Comparison of direct thrombus imaging to multi-contrast MRI for assessment of carotid atheroma

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Background and Purpose

Intraplaque haemorrhage has become an acknowledged risk factor in relation to plaque stability and clinical events, such as stroke [1, 2]. Multi-contrast MRI has become established as a method for detection of acute haemorrhage and complex plaque (AHA grade VI) [3], however the use of multiple sequences is time consuming for image acquisition and analysis. A technique, known as direct thrombus imaging (DTI), has previously been used to diagnose the presence of intraplaque haemorrhage [4, 5]. It has also been correlated against future clinical events [6]. The aim of this study was to assess whether DTI could be used independent of other sequences for the detection of thrombus and diagnosis of complex disease.

Materials and Methods

Fifty-five subjects with confirmed carotid atheroma (ultrasound demonstrated >30% stenosis) were imaged on a 1.5T whole body MR system *(Signa HDx, GE Healthcare, Waukesha, WI),* using a 4 channel phased-array carotid coil *(PACC, Machnet BV, Eelde, The Netherlands)*. Cardiac gated, double inversion recovery fast spin echo sequences with fat suppression were performed to give T1-weighted, T2-weighted and proton density-weighted images. DTI was performed using a 3D IR-prepared fast gradient echo sequence in the coronal plane giving an imaging time of approximately 2.5 minutes. Imaging parameters were: TE 2.6ms; TR 5.7ms; matrix 160x160; flip angle 15°; TI 19ms; FOV 10x10cm; NEX 2; slice thickness 1mm (spacing –0.5mm); number of slices acquired 120. The first observer reviewed only the DTI images (i.e. excluding the multi-contrast data), in the coronal plane to decide whether vessel wall enhancement was present. A second independent observer reviewed only the multi-contrast data (i.e. excluding the DTI) to detect the presence of thrombus. The DTI images were then reformatted into the axial plane to match the multi-contrast slices and regions of interest (ROIs) were defined for the lumen, vessel outer wall and within the sternocleidomastoid (SCM) muscle using Vesselmass *(Leiden University Medical Centre, Leiden, The Netherlands)*. Mean signal intensities for these ROIs on DTI were then recorded. The sensitivity and specificity of DTI was calculated using multi-contrast imaging as the 'gold' standard. The signal intensities for the ROIs were averaged to a vessel level (right and left carotid arteries were considered independently) and the vessel wall measurement compared to the SCM measurement for the same patient to give percentage signal intensity for the vessel wall averaged against the muscle. These results were then compared to the subjective categorisation of the images.

Results

Out of the 55 patients recruited 5 were discounted as the DTI was of poor quality due to patient motion. Out of the remaining 50, when considering both carotid arteries there were 71 disease affected vessels. The results of the subjective assessment of thrombus presence are shown in Table 1. An example of a positive image is illustrated in Figure 1. When the multi-contrast images were reviewed for the presence of complex plaque (AHA grade VI) rather than just thrombus the correlation between the two imaging types on subjective review improved (Table 2). DTI demonstrated a sensitivity and specificity of 94.9% and 90.6% respectively when compared to the 'gold' standard of multi-contrast MRI for the detection of type VI lesions. For detection of type VI lesions DTI imaging has a positive predictive value (PPV) of 92.5% and a negative predictive value (NPV) of 93.6%. Analysis of the signal intensities demonstrated that cases positive on DTI and AHA type VI lesions had a higher average signal intensity when normalised to muscle on DTI ($85.7\pm20.7\%$) than those that were negative ($62.5\pm7.9\%$).

Discussion

The ability to detect complex lesions from imaging is of great benefit as these patients are more likely to develop future clinical events [2]. DTI has been shown to highly sensitive and specific for the detection of complex lesions (type VI). It less sensitive compared to multi-contrast imaging if only thrombus is considered, however, there was evidence of enhancement on DTI where there was fibrous cap disruption on multi-contrast imaging which increased its sensitivity and specificity when considering type VI lesions as a group. This is more clinically useful as both the presence of thrombus and fibrous cap disruption has been linked to clinical events [2, 7, 8]. Therefore the sequence can be used with confidence for the detection of complex lesions as it has a high PPV and NPV.

Although multi-contrast imaging is the 'gold' standard for the characterisation of plaque morphology, the DTI sequence provides a fast method of establishing the presence or absence of complex atheroma. Use of an automated classifier to define boundaries and extract the signal intensities provides quantitative information to assess whether the plaque is stabilising over time.

Conclusion

DTI is a highly sensitive and specific way of identifying complex carotid lesions (AHA type VI). The speed of acquisition means that this information can be provided rapidly. Analysis using an automatic classifier may provide the ability to quantitatively monitor patients for changes in their disease. Follow-up studies are required to test this hypothesis.

Table 1: Results of subjective image review (presence of thrombus)

| | | Direct thrombus imaging | | Total |
		Negative	Positive	
Multi-contrast imaging	Negative	26	15	41
	Positive	5	25	30
Total		31	40	71

Figure 1: example of positive direct thrombus imaging (DTI)
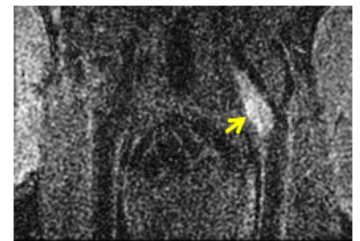

Table 2: Results of subjective image review (AHA grade VI on multi-contrast imaging)

| | | Direct thrombus imaging | | Total |
		Negative	Positive	
Multi-contrast imaging	Negative	29	3	32
	Positive	2	37	39
Total		31	40	71

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