Distribution of Intraplaque Hemorrhage in Carotid Complicated Plaques Defined by High-Resolution Magnetic Resonance Direct Thrombus Imaging (hiresMRDTI)

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Background: Intraplaque hemorrhage (IPH) is increasingly being recognized as one of the markers that defines atherosclerotic plaques as being at increased risk of causing symptomatic disease, as well as being a potential stimulus for the progression of atherosclerosis (1-2). Classically, IPH has been thought to occur due to plaque ulceration, allowing flowing blood from the lumen to enter the plaque, resulting in IPH/thrombosis (2). However, a large amount of evidence currently suggests that IPH might be the result of rupture/leakiness of the fragile vasa vasorum (2), neovessels which originate from the adventitia of the artery and extend in the direction of the vessel lumen. We have successfully developed high-resolution MRI techniques that, by exploiting the T1 shortening effects of methemoglobin, directly visualize hemorrhage/thrombus in atherosclerotic plaque with 500μm isotropic resolution, allowing very good delineation of the exact location of intraplaque hemorrhage (3). Our hypothesis was that in carotid complicated plaques, IPH is due to vasa vasorum rupture/leakage, and the majority of IPH would be present deep to the vessel lumen (vessel wall/adventitial side). The purpose of this study was to evaluate the distribution of IPH within complicated carotid atherosclerotic plaques.

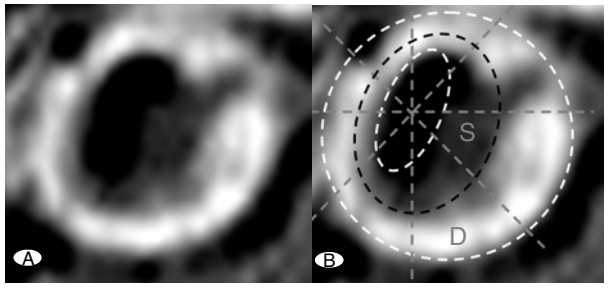

Figure 1. Example of 16-segment comparative grid. High-resolution MRDTI (hiresMRDTI). (A) Original image without placement of grid. IPH is seen as regions of high signal intensity. (B) Image with grid placement. White-dashed lines outline the vessel wall and luminal boundaries. The dashed black line divides the deeper (D) region from the superficial region (S).

Methods: Fifteen patients (13 male, 2 female, mean age 71 ± 6.1 years [59-80 years]) with symptomatic or asymptomatic carotid artery stenosis were imaged at 1.5T (GE Twin Speed MR scanner, USA) using high-resolution Magnetic Resonance Direct Thrombus Imaging (hiresMRDTI) and a dedicated carotid surface coil (SCANMED, USA). The scanning parameters were: TR 11.2ms, TE 3.3 ms, flip angle 15°, FOV 80mm^2, matrix 160^2, slice thickness 1mm, spatial resolution 0.5mm x 0.5mm x 0.5mm (IP). Fat suppression was achieved using *SPECIAL* (*SPEC*tral *I*nversion *A*t *L*ipids), a GE proprietary technique. The location of IPH was assessed by tracing the boundaries of the vessel wall and lumen. The region within these two boundaries, representing atherosclerotic plaque, was divided in half. Segments closer to the vessel wall represented the deep portions of the plaque, and segments closer to the lumen the superficial portions (Fig. 1). A 16-segment template was used for analysis. Some patients underwent carotid endarterectomy, and their excised plaques were analyzed. Endarterectomy specimens were fixed, decalcified, sectioned and stained with Hematoxylin & Eosin and Silver stain (to assess for plaque surface disruptions). Matching of MRI and histology slices employed the distance from the bifurcation, and vessel/plaque morphology. Statistical comparisons were performed using chi-square.

Results: A total of 158 axial images were reviewed. Nine-hundred and eighty-four segments contained IPH and were used in the analysis. IPH was more frequently present in the deep segments of the plaque (603/984 segments, 61.3%) compared to the superficial segments (381/984 segments, 38.7%) ($p<0.001$). While IPH in the superficial segments was commonly seen in close proximity to IPH in deep segments, a large proportion of the deep plaque segments (231/603, 38.3%) contained IPH without proximal superficial IPH, and only a very small proportion of IPH was present in a superficial segment on its own (29/381, 7.6%) ($p<0.001$) (Figure 2). Preliminary histology results confirm the hiresMRDTI findings, with the majority of the plaques not showing evidence of surface disruption.

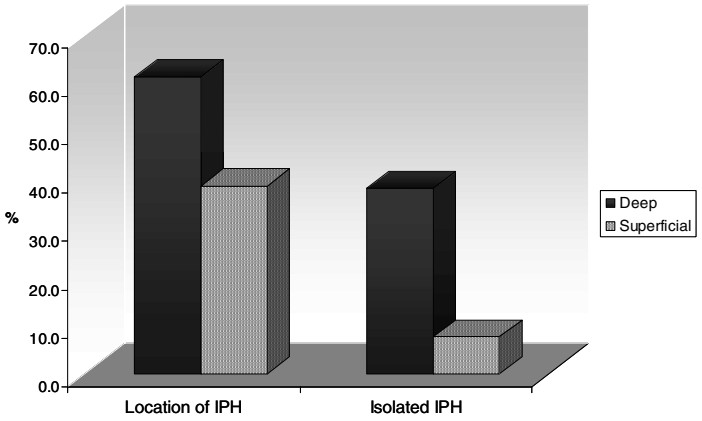

Figure 2. Distribution of IPH. The majority of the IPH was present in the deeper portions of the plaque, closer to the vessel wall (adventitia).

Conclusion: hiresMRDTI allowed delineation of the exact location of IPH in the carotid atherosclerotic plaque. While IPH was present both in the deeper segments (closer to the vessel-wall/adventitia) and superficial segments (closer to the lumen), its predilection for the deeper segments suggests that the majority of IPH in complicated carotid plaques does not arise from the luminal surface and is likely due to adventitial vasa vasorum rupture/leakage.

References:

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(3) Bitar *et al*. ISMRM 2006, Abstract submitted.