Assessment of neovascularization within carotid plaques in human using ultrasound super-resolution

Jiaqi Zhu[1], Sevan Harput[1], Fangting Xu[2], Kirsten Christensen-Jeffries[3], Ge Zhang[1], Jemma Brown[3], Chao Zhang[2], Qunying Li[2], Christopher Dunsby[4], Robert J. Eckersley[3], PinTong Huang[2], Meng-Xing Tang[1]; *[1]Dept. of Bioengineering, Imperial College London, London, UK, [2] Dept. of Ultrasound, Zhejiang University College of Medicine, Hangzhou, China, [3]Biomedical Engineering Dept., Kings College London, London, UK, [4] Dept. of Physics and Centre for Pathology, Imperial College London, London, UK*

Background, Motivation and Objective

Atherosclerosis is a systemic inflammatory disease that leads to acute cardiovascular complications triggered by plaque rupture and primarily manifests as stroke and myocardial infarction. The presence of vasa vasorum (VV) neovascularisation in atherosclerotic plaque has been shown to be associated with plaque progression and instability, leading to atherosclerotic cardiovascular events. Contrast enhanced ultrasound (CEUS) is a valuable tool for visualising plaque neovascularisation in the carotid artery, in addition to this super resolution ultrasound (SR-US) enables non-invasive visualisation of sub-wavelength microvasculature and quantification of flow. The aim of this study is to demonstrate the feasibility of VV assessment within carotid plaques via SR-US.

Statement of Contribution/Methods

Ultrasound examinations were performed on patients with diabetes using a clinical scanner Mindray Resona 7S which provides live dual images of B-mode and CEUS. A L11-3U transducer was used at 5.6 MHz. SonoVue microbubbles were administered intravenously as a 2 second bolus of 2.4 mL through a 19-gauge cannula in an antecubital vein. In order to control the concentration, destruction pulses were performed at a high mechanical index (MI) of 0.553 to achieve bubble destruction after the routine clinical CEUS examination. After the destruction pulses, images were acquired at a frame rate of 10 Hz using a MI of 0.085. Two-stage motion correction (Harput et al. 2018) was applied before spatially isolated microbubbles were extracted and localized. SR velocity map were generated by tracking individual microbubble trajectories.

Results, Discussion and Conclusion

Figure 1A shows Colour Doppler image where only fast blood flows (24.1 cm/s in carotid artery) and large vessels are detected. In Figure 1B contrast mode image with isolated microbubbles in the plaque can be seen. An image of maximum intensity projection over time of these signals is provided in Figure 1C. This again does not reveal the smaller vessel structures. In the SR velocity map (Fig. 1D) the structure and direction of underlying slow microbubble flow of around 2 mm /s in the carotid atherosclerotic plaque are clearly represented. In the future, such structural and functional measures generated using ultrasound SR processing could be used to predict plaque instability.

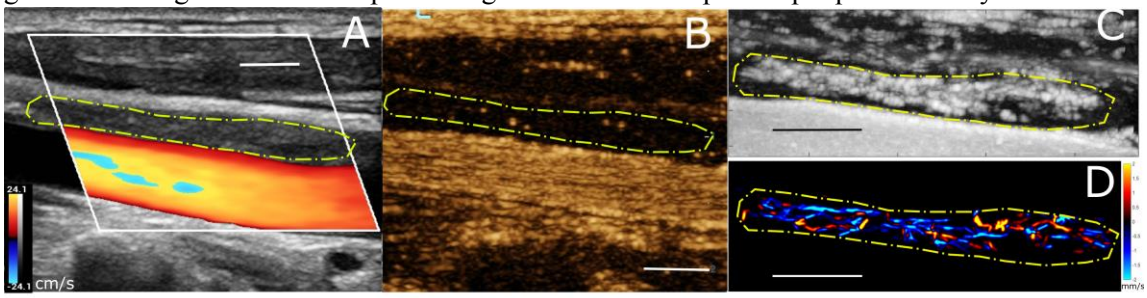

Figure 1 (A) Color Doppler image from clinical scanner, Blue indicates blood flowing away from transducer and red indicates blood flowing towards transducer; (B) Contrast mode image from clinical scanner; (C) Maximum intensity projection over time (MIOT); (D) SR-US velocity map. Blue indicates blood flowing away from transducer and red indicates blood flowing towards transducer. Yellow contour denotes the plaque. Scale bar: 5 mm