MRI observation of intraplaque hemorrhage and atherosclerotic plaque severity in patients

James Qiupeng Zhan[1], Alan Moody[1], and Cristina Nasui[2]
[1]*Sunnybrook Hospital, Toronto, Ontario, Canada,* [2]*Medical Imaging, University of Toronto, Toronto, Ontario, Canada*

Introduction. Intraplaque hemorrhage (IPH) plays a critical role in the increase of plaque vulnerability. It has been thought to be a stimulant in the progression of atherosclerosis. Methemoglobin may provide an endogenous contrast agent to depict vessel-wall disease activity in the setting of intraplaque hemorrhage. 3D MR imaging of intraplaque hemorrhage (MRIPH) is a high-spatial resolution 3D sequence that depicts complicated plaque in the carotid arteries by use of a single contrast weighting; the innate T1 hyperintense tissue contrast is thought to be provided by methemoglobin. MRIPH also has been used to identify red blood cell–derived methemoglobin as a driver of lipid oxidation, reflected by increased T1 signal intensity. Multicontrast-weighted MRI has been utilized to observe IPH causing progression of human atherosclerosis. The aim of this study was to use 3D MRIPH and 3D TOF MRA at 3T to observe IPH and plaque severity in atherosclerotic patients.

Materials and Methods. 16 patients with confirmed 30-70% carotid stenosis by clinical TOF MRA and CeMRA were recruited. IPH positive was defined as equal to or higher than 150% of signal of adjacent muscle on MRIPH. The scans were conducted on a 3T clinical scanner (Philips Achieva, R2.6.1, Best, the Netherlands) with a 16 elements neurovascular coil (Philips Achieva, SENSE-NV-16). 3D High-Spatial-Resolution MRIPH was performed using a 3D Fast Field Echo (FFE) sequence in the coronal plane (TE=4ms, TR=11ms, matrix 512x256, FA=15°, FOV=27x19cm, NEX=4, slice thickness: 0.5mm). 3D TOF MRA was performed using a 3D FFE sequence in the axial plane (TE=3.5ms, TR=26ms, matrix 360x232, FA=18°; FOV=19x19cm; NEX=1, slice thickness:0.7mm). All images were reformatted into axial plane in 2 mm thickness. 16 slices of MRIPH and 16 slices of TOF of each patient were generated. QPlaque (Medis, The Netherlands) was used for segmentation. Both automatic and manual segmentation were used to delineate lumen contour and outer wall contour. Multivariate ANOVA is used to compare lumen area, outer wall area, vessel wall area, and maximum vessel wall thickness with IPH positive slices and IPH negative slices at each patient.

Results. 132 slices of MRIPH negative and 124 slices of MRIPH positive were compared. Over all, outer wall area in the MRIPH negative slices was found to be 153.43±5.48mm^2 while in the MRIPH positives slices were 208.88±4.76 mm^2. The lumen area was 66.96±3.12mm^2 and 50.5±2.29 mm^2 in the MRIPH negative and positive slices, respectively. The vessel wall area in the MRIPH negative slices was 86.45±3.52mm^2, while in the MRIPH positive slices it was 160.12±4.23 mm^2. Maximum vessel wall thickness was 2.74±0.1mm and 5.16±0.12 mm in the MRIPH negative and positive slices, respectively. Multivariate ANOVA showed Levene's test of equality was 4.394 for outer wall ($P<0.001$), 4.475 for lumen ($P<0.001$), 2.993 for vessel wall ($P<0.001$) and 2.032 for maximum vessel thickness ($P<0.01$), multivariate tests show Wilks' lambda was 0.482 ($P<0.001$), Hotelling's trace was 1.074 ($P<0.001$).

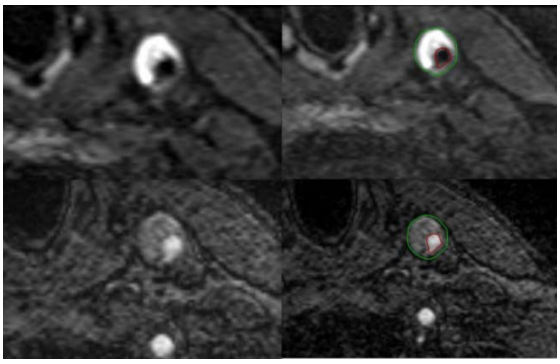

Fig 1. Formatted axial 3D MRIPH and 3D TOF images showing carotid artery with IPH on the left and contoured outer wall and lumen boundary images on the right

Discussion and Conclusions: This study shows that IPH occurs at the more severe atherosclerotic cases having the following characteristics: a thicker outer wall, smaller vessel lumen bigger vessel wall and bigger maximum vessel wall thickness. This indicates that IPH is one of the main factors in advanced atherosclerotic plaque. This is a first time use of the MRIPH sequence to measure vessel wall and to define IPH at the same time. Through the use of this sequence, one eliminates the need for multi-parametric MRI due to the better correlation of IPH and slice volume. So, comparing with multi-parametric imaging, the rapidly acquired 3D MRIPH and 3D TOF scans could be used clinically.

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