Combination of group and phase velocity shear wave elastography for the characterization of vulnerable carotid plaques

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Background, Motivation and Objective

Rupture-prone carotid plaques are often distinguished by their composition rather than protrusion, and routine imaging might not effectively detect such culprit lesions. Acoustic radiation force-based techniques such as shear wave elastography (SWE) have shown promise in mapping plaque constitutive behavior, however spatial confinement affects accuracy [Maksuti et al, UMB 2016] and utilizing both spatiotemporal group and frequency-dependent phase velocity analysis might be required for accurate plaque differentiability [Marlevi et al, PMB, 2019]. The aim of this study was therefore to apply such combined SWE analysis on a carotid plaque cohort, evaluating output against reference magnetic resonance imaging (MRI).

Statement of Contribution/Methods

22 subjects with a total of 27 plaques were scanned with SWE and MRI, respectively. SWE was performed using a GE Logiq E9 with 5-15 acquisitions in longitudinal (L) and transverse (T) view, respectively (dual-sided push, push frequency: 4.1-5 MHz, push duration: 400 µs, plane wave imaging: 5 MHz). In a plaque region-of-interest from B-mode imaging, depth-averaged axial particle velocities were derived using 2D autocorrelation with directional filtering. Group velocity was calculated using a time-to-peak method with random sample consensus filtering [Wang et al, UMB 2010], whilst phase velocities in discrete frequency bands were estimated from the maximum intensity as a function of frequency in the 2D fast Fourier transform. Reference carotid MRI was acquired on all plaques, where a multi-contrast protocol and dedicated identification software (MRI-PlaqueView, VP Diagnostics) were used to identify intraplaque components and American Heart Association (AHA) type plaque grade. Group and phase velocities were evaluated as a function of AHA type, and correlations were evaluated using Pearson and Spearman correlation analysis, respectively.

Results, Discussion and Conclusion

AHA type VI plaques showed significantly higher group velocity compared to all other plaque types (mean group velocity: 5.8 m/s (L-view) and 7.3 m/s (T-view) versus 4.0-4.2 m/s (L-view) and 3.1-3.6 m/s (T-view)). Similarly, at the highest frequency band (400-500 Hz), phase velocities were significantly higher in AHA type VI plaques in L-view (7.0 m/s versus 4.1-4.8 m/s). For group velocity, positive linear correlation was seen with the amount of lipid-rich necrotic core (Pearson R = 0.57, p = 0.02), whereas complementary inverse rank correlations with fibrous cap/necrotic core ratio (Spearman R = -0.61, p = 0.02) and intraplaque haemorrhage volume (Spearman R = -0.94, p = 0.02) were observed with phase velocities at different frequency bands. The results highlight the potential of SWE as a method for refined plaque risk stratification, and underline the added value of complementary group and phase velocity analyses for arteriovascular SWE. Larger studies are needed to clarify the clinical impact of SWE-derived plaque biomarkers.

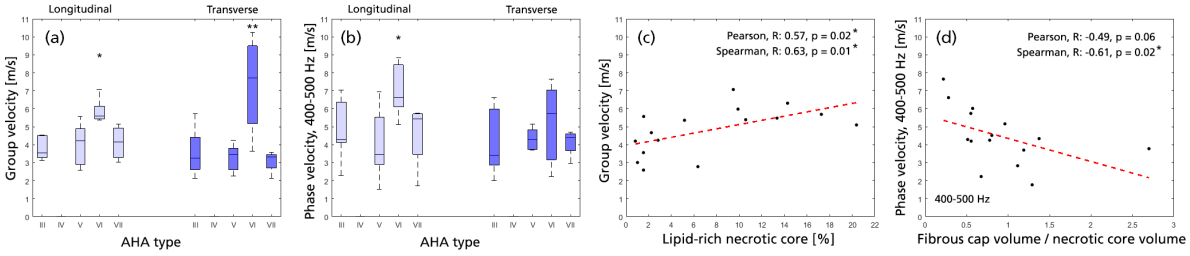

Figure 1: Group (a) and phase velocity at 400-500 Hz (b) as a function of AHA type plaque, showing increased wave velocities in AHA type VI plaques. Furthermore, identified group velocity correlation with lipid-rich necrotic core content (c), and phase velocity correlation with the ratio between fibrous cap and necrotic core volume (d) are provided.