Contrast CT classification of asymptomatic and symptomatic carotids in stroke and transient ischaemic attack with deep learning and interpretability

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Background: Convolutional neural networks (CNNs), part of deep learning, are used widely for computer vision tasks and in some medical domains, such as mammography interpretation. The application of deep learning to carotid artery imaging is scarce. We investigated the ability of deep learning to correctly classify contrast CT images of the carotid arteries without the need for prior feature selection.

Purpose: (1) To assess the ability of deep learning to differentiate symptomatic patients (had prior stroke or transient ischaemic attack [TIA]) from asymptomatic patients (no prior stroke/TIA) using contrast CT scans alone. (2) To investigate whether deep learning can further discriminate between culprit and non-culprit carotid arteries in symptomatic patients. (3) To assess the interpretability of the deep learning models.

Methods: Carotid contrast CT scans of consented research subjects were included in the study. Symptomatic patients had confirmed carotid artery-related ischaemic stroke or TIA in the 7 days before CT imaging, and asymptomatic patients had no prior cerebrovascular events. The dataset comprised 1148 axial symptomatic slices (covering a 3cm area of each carotid artery in 41 patients; 41 culprit and 41 non-culprit carotids) and 700 asymptomatic slices (from the bilateral carotid arteries of 25 patients). The dataset was split such that 75% was used for training and 25% for testing. A 30x30 bounding box was used to create patches of the carotid arteries from these axial slices for use as input to the CNN, a modified VGG16 architecture initialised with ImageNet weights to leverage transfer learning (the application of a model trained in one domain to a different domain) implemented in Python. Data augmentation was applied to the training set and the model was trained for 100 epochs using a cyclic learning rate, the RMSProp optimizer and binary cross-entropy loss. Class activation heatmaps were generated using the GradCAM method to highlight the areas of the image that were most important to the model for making its classification decision.

Results: The deep learning model was 92% accurate in correctly identifying carotid arteries from symptomatic patients versus those from asymptomatic patients. Discriminating between culprit versus non-culprit carotid arteries in symptomatic patients alone was 71% accurate. The class activation heatmaps demonstrated how the model learnt to localise the carotid artery within the image patch, and to ignore the arterial lumen when making its classification decision.

Conclusions: Deep learning can be used to differentiate between symptomatic and asymptomatic carotid CT scans from stroke/TIA subjects without the need for prior feature engineering. The model learns to identify relevant features in the image that predict the patients' symptom state. If further validated, this approach could be used to identify high-risk patients for intensive medical therapy.

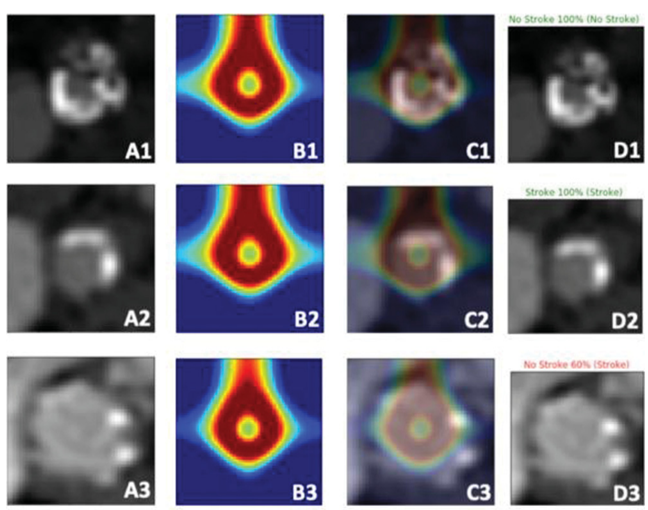

Figure 1. Class Activation Maps of CNN Classification Decision
A) Contrast CT images patches B) Class activation heatmaps of CNN classification decisions, red indicates the most important areas. C) Overlay of heatmaps and contrast CT image
D) Confidence of deep learning model as %. CNN prediction outside bracket, Ground-truth label inside bracket. Green = correct classification, Red = incorrect classification.
1 = asymptomatic carotid, 2 = symptomatic carotid, 3 = symptomatic carotid.