Characterization of carotid plaque composition using ex-vivo Magnetic Resonance Imaging at 7T and histopathology

Rosario Lopez-Gonzalez[1], Sin Yee Foo[2], William M Holmes[3], William Stewart[4], Keith Muir[5], Barrie Condon[6], George Welch[7], and Kirsten Forbes[8]
[1]*Clinical Physics and Bioengineering, NHS, Glasgow, Glasgow, United Kingdom,* [2]*School of Medicine, University of Glasgow, Glasgow, United Kingdom,* [3]*GEMRIC, Institute of Neuroscience and Psychology, Glasgow, United Kingdom,* [4]*Neuropathology, NHS, Glasgow, United Kingdom,* [5]*Division of Clinical Neurosciences, University of Glasgow, Glasgow, United Kingdom,* [6]*NHS, Glasgow, United Kingdom,* [7]*Vascular Surgery, NHS, Glasgow, United Kingdom,* [8]*Institute of Neurological Sciences, NHS, Glasgow, United Kingdom*

Introduction

Surgical excision of atherosclerotic carotid plaque (carotid endarterectomy, CEA), based on the extent of luminal narrowing, reduces risk of subsequent stroke. However, 70% of patients with severe stenosis remain stroke-free over the next 5 years with medical therapy alone. Outcomes from CEA could be improved by targeting treatment at high-risk subgroups. Atherosclerotic plaque morphology and plaque composition may identify unstable or vulnerable plaque that defines higher risk.

This study aims to evaluate the ability to identify all major carotid plaque components using *ex-vivo* 7T MRI and correlation with histology.

Methods

Datasets were obtained from 30 selected symptomatic stroke patients (71±15 years). Only 14 of these patients underwent CEA. The specimens from these patients were imaged on a Bruker Biospec Avance system using a 7T horizontal 30 cm bore magnet. Carotid plaque specimens were imaged in a sealed syringe filled with fomblin, to reduce susceptibility artefacts. A small phantom containing $MgCl_2$ was placed within the field of view as a standard. T1-w, T2-w (100x100x100 μm^3 isotropic resolution) and diffusion weighted images (DWI) (181x181x181 μm^3 isotropic resolution) were carried out. We segmented the different plaque components by multiple thresholding of the MR signal and using a semi-automated analysis programmed in MatLab.

Serial sections of the specimens were taken and stained with haematoxylin-eosin and Elastic van Gieson. Digital images of the histological preparations were acquired at 0.54x0.54 μm^2 resolution. Histological correlation with the *ex-vivo* 7T MRI data was carried out. All the images were co-registered using a commercial package Analyze (Biomedical Imaging Resource, Mayo Foundation).

Results and Discussion

A training set was used to classify the carotid plaque tissue into different categories such as fibrous tissue, lipid rich necrotic core (LR/NC) with/without haemorrhage and calcium. Table 1 shows the MR signal intensities relative to the $MgCl_2$ phantom. Measurements for all plaque material were comparable between histology and MRI. Fibrous tissue (68.2% by histology versus 72.4%; p=0.362), LR/NC with out haemorrhage (3.4% by histology versus 6.7% by MRI; p=0.102), LR/NC with haemorrhage (19.5% by histology versus 15.0% by MRI; p=0.308) and calcification (9.2% by histology versus 8.6% by histology; p=0.805).

Plaque Components	T1	T2	DWI
Fibrous Tissue	---/--	++/+++	--- to 0
LR/NC without haemorrhage	--	+/++	---
LR/NC with haemorrhage	--/-	0	----
Calcium	----	0	

Table 1: Tissue Classification Scheme for MR images.
LR/NC: Lipid rich necrotic core; Signal intensity of phantom is 0 (iso-intense); -,--,---,---- denotes different degrees of hypointensity; +,++,+++,++++ denotes different degrees of hyperintensity relative to the phantom.

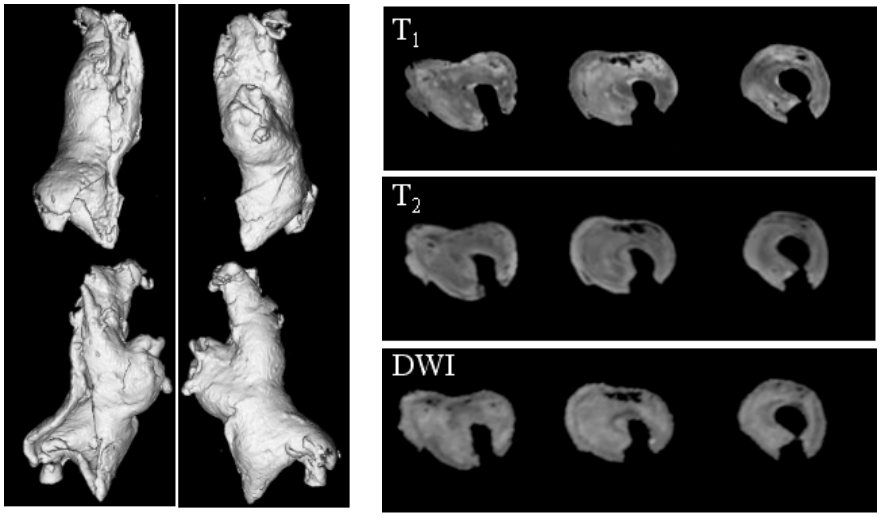

Figure 1. Left different views of a rendered specimen and right T1, T2 and DWI weighted 7T MR images.

Conclusions

Ex-vivo results show relatively good agreement with histology for all components, though haemorrhage was considerably overestimated by MRI. All our ex-vivo results consistently overestimates all plaque components absolute volumes, though this could be explained as the effect of shrinkage in the specimen due to the time interval between CEA procedure and dissection. Shrinkage of the specimen size has been reported to be in average 15% in width and 30% in length[1].

References

1. Eubank WB et al. J Vasc Invest. Endarterectomy plaque shrinkage: comparison of T2-weighted MR imaging of ex vivo specimens to histologically processed specimens 1998;4:161-170.