Flow Vector Field and Streamline Visualization of Hemodynamics near Carotid Plaque- A High Field 3T Study

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Introduction

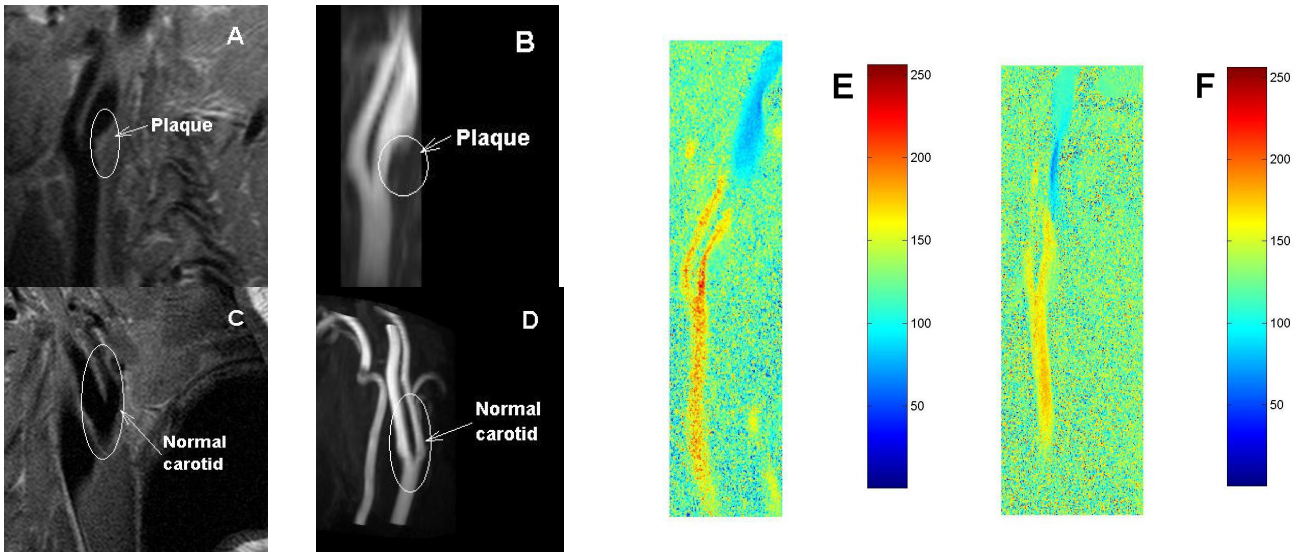
The principal methods for determining the severity of carotid atherosclerosis have been ultrasonography and angiography. These methods measure the percentage of vessel stenosis whereas plaque morphology and composition may be better able to identify high risk plaques. The potential of employing non-invasive intravascular MRI for characterization of plaques has been recently shown, and recognized to be a promising modality. However, though MR offers the possibility of characterization, the limiting factor is the spatial resolution/ SNR achievable. Our objective in this study is to explore the feasibility of plaque imaging at 3T to circumvent the biggest drawback of current MR plaque imaging, namely that of resolution achieved at 1.5T. We utilized high resolution imaging at 3T with phased array coil to visualize the carotid bifurcation in normal, carotid plaques in patients, and flow quantification both through and in-plane.

Methods and Materials

Four normal and ten patients with plaque, detected previously by ultrasound, were scanned (under UCLA IRB guidelines) on a 3.0 T Siemens TRIO. Since specialized coils were not available, the built-in spine phased array was used. The MR imaging protocol consisted of the following sequences: (i) 2D TSE with dark blood, (ii) 3D TOF-MRA, and (iii) phase contrast FLASH were performed to visualize carotid bifurcation, plaque and flow quantification. The sequence parameters are:. TSE: 8.3 ms TE, 180^0 FA, 9 ETL, 1-3 averages, pulse trigger 2 R-R triggers (1.8 s TR), 2mm Slice Thickness; 3D TOF-MRA: TE/TR of 4.51/27ms, 2 averages, 25^0 FA, 256x256 FOV; PC-FLASH: TE/TR of 5.2/57ms, 2 averages, 3mm slice thickness, 25^0 FA, 320x320 FOV, VENC=100 for SI (through-plane) and 50 cm/sec for RL (in-plane) , encoded in two different scans.

Results

Fig. A and C are PDW oblique saggital TSE images of plaque and carotid for abnormal and normal subject respectively, and fig. B and D are corresponding MIP images from 3D TOF-MRA. In fig. A, plaque is shown to form at the bifurcation of the common carotid. Fig. C shows clearly right internal carotid surrounded by plaque for abnormal subject. Velocity values derived from the phase contrast images are shown as color maps for the abnormal (Fig. E) and normal data (Fig. F). The area of increased velocity at the level of the plaque in the patient can be readily appreciated. Distal to the plaque, the velocity is reduced by about 20% compared to the plaque region, while less than 10% for the normal.



Discussion

We have shown the feasibility of high spatial resolution carotid plaque imaging for morphology and flow at 3T. The increase in velocity measured at the level of the plaque is in accordance with fluid dynamics where an increase in velocity is expected at the level of the constriction (plaque). The flow quantification could potentially provide a measure of the luminal narrowing as well as hemodynamic indices such as impinging flow and wall shear stress. These hemodynamic indices along with plaque composition may help in identification of the high-risk plaque.