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Using 3D Thin-Layer Model with *in Vivo* Patient-Specific Vessel Material Properties to Assesse Carotid Atherosclerotic Plaque Vulnerability

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1 Introduction

Image-based computational models have been introduced to calculate plaque stress/strain conditions and investigate their association with plaque progression and rupture [Tang, Yang, Zheng et al. (2004)]. However, the accuracy of the computational results is heavily dependent on the data and assumptions used by those models. Patient-specific vessel material properties are in general lacking in image-based computational models, limiting the accuracy of their stress/strain calculations.

A noninvasive approach of combining *in vivo* 3D multi-contrast and Cine magnetic resonance imaging (MRI) and computational modeling was used to quantify patient-specific carotid plaque material properties for potential plaque model improvements [Wang, Canton, Guo et al. (2017)]. The stress-based plaque vulnerability index (SPVI) was proposed to combine mechanical analysis, plaque morphology and composition for more complete carotid plaque vulnerability assessment.

2 Method

In vivo 3D multi-contrast and Cine MRI carotid plaque data were acquired from 8 patients with follow-up (18 months) with written informed consent obtained. 3D thin-layer model and an established iterative procedure were used to determine parameter values in the Mooney-Rivlin models [Wang, Canton, Guo et al. (2017)] for plaque vulnerability assessment. The morphological plaque severity index (MPSI) was used and assigned to each segmented MRI slice based on plaque morphological features known to correlate with plaque vulnerability from histopathological studies [Kerwin, Xu, Liu et al. (2007)].

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3 Results

A simple numerical code was used to determine five stress intervals [0, a), [a, 2a), [2a, 3a), [3a, 4a), and [4a, +∞) corresponding to SPVI values 0-4 to reach the best agreement between SPVI and MPSI. The five intervals (unit: kPa) [0, 46.8), [46.8, 80), [80, 92), [92, 103), and [103, +∞) from in vivo material models were used for SPVI values of 0, 1, 2, 3 and 4, respectively. According to the SPVI stress intervals, a plaque will be considered unstable (at risk) if its critical stress is higher than 100 kPa from in vivo material models. The optimized agreement rates from in vivo material models and old material [Tang, Yang, Zheng et al. (2004)] models were 85.19% and 83.95%, respectively. The Pearson correlation coefficient between SPVI and MPSI was 0.9103 (p<0.0001) and 0.8661 (p<0.0001), respectively. The SPVI change rate for slices using old material models compared to using *in vivo* material models. The total change rate was 20.99%. The ones with SPVI being 3 have the highest change rates, which was 83.33%.

4 Conclusions

The use of patient-specific material properties in plaque models could potentially improve the accuracy of model stress/strain calculations. *In vivo* material model shows significant difference with old material model on SPVI calculations. Large-scale studies are needed to further demonstrate that SPVI has the potential to improve the current image-based screening and plaque vulnerability assessment schemes.

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