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High Dice, Broken Vessels: Evaluating Topology Errors in Deep Learning Vessel Segmentation

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INTRODUCTION

- Deep learning methods achieve state-of-the-art results in vascular segmentation from CT images.
- Segmentation quality is commonly evaluated using overlap-based metrics, especially the **Dice similarity coefficient**.
- However, vascular structures have complex, tree-like anatomy.
- Small segmentation errors can break vessel continuity, even when the Dice score remains high.
- Such topology-related errors may reduce clinical usefulness in:
  - surgical planning,
  - hemodynamic modeling,
  - quantitative vascular analysis.

INTRODUCTION

- Dice Similarity Coefficient
- Dice measures the overlap between the predicted segmentation and the ground-truth segmentation.

$$Dice = \frac{2|P \cap G|}{|P|+|G|}$$

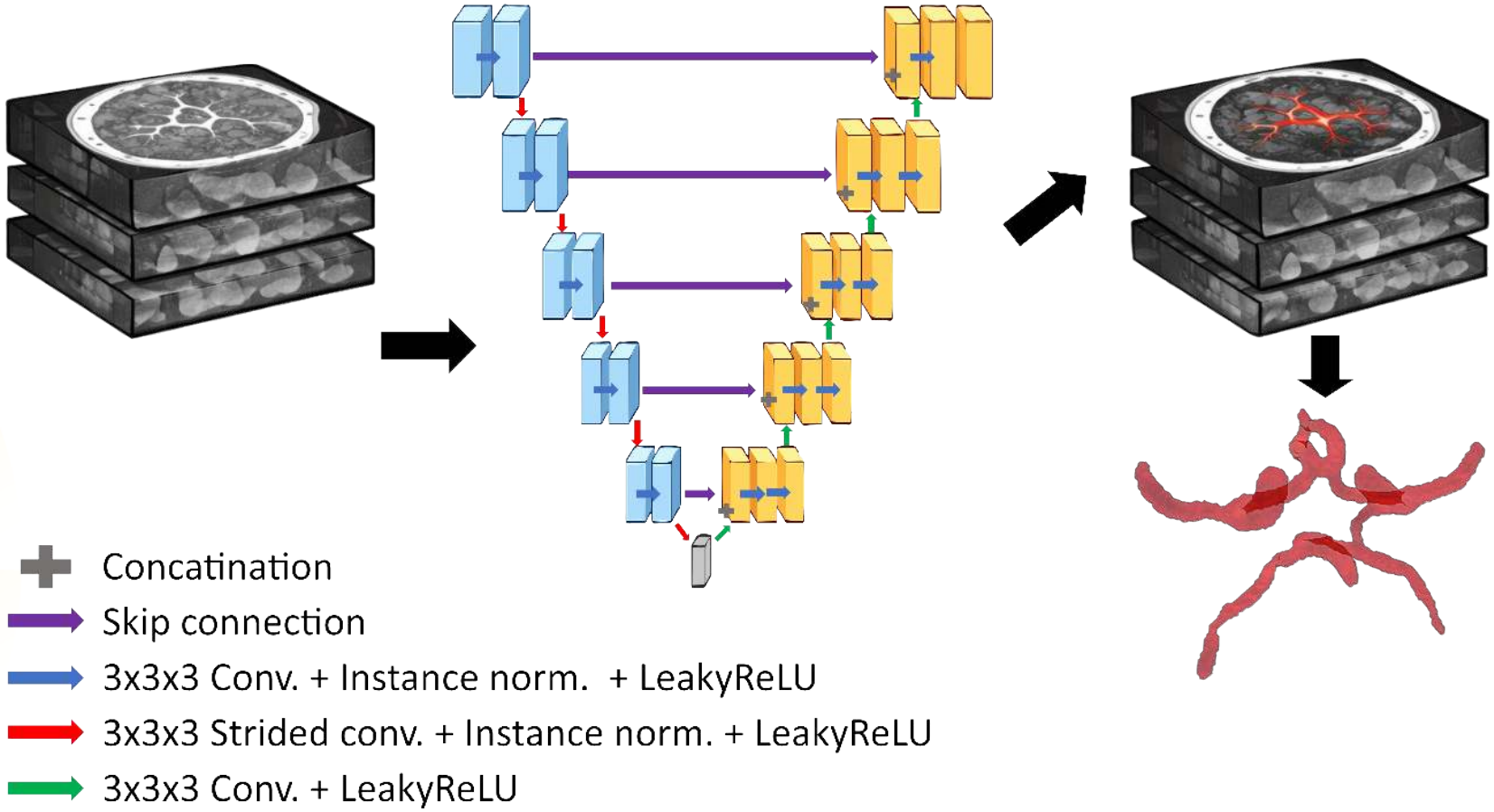
- Where:
  - P — predicted segmentation mask
  - G — ground-truth segmentation mask
  - P ∩ G — overlapping region between prediction and ground truth
  - |P| — number of voxels/pixels in the predicted mask
  - |G| — number of voxels/pixels in the ground-truth mask

METHODS

- Segmentation models were trained using the nnU-Net framework.
- Training was performed on four public vascular CT datasets:
  - SEGA
  - AortaSeg24
  - PARSE2022
  - TopCoW2024
- Predicted segmentations were compared with ground-truth annotations.
- Evaluation included both:
  - conventional overlap-based metrics,
  - topology-aware structural metrics.

METHODS

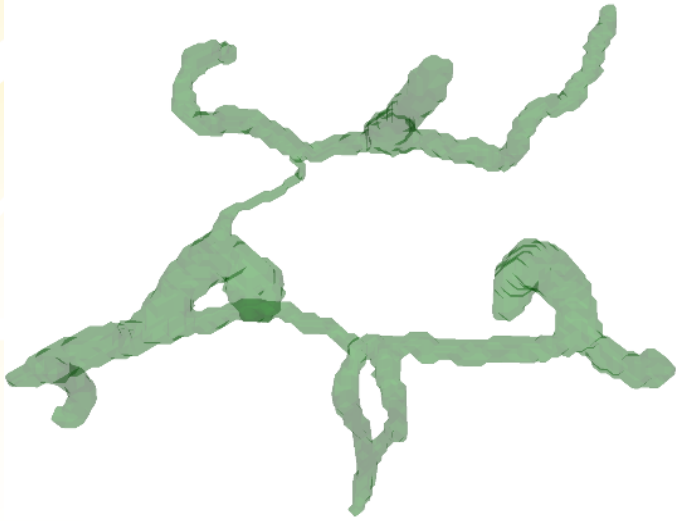
- **nnU-Net** is a self-configuring deep learning framework for medical image segmentation



METHODS

- **Datasets used in experiments**

TopCoW 2024 Dataset	PARSE 2022 Dataset	SEGA & AortaSeg24Dataset
125cases total (100 train,25 val)	100cases total (80 train,20 val)	145cases total (116 train,29 val)
Modality: CT (raw scans)	Modality: CT (raw scans)	Modality: CT (raw scans)
Anatomy: Circle of Willis	Anatomy: Pulmonary Artery	Anatomy: Aorta





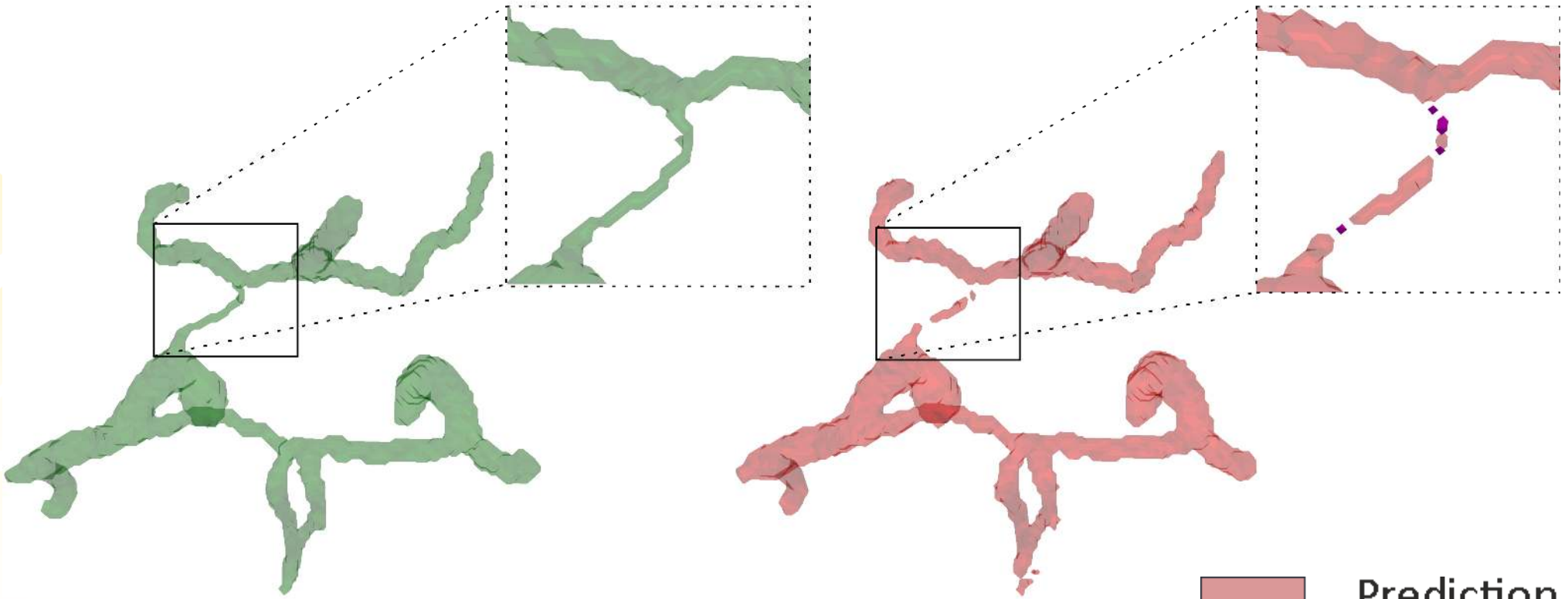


Segmentarion-overlap

RESULTS

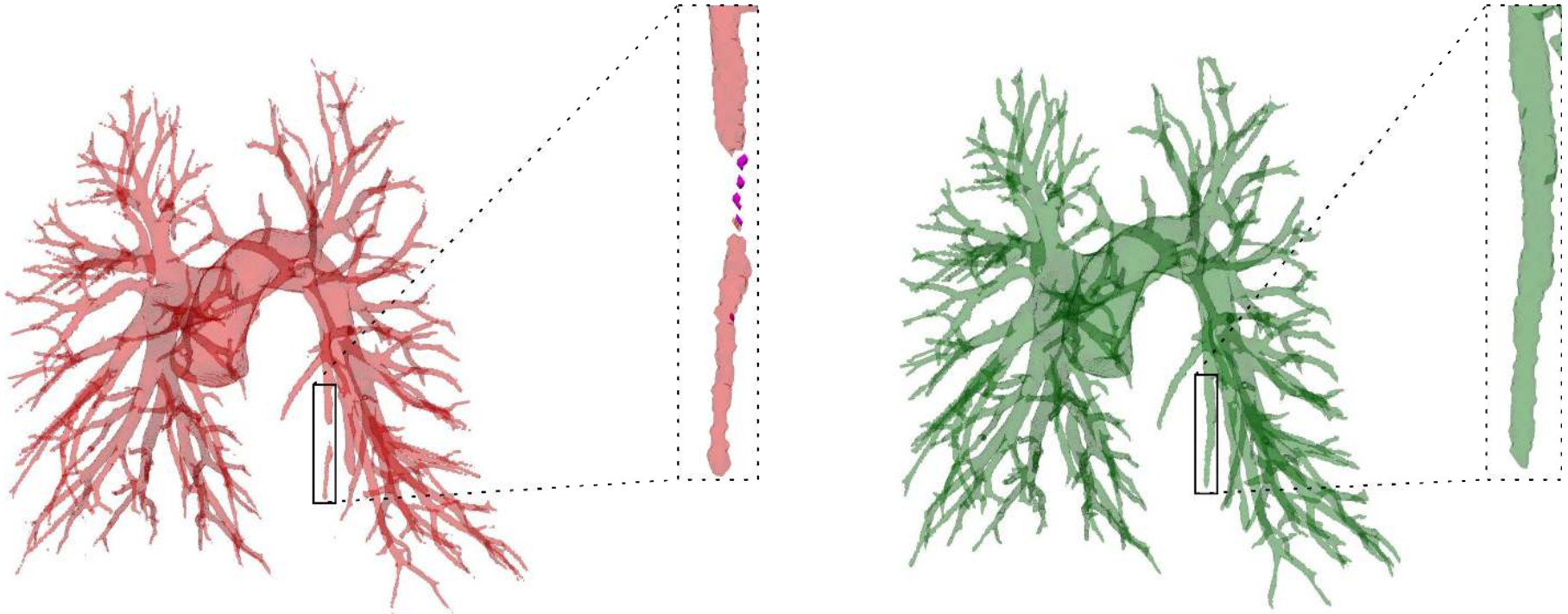
RESULTS

Circle of Willis



RESULTS

Pulmonary Artery



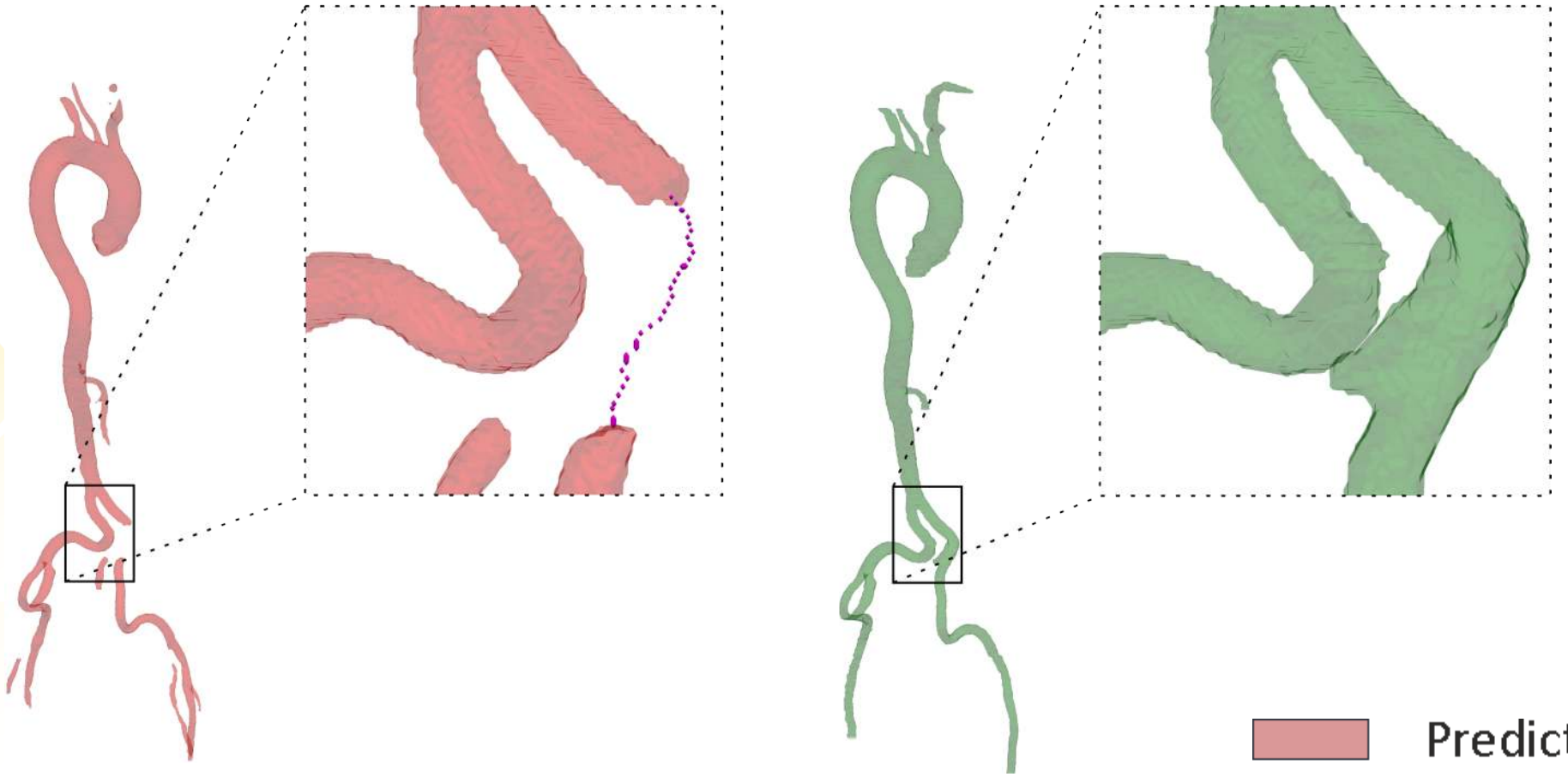
Prediction

Ground truth

Missing connection

RESULTS

Anatomy: Aorta



CONCLUSION

- The results show an important limitation of Dice-based evaluation in vascular segmentation
- Deep learning models can achieve high Dice scores, but still produce structural errors
- Such topological inconsistencies can reduce the clinical usability of automatic segmentation
- Topology-aware metrics provide a more complete evaluation of vascular segmentation quality.
- Future work will focus on topology-preserving training strategies, including:
  - alternative anatomical representations, e.g. meshes,
  - geometry-based supervision mechanisms.

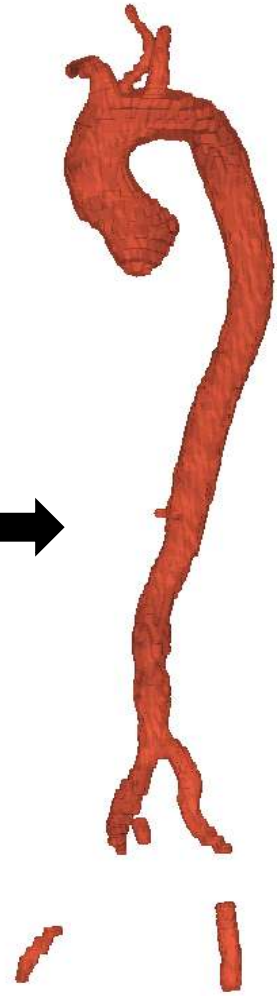
SOLUTION

Template cylinder

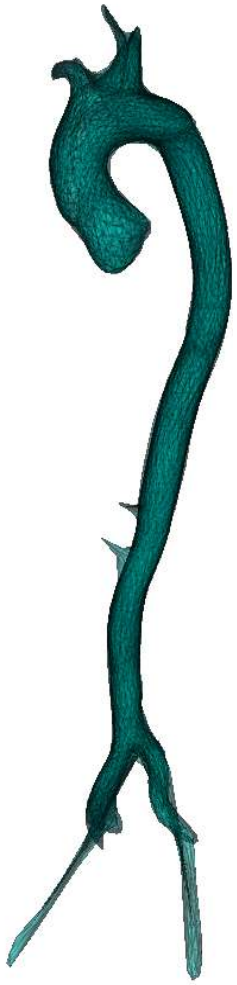


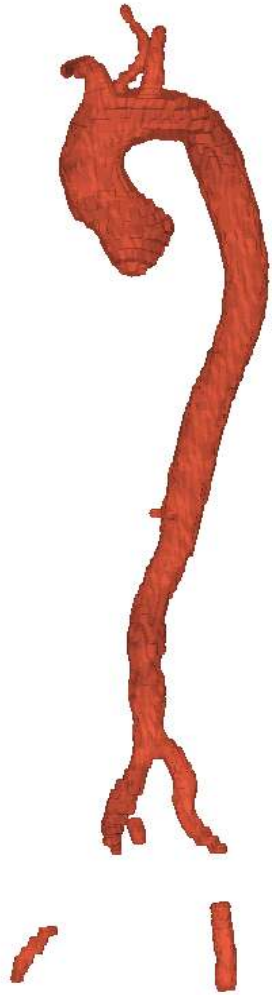
Deforming network

nn-Unet broken mask

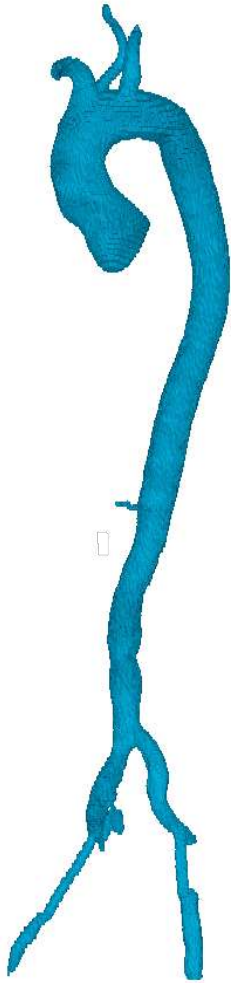


3D surface mesh of the aorta





Repaired mask



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NATIONAL SCIENCE CENTRE POLAND

This work was supported by the National Science Centre, Poland, under Grant "MultiGeoMed" No. 2024/55/D/ST6/02081.
We gratefully acknowledge Polish high-performance computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) for providing computer facilities and support within computational grant no. PLG/2025/018770 and grant no.PLG/2026/020104.

Thank you for your attention

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857533 and from the International Research Agendas Programme of the Foundation for Polish Science No MAB PLUS/2019/13.

European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund

Ministry of Science and Higher Education Republic of Poland

Funded by the initiative of the Minister of Science and Higher Education "Support for the activities of Centers of Excellence established under the Horizon 2020 program"