Purpose: 3D ultrasound (3DUS) vessel wall volume (VWV) is a 3D measurement of vessel wall thickness plus plaque within the carotid artery for monitoring carotid plaque progression and regression. In this paper, we describe a segmentation algorithm to delineate the media-adventitia (MAB) and lumen-intima (LIB) boundaries of the carotid arteries to quantify VWV measurements.

Methods: An operator places four anchor points on each boundary of every transverse carotid image slice to initialize the algorithm. The MAB and LIB boundaries are segmented using two level set segmentations that are coupled. The two segmentations evolve independently based on their objective functions, when they are separated by more than a minimum allowable separation distance. When two curves are closer than the minimal allowable distance, they repel each other to maintain the separation. The algorithm was evaluated with respect to manual segmentations using volume-, region-, and boundary distance-based metrics. Our data set consisted of manual and algorithm repeatedly (5) segmented boundaries of 231 transverse 2D slices extracted from 21 3DUS carotid images.

Results: The algorithm provided a mean VWV error of 5.2%±3.9%. For the MAB and LIB respectively, our method yielded Dice coefficients of 95.6%±1.5% and 92.8%±3.2%, and mean absolute distances of 0.2±0.1 mm and 0.3±0.1 mm. The algorithm yielded a minimum detectable difference (MDD) of 63.1 mm3, which is smaller than the previously reported annual VWV change of 120 mm3/year. The average time saved using the algorithm was 4.6 min (8.3 min - 3.7 min).

Conclusions: The algorithm provided small volume-based errors, high Dice coefficients, and sub-millimeter boundary distance-based errors. The MDD suggests that a follow-up period of seven months or more would be appropriate using our method for monitoring carotid atherosclerosis. The realization of a semi-automated method would assist the translation of carotid 3DUS for clinical research and clinical care.