger delay times were 165ms and 460ms. Acquisition time per FB image was 3-5s, almost half of typical FB acquisition times.

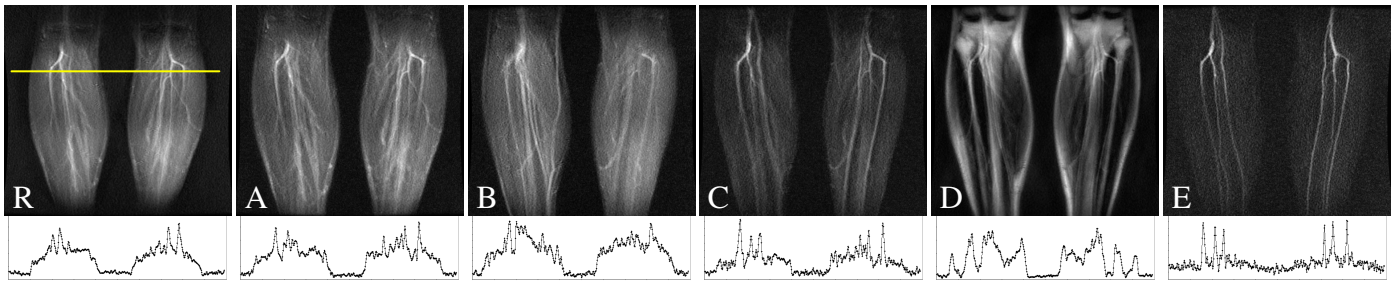

Figure 1 A representative set of FB images illustrating the effects of various tissue suppression methods: (R) Reference; (A) MT prep;, (B) Projection dephaser with dephasing over 6cm; (C) IR prep; (D) Variable flip train with systole refocusing flip at 40° and (E) Fixed TR = 1550ms. The line profile (yellow) is plotted for each case to illustrate the suppression.

DISCUSSION

Preliminary results demonstrate varied efficacies by the background suppression strategies in interactive projection Fresh Blood Imaging. MT effects showed only subtle improvement in background suppression (A). The projection dephaser was relatively ineffective except when using a large gradient which also unacceptably reduced flow signal. IR, though optimised for fat rather than muscle suppression, was effective without affecting flow signal across the field of view. Muscle suppression was excellent using the variable flip train method but requires additional fat suppression. Fixed TR method was the most acquisition time efficient method (3.1s/image compared to others at 4-5s/image) and produced excellent background suppression provided the heart rate is stable otherwise there is loss of flow signal.

Future work is planned to further optimise the MT RF pulse train prep, combine the variable flip train with fat suppression methods, and adapt the fixed TR method to cope with cardiac beat-to-beat variation.

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