Hemorrhage detection in the carotid atherosclerotic lesion – Initial results at 3T

K. DeMarco[1], D. Zhu[1], H. Underhill[2], M. Ferguson[2], M. Oikawa[2], W. Yu[2], and C. Yuan[2]

[1]Michigan State University, East Lansing, Michigan, United States, [2]University of Washington, Seattle, Washington, United States

Introduction

There is increasing evidence that carotid plaque hemorrhage may be important determinate of stroke risk [1]. Hemorrhage in the atherosclerotic carotid plaque has been detected on *in vivo* 1.5T MR with high sensitivity and moderate specificity using multi-contrast technique [2]. An alternate approach to detect plaque hemorrhage using a T_1-weighted magnetization-prepared 3D gradient echo sequence at 1.5T has also been described with good sensitivity and specificity compared to histology [3]. We have recently developed a similar optimized 3D inversion recovery prepared fast spoiled gradient-recalled sequence (IR FSPGR) on a GE 3T EXCITE scanner for carotid plaque imaging. This new axially oriented 3D IR FSPGR sequence has improved time efficiency which supports 500-600 micron in plane resolution with sufficient superior-inferior coverage to include both carotid bifurcations in under 5 minutes. We wish to validate plaque hemorrhage detection at 3T using all of these *in vivo* MR techniques compared with the detailed histological correlation of the carotid endarterectomy specimen.

Methods

Ten subjects scheduled for carotid endarterectomy have been imaged on a 3T GE MR scanner prior to surgery. Currently, 6 CEA specimens have undergone detailed histological analysis and comparison to the *in vivo* 3T MR images. Dedicated 3T carotid surface coils were placed on either side of the neck at the level of the carotid bifurcations. High resolution non-contrast 3D time-of-flight MR angiographic images (partition thickness 1 mm, every 0.5 mm), 2D non-contrast T2 weighted plaque images with double inversion recovery pulse [4], 3D inversion recovery prepared fast spoiled gradient-recalled sequence (partition thickness 1 mm, every 0.5 mm), pre- and post-contrast T1 weighted plaque images with quadruple inversion pulse [5] were obtained. Two experienced reviewers each independently reviewed 2 sets of images from each of these 6 patients.

Image Set 1: T1WI, T2WI, TOF MRA, and post-contrast T1WI

Image Set 2: T1WI, T2WI, TOF MRA, post-contast T1WI, and IR FSPGR

Quantitative analysis of intraplaque hemorrhage was performed using CASCADE (University of Washington, Seattle, WA). For image set 1, hemorrhage was determined based on the TOF and T1 imaging characteristics. For image set 2, hemorrhage was determined based on the IR-FSPGR sequence. Both reviewers were blinded to histology, to each other's results and also from the results of the corresponding image set from the same patient. Cohen kappa (κ) and Pearson correlation were computed to quantify the agreement between 3T MRI and histology, and between the 2 MRI reviewers.

Results

Six patients have been analyzed to date. The T1WI, T2WI, TOF MRA, post-contast T1WI, and IR FSPGR sequences were matched at 17-18 locations per carotid artery for a total of 105 slices per imaging set. These 105 MR slice locations were then matched to the corresponding histology images. Figure 1 is a representative example comparing histology of the hemorrhagic carotid plaque specimen with T1WI, TOF MRA, and IR FSPGR at 3T. The boundary of plaque hemorrhage is somewhat more distinct on the IR FSGPR image. High quality IR FSGPR multiplanar reformations are possible. For hemorrhage detection at the slice level (N=105), Cohen κ between the 2 MR reviewers was 0.854 for Image Set 1 and 0.880 for Image Set 2. For hemorrhage detection at the slice level (N=105), the Cohen κ comparing MR results to histology for each reviewer was:

Image Set 1:	Reviewer 1:	$\kappa = 0.684$	Image Set 2:	Reviewer 1:	$\kappa = 0.753$
	Reviewer 2:	$\kappa = 0.671$		Reviewer 2:	$\kappa = 0.659$

At the arterial level (N=6), the Pearson's correlation between quantitative size of plaque hemorrhage on 3T MRI compared with histology for each imaging set and each reviewer was:

Image Set 1:	Reviewer 1:	$R = 0.996$	Image Set 2:	Reviewer 1:	$R = 0.984$
	Reviewer 2:	$R = 0.977$		Reviewer 2:	$R = 0.960$

All of these Pearson's correlations were significant to $p<0.001$.

Conclusion

These preliminary findings suggest that carotid plaque hemorrhage can be identified at 3T using criteria similar to those developed for 1.5T MRI. Analysis of the images by expert readers with extensive experience in MRI plaque characterization demonstrated that the measurement of plaque hemorrhage with 3D IR FSPGR was similar to hemorrhage detection using previously described techniques based on 3D TOF MRA and T1W image analysis. Larger studies are needed to more definitively determine whether reader reproducibility is improved with 3D IR FSPGR.

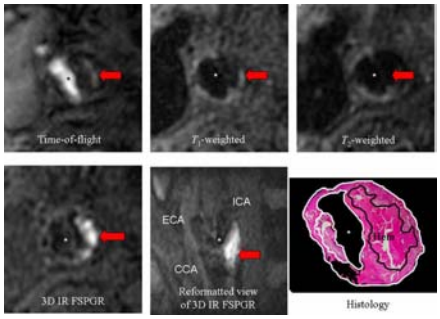

Figure 1. Matched *in vivo* 3T MR and histology cross-sectional images of internal carotid artery

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