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Automatic clot detection in NECT images of acute ischemic stroke patients using a convolutional neural network

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Introduction

We aimed to investigate if clots represented by the hyperdense artery sign can be automatically detected in NECT images using a deep learning approach. Afterwards, an observational study was conducted to compare the results to the capability of two neuroradiologists.

Material and Methods

Thin slice NECT images of 185 patients with acute ischemic stroke due to proximal cerebral artery occlusion were registered with the CT angiography (CTA) images scanned immediately after. On the CTA images, the contrast gap indicating the site of occlusion was marked with a 3D region of interest (ROI). A deep convolutional neural network (CNN) with 3 layers of convolutional filters followed by totally connected deep neural layers was trained to identify the ROI for every patient as defined in the NECT images for 150 stroke and 100 non-stroke cases without a predefined ROI. Using the remaining 35 stroke and 30 non-stroke scans, we measured ROC curves for correct site of occlusion identification.
For the observational study, the doctors received NECT images of 40 stroke and 40 non-stroke cases in an anonymized, randomized and shuffled list to assess. Afterwards, we again measured ROC curves for correct site of occlusion identification.

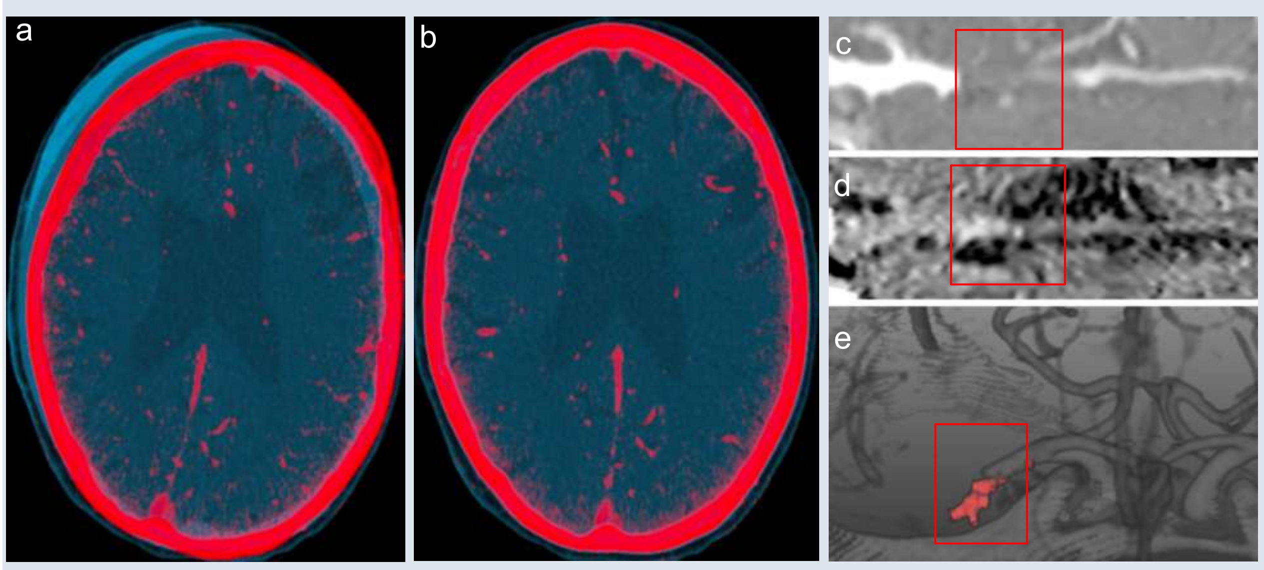

Figure 1
Due to disalignment (a), CTA images (red) and NECT scans (grey) are registered in as the initial image preprocessing step (b). Registration leads to optimal local matching on CTA (c) and thin slice NECT (d) reconstructions along the axis of the occluded vascular segment, allowing for defining a ROI encasing the clot (red box, e).

Results

Training time for the CNN: 7 days, 3.5 hours on a standard workstation with a modern high performance graphic card (gpu).
Area under the curve for the identification of an occlusion site and its correct position in the test set: 0.893.

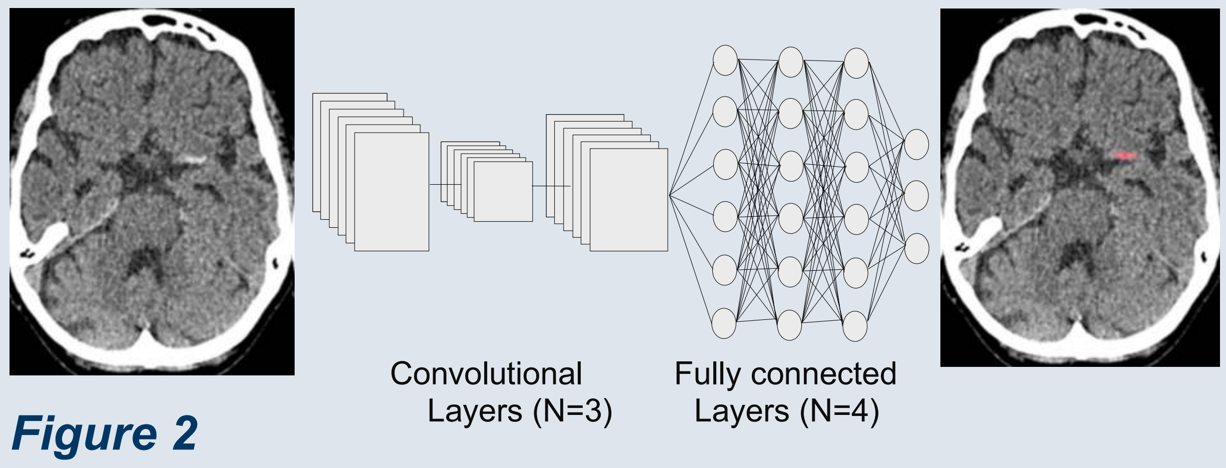

Figure 2
Schematic convolutional neural network (CNN) architecture. The implementation was done in Tensorflow (version 1.28) in Python 3.

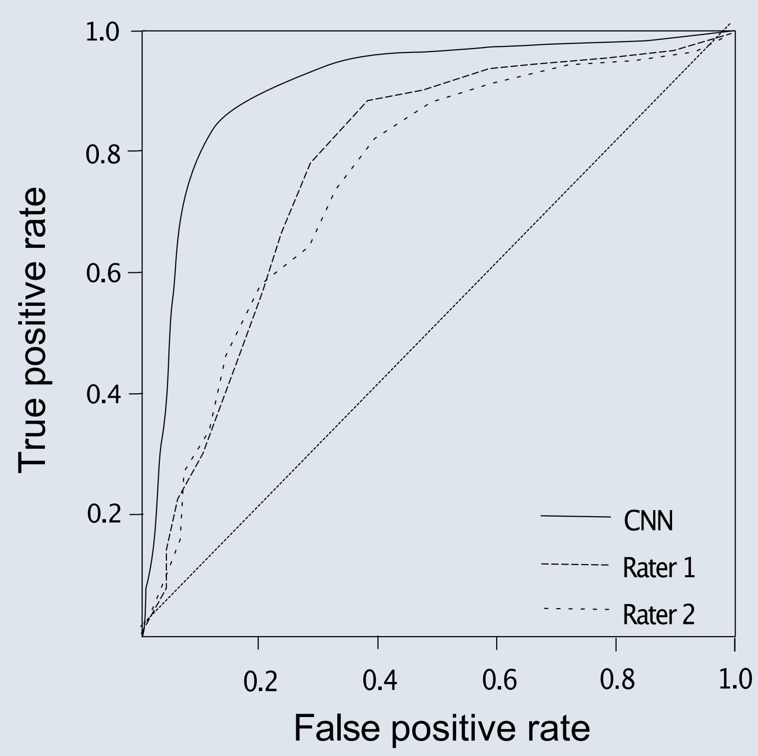

Figure 3
ROC curve showing: After the described training phase, the CNN´s results are exceeding those of human experts.

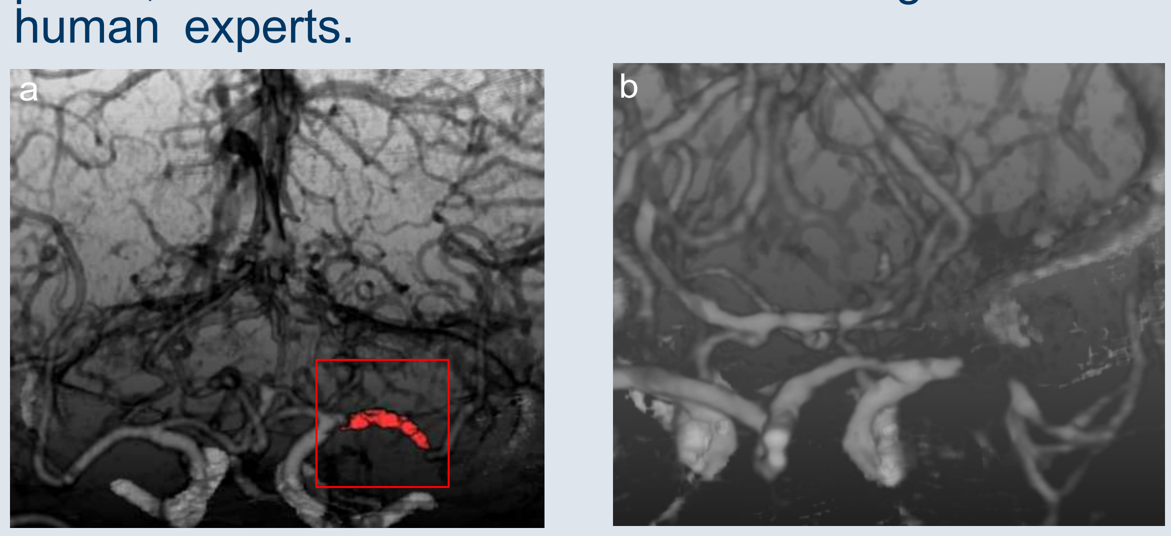

Figure 4
a) Typical bounding box detection case for a clot that is well defined on thin slice NECT imaging. In b) no bounding box is detected. In this particular case, vascular obliteration was found to be due to intracranial atherosclerosis resulting in left MCA mainstem occlusion.

Conclusion

Convolutional neural networks help to easily define the typical characteristics of a thrombus as seen on thin-slice NECT reconstructions. They can thus be used for fully automatic clot detection and might be used as a technique to confirm or rule out this typical neuroradiological “red flag”.

References:
[1] Riedel et al.,“Thin slice reconstructions of non-enhanced CT images allow for detection of thrombus in acute stroke“, Stroke 2012, 43(9), 2319-23.

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