Characterization of carotid plaque *in-vivo* and *ex-vivo* using MRI, CTA and histology

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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.

Recent publications have shown that *in-vivo* 1.5T MRI can identify the main components of the atherosclerotic plaque, such as the lipid–rich/necrotic core (LR/NC), calcification and haemorrhage. This study aims to evaluate the ability to identify all major carotid plaque components in *in-vivo* 3T, *ex-vivo* 7T MRI, CTA and correlation with histology.

Methods

Datasets were obtained from 30 selected symptomatic stroke patients (71±15 years). Subjects were imaged using 3T MR scanner (Sigma Excite, GE). T1-weighted (T1-w) pre/post contrast, T2-weighted (T2-w), Proton Density-weighted (PD-w) and MRA time-of-flight (ToF) scans were carried out. T1-w, T2-w and PD-w were carried out with 0.27x0.27x2.8 mm^3 resolution and ToF 0.46x0.46x1.9 mm^3. The CTA studies were obtained on a CT scanner (Brilliance 64 slice, Philips) with 0.34x0.34x0.33 mm^3. From the patients studied *in-vivo*, 14 of them 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 *in-vivo* 3T and *ex-vivo* 7T MRI data was carried out. All the images of the different modalities were co-registered using a commercial package Analyze (Biomedical Imaging Resource, Mayo Foundation).

Results

MR signal intensity was converted to signal intensity (SI) relative to the adjacent muscle. Then MR images were subdivided by signal threshold into hyperintense, isointense and hypointense. Carotid plaque was segmented into LR/NC, fibrous tissue, dense fibrous cap and calcification using the semi-automated method programmed. LR/NC was identified as isointense to hyperintense on T1-w and PD-w images. This variation is due to the amount and age of haemorrhage presented[1-3]. Fresh or recent haemorrhage can be best distinguished on ToF images. Calcification is defined as hypointense signal in all the weightings. T1-w pre/post contrast images help to identify fibrous caps. CTA was used to verify the calcium content in the plaque. Histology and MRI datasets were review separately by experts blinded to each other technique and classified using the criteria established by the conventional AHA classification.

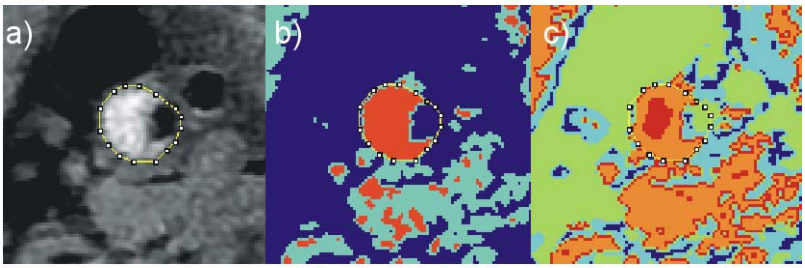

Figure 1: *In-vivo 3T MR image* ***a)*** *T1-w,* ***b)*** *thresholded T1-w image. The SI is relative to the adjacent muscle, blue hypointense, green isointense and red hyperintense,* ***c)*** *segmented plaque using T1-w, T2-w, PD-w and ToF MR images. Orange represents LR/NC and red fresh haemorrhage.*

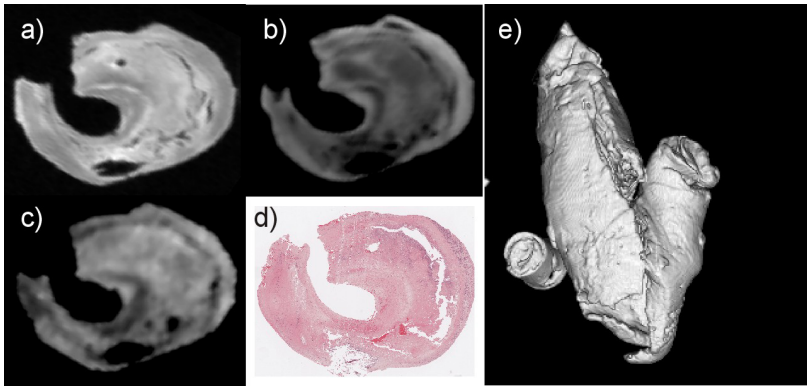

Figure 2: *Ex-vivo 7T MR data:* ***a)*** *T1-w image,* ***b)*** *T2-w image.* ***c)*** *DWI,* ***d)*** *histology and* ***e)*** *rendered T1-w data of the specimen.*

Conclusions

We are able to identify LR/NC, fibrous tissue, calcification, haemorrhage and haemorrhage age using different MR contrast images and CTA. The histology and MRI results show good agreement, highlighting the potential of MRI to distinguish between different major plaque components and plaque instability.

Bibliography

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