Deep learning-based assessment of internal carotid artery anatomy to predict difficult intracranial access in endovascular recanalization of acute ischemic stroke

Gregor Nageler[1, 2], Dr. Ingmar Gergel[2], Markus Fangerau[2], Prof. Martin Bendszus[1], MD, Prof. Markus Alfred Möhlenbruch[1], MD, PD Ulf Neuberger[1], MD

[1]Department of Neuroradiology, Heidelberg University Hospital, Germany
[2]mbits imaging GmbH, Heidelberg, Germany

Objectives:

Mechanical thrombectomy (MT) duration is an important predictor for neurological outcome[1]. Recently it was shown that an angle of <= 90° of the internal carotid artery (ICA) is predictive for longer MT duration[2]. As angle measurement is not trivial, deep learning (DL) could help identify difficult MT cases.

Methods:

379 CT-angiographies (CTA) of patients who underwent MT between 01/2016 and 12/2020 were included. Segmentation of the aortic arch, as well as common carotid artery (CCA) and ICA, was performed. These were used to train an nnUNet[3] (80 train, 20 validation, 21 test). The remaining 258 CTAs were segmented using the trained nnUNet with manual verification afterwards. Angles of left and right ICAs were measured, resulting in two classes: acute angle <= 90° and > 90°. The correlation between ICA angle and MT duration was explored using median and Whitney-U test. 692 segmentations of CCA and ICA were used to train a convolutional neural network (587 train, 105 test) to determine the ICA angle. The nnUNet was evaluated using Dice-Score, Precision and Recall. The classification was evaluated using AUC and Accuracy.

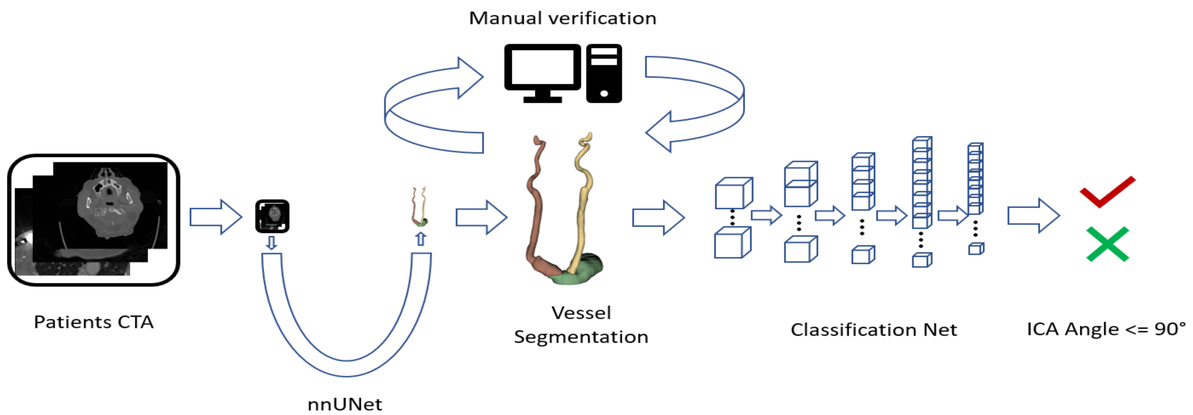

Fig. 1: Overview of the Data-Flow through the developed DL pipeline. The patient's CTA is passed to the trained nnUNet. The nnUNet segments the extracranial vessel tree, comprising the aorta, CCA, and ICA. The segmentation is manually checked for integrity. Afterward, the segmentation is passed to the trained classification net. It determines whether there is an ICA angle <= 90 ° present.

Metric / Structure	Aorta	Left CCA/ICA	Right CCA/ICA
Dice	0.944	0.854	0.856
Precision	0.943	0.826	0.863
Recall	0.945	0.893	0.871

Table 1: Results of the evaluation of the trained nnUNet on the test set.

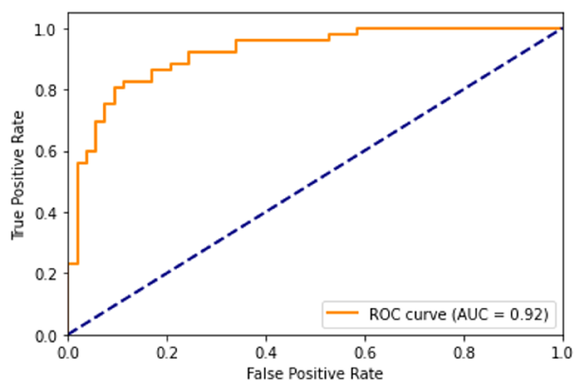

Figure 2: Receiver Operating Characteristic of the ICA angle classification by the trained Convolutional Neural Network.

Results:

Median MT duration for cases with manually measured ICA angle >90° was 48 minutes and with <=90° 64 minutes (p=0.001). Segmentation evaluation showed Dice Scores of 0.94/0.86, precision of 0.94/0.84 and recall of 0.95/0.88 for Aorta and CCA/ICA, respectively. Segmentation with the trained nnUNet took 30 s per CT with an average of 3 min of manual verification. Evaluation of ICA angle determination resulted in an AUC of 0.92 and an accuracy of 0.85.

Discussion:

It was possible to verify the correlation between ICA angle and MT duration and furthermore develop a DL-based method for semi-automatic assessment. The potential for full automation exists. A larger training set for the nnUNet training might render manual verification unnecessary. Higher performance of the angle determination could be achieved by applying more sophisticated preprocessing and data augmentation methods. Most probably, more anatomical features of interest can be identified in a similar fashion.

Conclusions:

A combined DL segmentation and classification approach is eligible for assessing difficult vascular anatomy in CTA of MT patients.

References:

1) Brugnara, G., et al., *Multimodal Predictive Modeling of Endovascular Treatment Outcome for Acute Ischemic Stroke Using Machine-Learning.* Stroke, 2020. **51**(12): p. 3541-3551.
2) Holswilder, G., et al., *The prognostic value of extracranial vascular characteristics on procedural duration and revascularization success in endovascularly treated acute ischemic stroke patients.* Eur Stroke J, 2022. **7**(1): p. 48-56.
3) Isensee, F., et al., *nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation.* Nat Methods, 2021. **18**(2): p. 203-211.