Using Deep Convolutional Neural Networks to Automate Classification of Carotid Plaques from Ultrasound Imaging

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Background: Stroke is a devastating consequence of plaque rupture from the carotid arteries. Current management of carotid plaques involves waiting for symptoms (e.g., stroke or ministroke); intervention itself has risk of stroke and not all plaques are vulnerable to rupture. There is a need to better risk-stratify plaque that causes stroke. Carotid ultrasound (US) examination is a noninvasive and inexpensive visualization of plaques, but is limited by human interpretation. We hypothesize that convolutional neural networks will identify unique features of carotid plaques for automated risk stratification.

Methods: Our workflow is illustrated in Figure A. A total of 141 B-mode US images of carotid arteries were included. 64 high-risk with symptomatic carotid plaques and 75 low-risk with no significant plaque. Data were cropped and divided into training (70%) and holdout (30%) subsets. During model training, an ensemble of ResNet-18 convolutional neural networks learned classification of low-risk and high-risk cases using five-fold stratified cross-validation and was used to predict on the holdout test set. The model was evaluated using area under the receiver operating characteristic curve (AUC) and sensitivity. Saliency maps were used for model interpretability to highlight relevant pixels for model decisions.

Results: The cross-validation AUC was 0.995 ± 0.010. The testing AUC was 0.909 and class-wise sensitivities were 0.88 (low risk) and 0.79 (high risk). The density plot (Figure, B) shows that the classifier correctly identifies both classes with confidence. Model interpretability using saliency maps (Figure, C) shows pixels corresponding to carotid artery vessel edges and in high-risk cases, carotid plaques.

Conclusions: Using this proof-of-concept model, carotid US long axis images are sufficient to identify high-risk plaques in symptomatic patients; we need to determine whether we can identify high-risk plaques before symptoms to prevent devastating stroke caused by carotid disease.