Leadless cardiac gating during brain imaging using a blood flow navigator

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Introduction and Background

Traditionally, the signal for cardiac gating in MR is obtained from ECG electrodes or a pulse oximeter probe in the magnet bore. The presence of ECG electrodes and cables in the magnet bore is associated with a very slight risk of heating and possible patient burns, and the presence of conductors in the magnet may induce artifacts in the images. These effects may increase at higher field strengths.

To eliminate the need for external ECG monitoring hardware, we use a blood flow navigator (BFN). The BFN is a sequence block of around 25 ms that can be inserted between the lines or slices of a regular scan to measure blood flow in the neck, and from which a real-time estimate can be made of the phase in the cardiac cycle while acquiring an image of the brain. This can be used for gating, on-line correction or post-processing of the image [1], and does not require any additional hardware inside or near the scanner bore. It may also be more reliable with larger subjects in whom the detected ECG signal may be noisier. In addition, certain imaging sequences may introduce interfering noise in the externally measured ECG signal. We demonstrate the BFN inserted every fifth TR of a 3D FLASH sequence with TR = 30 ms, yielding a blood flow measurement every 150 ms.

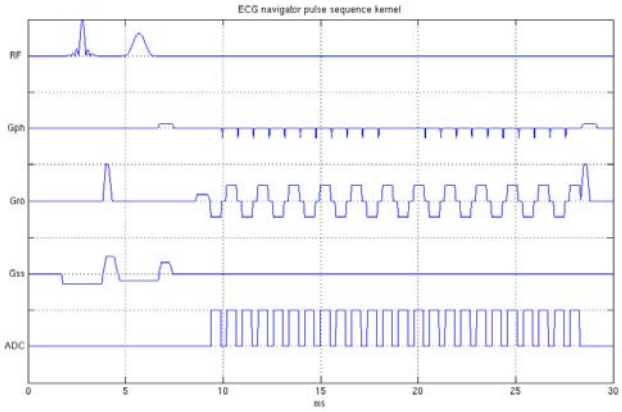

Figure 1: Pulse sequence for blood flow navigator kernel used in FLASH sequence, inserted after every n-th regular FLASH block.

Methods

The gradients, ADC reads and RF pulses required for the FLASH BFN kernel are shown in Figure 1. The first RF pulse excites the spins in the imaging slab and is present only to maintain steady-state for imaging. The signal is immediately spoiled, and a second RF pulse applied to excite the spins in the BFN slice (positioned axially in the neck). The slice is then spatially encoded in the manner of an EPI scan i.e. in a Cartesian fashion starting at one edge of k-space and traversing the center of k-space half-way through the encoding. The central line is collected three times and serves as embedded phase navigator for N/2 ghost correction.

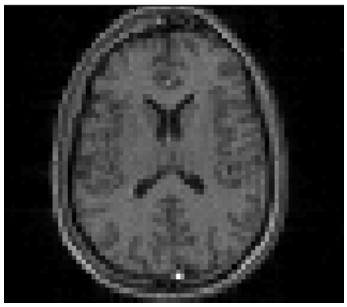

Figure 2: Slice through 3D imaging volume acquired with embedded blood flow navigators.

The BFN occurs every *n*-th block and occupies a period of one TR. The two RF pulses and equal spacing ensure that the spins in both the imaging slab and the BFN slice are kept in steady state. The slabs cannot overlap with one another. RF and gradient spoiling is used on both navigator and imaging blocks to reduce interference between TRs.

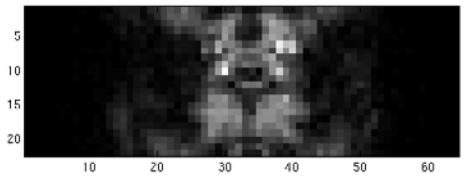

Figure 3: BFN slice including vertebral artery containing voxel at row 7 and column 40.

Results and Conclusion

Preliminary tests were done on a Siemens Avanto 1.5T scanner. We inserted the BFN every 5th TR of a 3D FLASH sequence. TR was 30 ms and TE was 3.77 ms. The field of view was 200 mm and thickness was 64 mm for the imaging slab (32 partitions and 64 matrix i.e. resolution 3.125 mm x 3.125 mm x 2 mm), while field of view was 100 mm and thickness was 10 mm for the BFN slice (12 x 32 matrix i.e. resolution 8.3 mm x 3.125 mm). Flip angle was 30° for the imaging volume and 45° for the navigator. Total acquisition time was 76 s and would have been 61 s without BFNs.

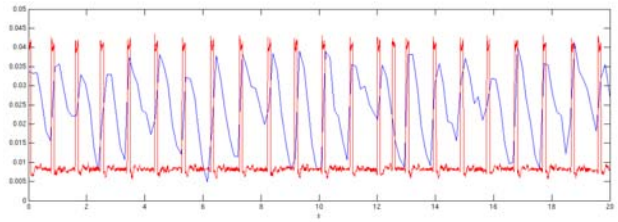

Figure 4: ECG signal detected using Siemens physiological monitor (red), and blood flow trace from BFN (blue) acquired while collecting the FLASH image shown in Figure 2. The signal from the ECG monitor has detected R waves indicated by an offset in the y-direction, and this corresponds with the rising edge of the blood flow signal.

Figure 2 shows the imaging volume for a human head acquired using the sequence with embedded BFNs. The volume obtained without embedded BFNs was visually indistinguishable. The ECG signal was collected using the built-in Siemens physiological monitoring hardware. This signal was compared with the blood flow signal obtained from the navigator. The voxel of interest (corresponding to the vertebral artery) was selected manually in post-processing. It is shown on the navigator image of the neck in Figure 3. Figure 4 shows the ECG trace measured using the Siemens equipment superimposed on the blood flow trace measured using the BFNs. The blood flow trace is simply the offset from mean of the signal intensity at the selected voxel (row 7, column 40) that corresponds to the left vertebral artery.

Total scan duration is increased by a factor of $n/(n-1)$ for a BFN every *n*-th TR and the technique requires a coil with coverage of the neck, such as the standard Siemens head coil. We intend to introduce an algorithm to automatically identify the appropriate region in the BFN for blood flow measurement. By adding velocity encoding to the BFN, the region of interest may be easier to find.

Acknowledgement

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References

1. Glover GH, Li TQ, Ress D: RETROICOR. Magn Reson Med 2000; 44:162-167.