# Voxel anisotropy in carotid MRI: impact on fibrous cap thickness and lipid-rich necrotic core size measurements of atherosclerotic plaques

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## PURPOSE:

Sudden rupture of carotid atherosclerotic plaques can lead to transient ischemic attacks and strokes, and thus contributes to the large mortality and morbidity rates caused by these events worldwide. Rupture prone, vulnerable plaques are constituted of a thin fibrous cap (FC) separated by a large lipid-rich necrotic core (LRNC) from the lumen [1]. *In vivo* carotid MRI is the method of choice to non-invasively image these plaque components with high contrast. Despite recent advances in 3D imaging, most clinical carotid MRI protocols today are 2D and therefore often employ anisotropic acquired voxel dimensions. This anisotropy could lead to axial intravoxel partial volume effects due to the larger voxel length ($\delta$) in the slice-select direction (i.e. slice thickness). In this study, we employ MRI simulations to quantify the influence of slice thickness on carotid plaque component measurements.

## METHODS:

MRI simulations allow an accurate ground truth comparison. Using JEMRIS, an open-source numerical Bloch-equation solver, we simulated a 3.0T clinically applied 2D $T_1$ weighted turbo spin-echo, contrast enhanced, black-blood sequence designed to image the fibrous cap, with no slice selection gradients and with hard RF pulses [2]. The original acquired anisotropic voxel size was $0.62 \times 0.62 \times 2.00$ mm$^3$. A doubling of the in-plane resolution (to 0.31 mm) was additionally simulated. We created 3D carotid plaque ground truth models (vessel wall and LRNC) of an axial length of 2 mm from five patients from histological sections and varied the slice thickness $\delta$: 0.5 mm, 1.0 mm and 2.0 mm. Single slice images were manually segmented by an MR reader blinded to the ground truth on preset contrast-brightness settings.

## RESULTS:

LRNC core size was underestimated while FC thickness was consistently overestimated (Figure 1). For LRNC, marginal or no significant improvement in relative measurement error was found for smaller $\delta$. The relative error in minimum FC thickness measurements improved significantly ($p<0.05$) for smaller $\delta$. For an in-plane resolution of 0.62 mm, the mean relative error improved from +230% for $\delta$=2 mm to +82% for $\delta$=0.5 mm. For an in-plane resolution of 0.31 mm, this error improved from +80% for $\delta$=2 mm to +19% for $\delta$=0.5 mm. We found no significant improvement in relative measurement error for luminal area and vessel wall area for smaller $\delta$.

## DISCUSSION AND CONCLUSION:

Our study indicates that for carotid MRI, the use of anisotropic voxels can be permitted for specific applications. The quantification of the lumen, wall or LRNC area is not - or marginally - affected by $\delta$.



**Figure 1:** Example model with segmentation and results for LRNC volume and minimum FC thickness

However, we found a significant improvement in minimum FC thickness measurement error for thinner slices.

## REFERENCES:

[1] Virmani, R., Burke, A.P., Farb, A., and Kolodgie, F.D. , 2006, "Pathology of the Vulnerable Plaque," J. Am. Coll. Cardiol., 47(8), pp. C13-18.

[2] Nieuwstadt, H.A., Geraedts, T.R., Truijman, M.T.B., Kooi, M.E., van der Lugt, A., van der Steen, A.F.W., Wentzel, J.J., Breeuwer, M., and Gijsen, F.J.H, 2013, "Numerical Simulations of Carotid MRI Quantify the Accuracy in Measuring Atherosclerotic Plaque Components In Viv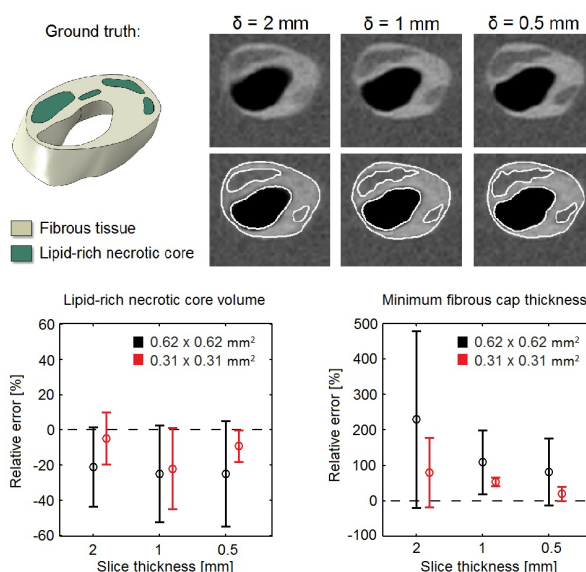o," Magn. Reson. Med., DOI 10.1002/mrm.24905.