Deep Learning for Segmentation of Intracranial Aneurysms on Time-of-Flight Magnetic Resonance Angiography

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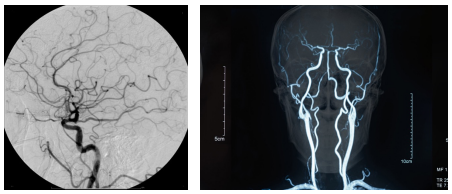
Introduction

- While the vast majority of intracranial aneurysms (IAs) go unruptured, those that do rupture pose a life-threatening risk of subarachnoid hemorrhage.
- However, predicting the rupture risk of IAs remains challenging even for experts in the field.
- Machine learning has emerged as a promising clinical tool in recent years, with the potential to help guide management of IAs.
- Deep learning, a subset of machine learning, has previously been shown to accurately segment IAs on digital subtraction angiography (DSA)[1,2].
- However, DSA is invasive. It is not routinely used for surveillance of IAs, and incidental IAs are more often found on alternative modes of imaging.



Comparison between DSA and MRA for cerebral angiography. Left: DSA[3]; right: MRA[4].

Aims and Objectives

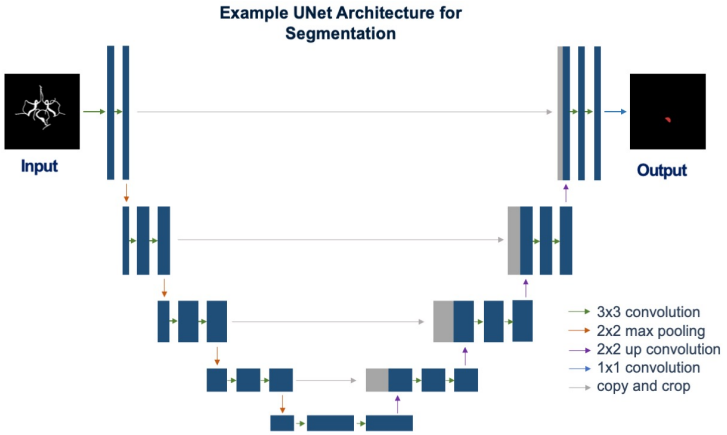
- As an initial step, we aim to demonstrate the success of deep learning at aneurysm segmentation tasks on time-of-flight magnetic resonance angiography (TOF MRA).
- Ultimately, we want to develop a deep learning-based model for the automatic detection, segmentation, and rupture risk stratification of IAs on TOF MRA to serve as a tool to aid clinical decision making.

Methods

- As the most commonly used imaging modality for noninvasive surveillance of IAs, TOF MRA was selected as the input to our model.
- We utilized an open-source TOF MRA dataset available on the OpenNeuro database. In this dataset, IAs are manually labeled by field experts to serve as ground truth. Labels are able to be removed for testing purposes.
- Deep learning algorithms that are well-established in the fields of computer vision and medical image segmentation were selected for analysis. We tested several convolutional neural network (CNN)-based models and transformer-based models.

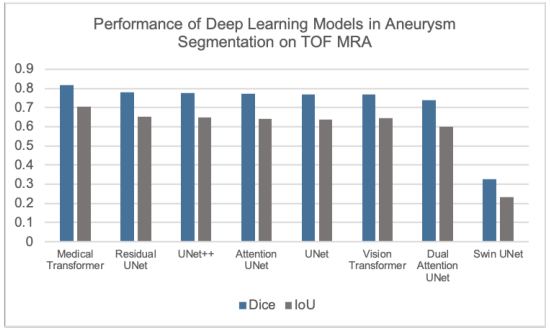
CNN-based models
- UNet
- Residual UNet
- UNet++
- Attention UNet
- Dual Attention UNet

Transformer-based models
- Vision Transformer
- Medical Transformer
- Swin UNet



- Outcome measures used were the Dice Similarity Coefficient (DICE) and Intersection Over Union (IOU), both of which range from 0 to 1.
- DICE and IOU are metrics used in the field of machine learning to evaluate performance of the model, namely by quantifying how similar the model's prediction is to the ground truth.

Results



- The Medical Transformer model performed best on segmentation of IAs on TOF MRA.
- Close in performance were Residual UNet, UNet++, Attention UNet, UNet, Vision Transformer, and Dual Attention UNet.
- Swin UNet had significantly lower performance with DICE of 0.327 and IOU of 0.232.

Conclusions

- We demonstrated the ability of several deep learning models to successfully perform aneurysm segmentation tasks on an open-source TOF MRA dataset.
- This is important for our overarching goal of developing a computer-based tool for rupture prediction of IAs seen on MRA.
- Additionally, tiny aneurysms can sometimes be missed, and a computer-based tool for detection and segmentation can help reduce the likelihood of such.
- Future directions include expanding the capabilities of the model to stratification of rupture risk, as well as time-series growth modeling to identify unstable IAs that may benefit from early surgical intervention.

References

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