How thick of Fibrous Cap Can Be Seen in MRI? A Phantom Study

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Introduction: A lot of studies have shown that the rupture of atherosclerotic plaque is not only related to stenosis but also related to the components in the plaque. Almost all research states that thin fibrous cap with large lipid rich necrotic core is a major criterion of vulnerable plaque [1]. MRI is a powerful tool to investigate plaque components including fibrous cap, necrotic core, calcification, loose matrix and intra-plaque hemorrhage because of its multi-contrast capability for soft tissue [2]. Several studies have shown fibrous cap can be distinguished from time of flight (TOF) [3], T2 weighted (T2) [4], or contrast enhanced T1 weighted images (CE-T1) [5]. However the minimum thickness of fibrous cap can be seen in MRI has not been investigated yet. We tried to find out the answer using a custom designed phantom in this study.

Methods: A custom designed phantom shown in figure 1 was produced of acrylic plastics. Two parts of structure insert fixed on the bottom side of a 190mm diameter cylinder container (figure 1a) 30mm distance from outer wall, which is similar to carotid location from skin. The first cubic part (figure 1b) sizes in 85mm(H)*9mm(W)*60mm(L) with 8 terrace steps in 0.2mm. The second part (figure 1c) has 8 protruding plates 1mm in thickness 60mm in length and 4mm in width located on an 85mm(H)*4mm(W)*60mm(L) cube, except the last plate 1.4mm wider than the other plates. Gaps from 0.2mm to 1.2mm in 0.2mm step were created at the location from 2nd plate to 7th plate after combining two parts face to face. $MnCl_2$ (3g/1000g) and NaCl (5g/1000g) solution was filled in the phantom to lower T1 value and provide coil loading. Final phantom photo was presented in figure1d, and its dimension and location error were controlled in 0.1mm by calipers and feeler.

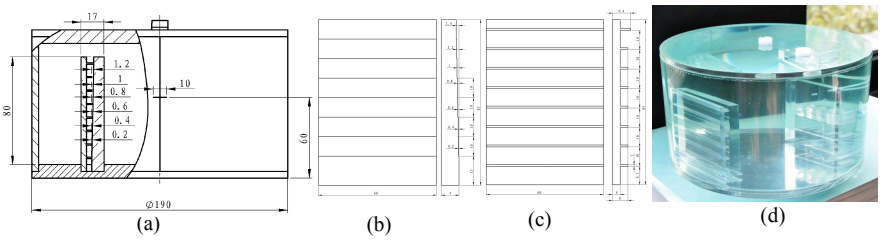

Fig 1. Designed fibrous cap phantom. a) assemble chart; b) 1st insert part ; c) 2nd insert part; d) photo

Table 1. High resolution protocols for plaque imaging

	T1WI	PDWI	T2WI
TR (ms)	800	2400	3000
TE (ms)	11	9	50
NEX	2	2	2
FOV (mm)	160×120	160×120	160×120
Matrix	256×192	256×192	256×192
SlcTH (mm)	2	2	2

Cross-sectional high resolution black blood image protocols exactly same as we used for in vivo carotid plaque imaging [2] was performed on a 3T scanner (Philips Achieva 3.0T TX, Best) with an 8 channel carotid coil [6] at each center of plate, after a sagittal localizer vertically through all protruding plates. The parameters were shown in table 1 which derived 0.625mm in plane resolution and 2mm through plane resolution. Since acquired slice was 2 times thicker than plate, the signal from plate region was halved comparing with the signal from gap. Black-white-gray (0-1-1/2) signal pattern representing lumen, fibrous cap and lipid rich necrotic core respectively.

Results and Discussion: Cross-sectional images were shown in figure 2 accompanied with the profile vertical to the direction of gap which mimic fibrous cap. 0-1-1/2 contrast cannot be seen in images with 0.2mm and 0.4mm gaps, while it is visible in images with gaps equal and larger than 0.6mm. Profiles agree with the visibility result.

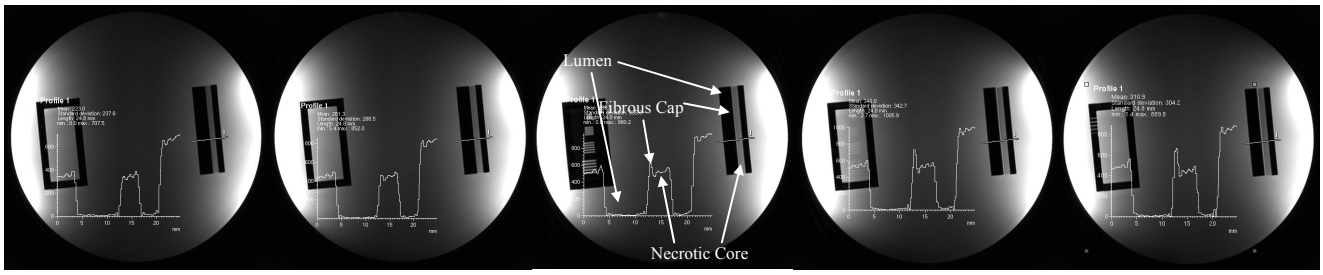

Fig 2. Cross-sectional images at 1mm plate center with 0.2mm to 1.0mm gaps from left to right and profiles through gap and half contrast plate

Conclusion: Fibrous cap thinner than the resolution of acquisition sequence is hardly to be seen in MR images with the hypnosis that the contrast of lumen, fibrous cap and lipid rich necrotic core is 0-1-1/2. This work has limitation that the gaps change discretely in 0.2mm step and the contrast is fixed to 1/2. Revised phantom design with continues fibrous cap thickness and continues contrast has been completed and will be sent out for manufacture recently. More convincing result will be available soon.

Reference: [1] Naghavi M, et al. Circulation, 2003 ; 108(14) : 1664-72. [2] Yuan C, et al. Radiology, 2001 ; 221(2) : 285-99. [3] Hatsukami TS, et al. Circulation, 2000 ; 102(9): 959-64. [4] Trivedi RA, et al. Neuroradiology, 2004 ; 46(9) : 738-43. [5] Cai J, et al. Circulation, 2005 ; 112(22) : 3437-44. [6] Balu N, et al. JMRI. 2009; 30(5): 1209-14.