Dynamic Fast Spin Echo Imaging of the Carotid Arteries

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Purpose: The majority of strokes are caused by large artery atherosclerosis. MR assessment of the carotid arteries has been shown to be associated with the incidence of ischemic stroke.[1] Bright blood cine MR demonstrates cross sectional luminal area change over the course of the cardiac cycle and has been used in distensibility studies.[2] However, bright blood imaging does not provide the vessel wall contrast necessary for distinguishing plaque components. A time-resolved black blood technique would enable simultaneous morphological and distensibility analyses in the carotid arteries. We implemented a dynamic fast spin echo (FSE) technique [3] and investigate its for carotid imaging.

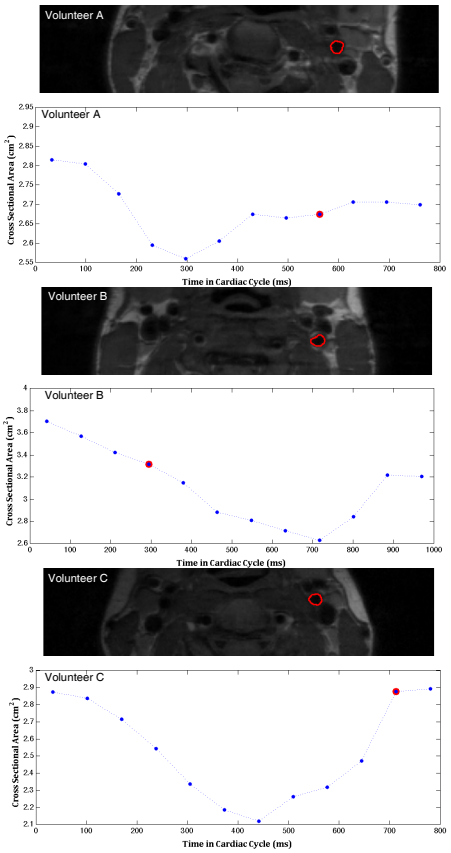

Fig 1 – Example of area change of the left internal carotid over the cardiac cycle in three healthy volunteers. Highlighted data point corresponds to image contour.

Methods: The dynamic FSE sequence was implemented by collecting FSE data (using a 3 T GE Discovery MR750 with imaging parameters: TR/TE of 2500/9.4 ms, FOV of 160 × 160 mm², acquisition matrix of 252 × 256 and slice thickness of 3 mm). The cardiac cycle was simultaneously recorded with a pulse-oximeter. The sampling density was altered to sample the centre of *k*-space with higher density than the edges. Each line of *k*-space was retrospectively gated into 12 evenly spaced undersampled phases of the cardiac cycle. Each phase was then reconstructed using the following temporally constrained sparse-SENSE algorithm:

$$\arg\min_{\mathbf{m}}\left\{\left\|\mathbf{FSm}-\mathbf{y}\right\|_2^2+\lambda_1\left\|\Psi\mathbf{m}\right\|_1+\lambda_2\left\|\overline{\mathbf{m}}-\mathbf{m}\right\|_1+\lambda_3\mathbf{TVm}\right\}$$

Where **F** is a 2D Fourier transform operator, **S** is the coil sensitivity encoding matrix, Ψ is the wavelet transform matrix, $\overline{\mathbf{m}}$ is the temporal average of all phase images and **TV** acts as a high pass filter. The weighting factors λ_n allowed for fine-tuning of the trade off between temporal averaging and artifact suppression.

A single axial slice just distal to the carotid bifurcation was acquired in ten healthy volunteers, retrospectively gated and then reconstructed into a temporal series. Images were interpolated to a 1008 × 1024 matrix and the cross-sectional areas of the left internal carotid arteries were segmented automatically using a thresholded region-growing algorithm (red contours in Fig 1).

Results: The temporal series show pulsation in the internal carotid arteries (Fig 1). However, automated segmentation failed on images (22.5%) with noise in the lumen signal or closely spaced vessels. The fully sampled static reconstructions of the dynamic datasets provided images equivalent to the standard FSE sequence with less motion artifact (Fig 2) due to the variable-density sampling scheme.[4]

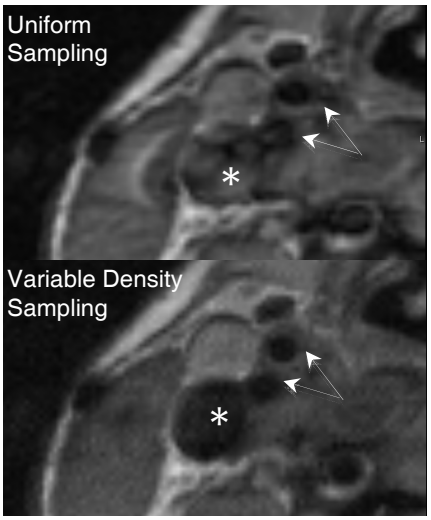

Fig 2 – Comparison of uniform sampling and variable density sampling FSE of the carotid bifurcation (arrows) and jugular vein (*).

Discussion: The temporally resolved FSE sequence maintains the lumen to vessel wall contrast of a standard FSE acquisition but also provides temporal information. Automatic segmentation results may be improved with higher resolution acquisitions and the increase in SNR afforded by dedicated carotid coils. Static reconstructions of variable density fully sampled datasets result in an excess of high frequency noise but also a clear decrease in motion artifact compared to a uniformly sampled FSE dataset.

Conclusion: The dynamic FSE sequence shows promise in distensibility studies of the carotid arteries. Acquired in the same amount of time as a standard FSE sequence, this temporal series provides both vessel and lumen motion over the cardiac cycle. Additionally, the static averaging of the temporal series results in a single image that is less affected by motion artifact than a standard static FSE acquisition.

References

[1] Yang E, *et al. Stroke.* 2012; **43**: 103.
[2] Canton G, *et al. Med Phys.* 2012; **39**: 6247.
[3] Mendes J, *et al. Magn Reson Med*. 2011; **66**: 1286.
[4] Liao JR, *et al. Magn Reson Med.* 1997; **37**: 569.