# Grading of carotid atherosclerotic plaques using super-resolution ultrasound imaging: An *in-vivo* feasibility study

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## Background, Motivation and Objective

Rupture of carotid atherosclerotic plaques is a major cause of ischemeic stroke. Neovasculature is a characteritic of vulnearable plaques, and the density and distribution of microvasculature (MV) are considered as significant markers for assessment of the pathological state of plaques. However, it can hardly be detected by traditional imaging modalities. Recently, super-resolution ultrasound imaging (SR-UI) breaks the diffraction limit of conventional ultrasound imaging and can detect MV at extremely high resolution. The objective of this study was to investigate the *in-vivo* feasibility of SR-UI with traditional contrast enhanced ultrasound (CEUS) in grading of carotid atherosclerotic plaques.

## Statement of Contribution/Methods

CEUS imaging of 9 plaques was performed on an Aplio 500 system (Toshiba, Japan) with an L11-4 probe at a frame rate of 15 Hz for about 90 seconds. The images were stored in DICOM format and analyzed offline. The progression grades of the plaques were determined by Staub grading criteria, with grades 0 (n=1), 1 (n=4) and 2 (n=4) representing absent, moderate, and extensive contrast enhancement in the plaque, respectively. The rigid motion of a manually selected high-echogenicity background region (~2.5 × 2.5 $mm^2$) between the CEUS frames were estimated by 2D normalized cross-correlation algorithm. The microbubble (MB) signal within the plaque was extracted by singular value decomposition based clutter filtering. Thereafter, the plaque was manually segmented for further analysis. Individual MBs were located, motion compensated, paired, tracked, and accumulated. Finally, the MV distribution information including the MV density, blood flow speed and direction was obtained. Number of MBs normalized by area and time and blood flow directional entropy were then calculated in the core and shoulder areas, respectively. Statistical analysis was performed to compare these parameters with different progression grades.

## Results/Discussion

MV hemodynamics are obviously different in plaques with different grades (Figs. a-c). More MBs are detected in both the core and shoulder of plaque in higher progression grade (*p < 0.05) (Figs. d-e). The shoulder of plaque has a higher density of MV, which may be related to the neovasculture and higher vulnerability. And higher directional entropy is found in higher plaque progression grade (*p < 0.05) (Fig. f). More study compared with other imaging modalities and pathology will be performed to further investigate the feasiblity of SR-UI in assessment of plaque vulnerability and grading of atherosclerosis.