Amsterdam UMC
Universitair Medische Centra

Can we use AI to predict spinal cord ischemia?

Critical issues 2024

March 22, 2024

Associate prof. Dr. Kak Khee Yeung, MD, PhD, FEBVS
Vascular surgeon, PI
Department of Vascular Surgery, Amsterdam UMC

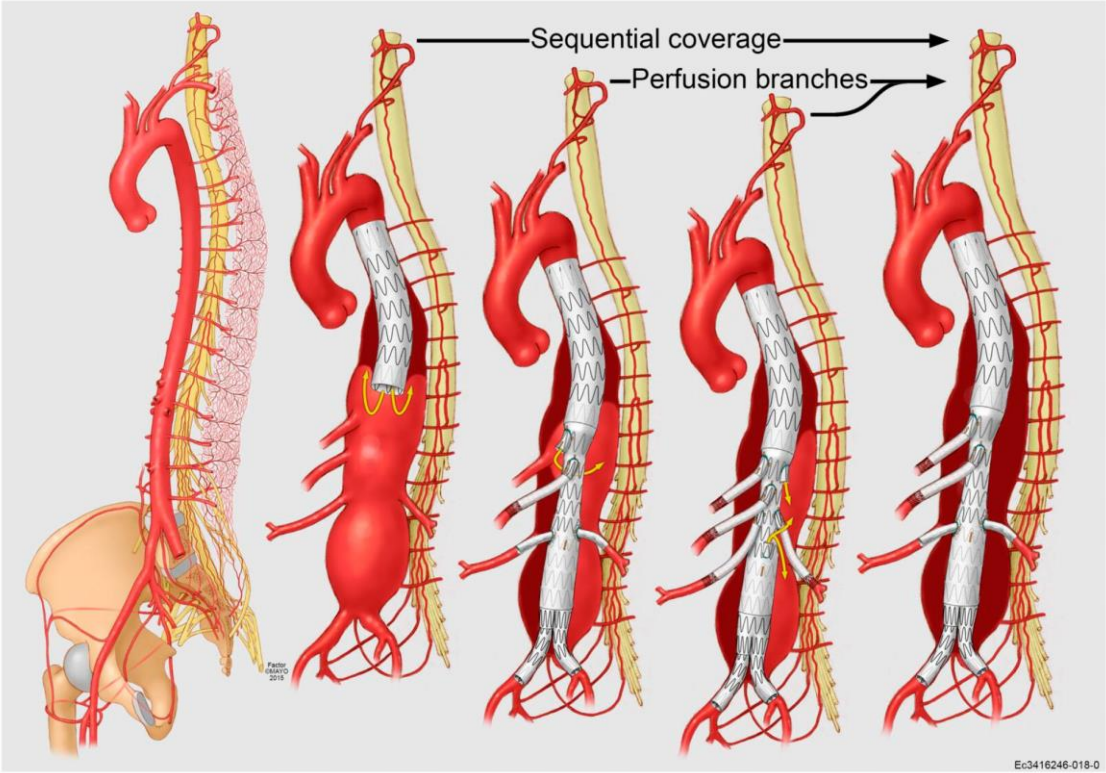
Disclosures

- Research grants:
  - Philips Medical
  - Medtronic (unrestricted research grant)
  - ZonMw
  - Horizon Europe
  - W.L. Gore & Associates (unrestricted research grant)
  - Artivion
  - Hartstichting Senior Clinical Scientist Dekkerbeurs
  - Stichting VUmc & AMC Foundation

- Consultancy:
  - Terumo Aortic
  - W.L. Gore & Associates
  - Medtronic

Complication of complex aortic repair

- Supplying artery blockage → Spinal Cord Ischemia (SCI)[2]
- Incidence:
  - 10 % – 15 % in population type II and III[3]
- Types of SCI:
  - Paraparesis
  - Paraplegia

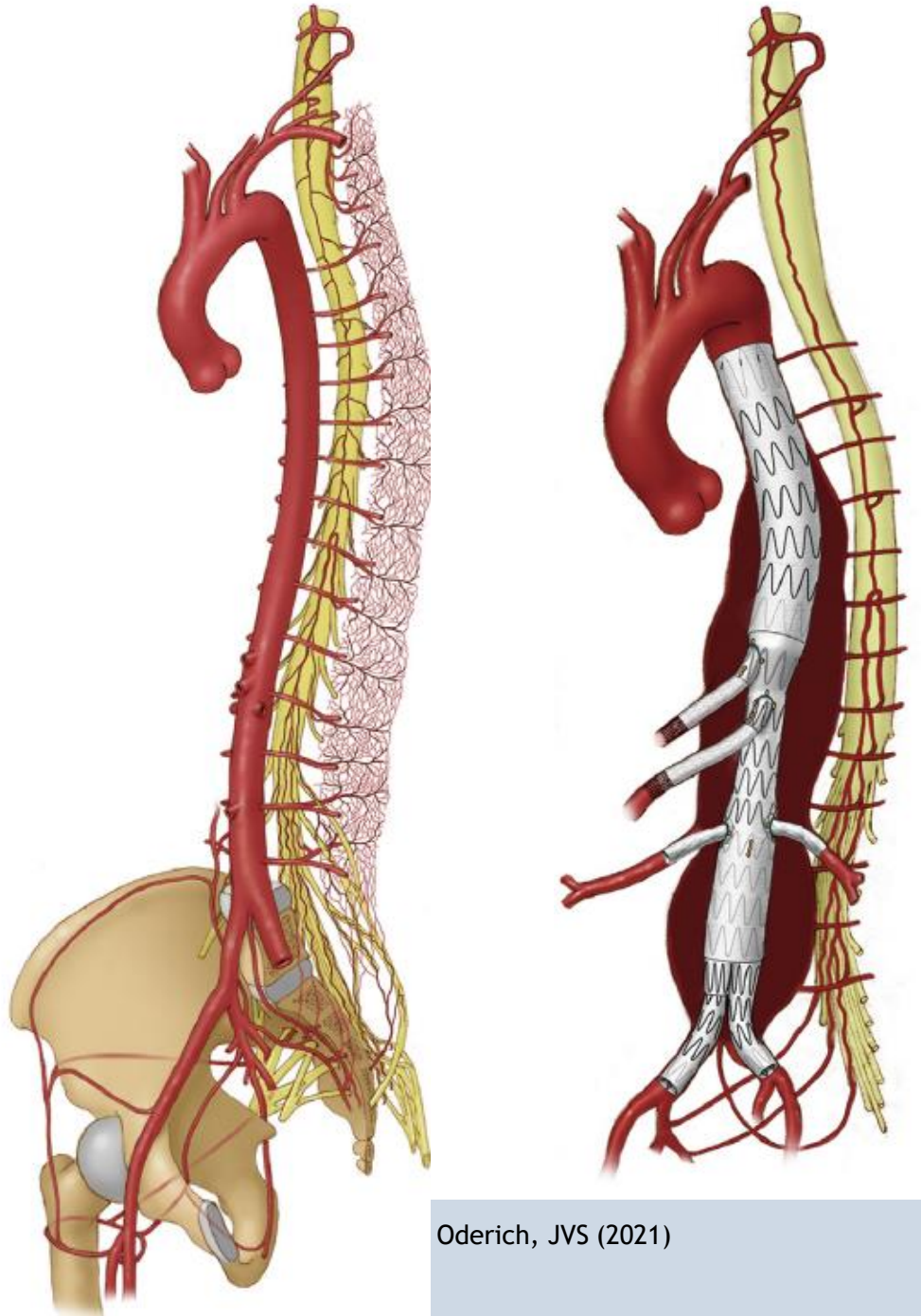


[2] Griepp EB, Di Luozzo G, Schray D, Stefanovic A, Geisbüsch S, Griepp RB. The anatomy of the spinal cord collateral circulation. Ann Cardiothorac Surg. 2012;1(3):350-7

[3] Dias-Neto M, Tenorio ER, Huang Y, Jakimowicz T, Mendes BC, Kölbel T, et al. Comparison of single- and multistage strategies during fenestrated-branched endovascular aortic repair of thoracoabdominal aortic aneurysms. J Vasc Surg. 2023;77(6):1588-97.e4

Spinal Cord Ischemia

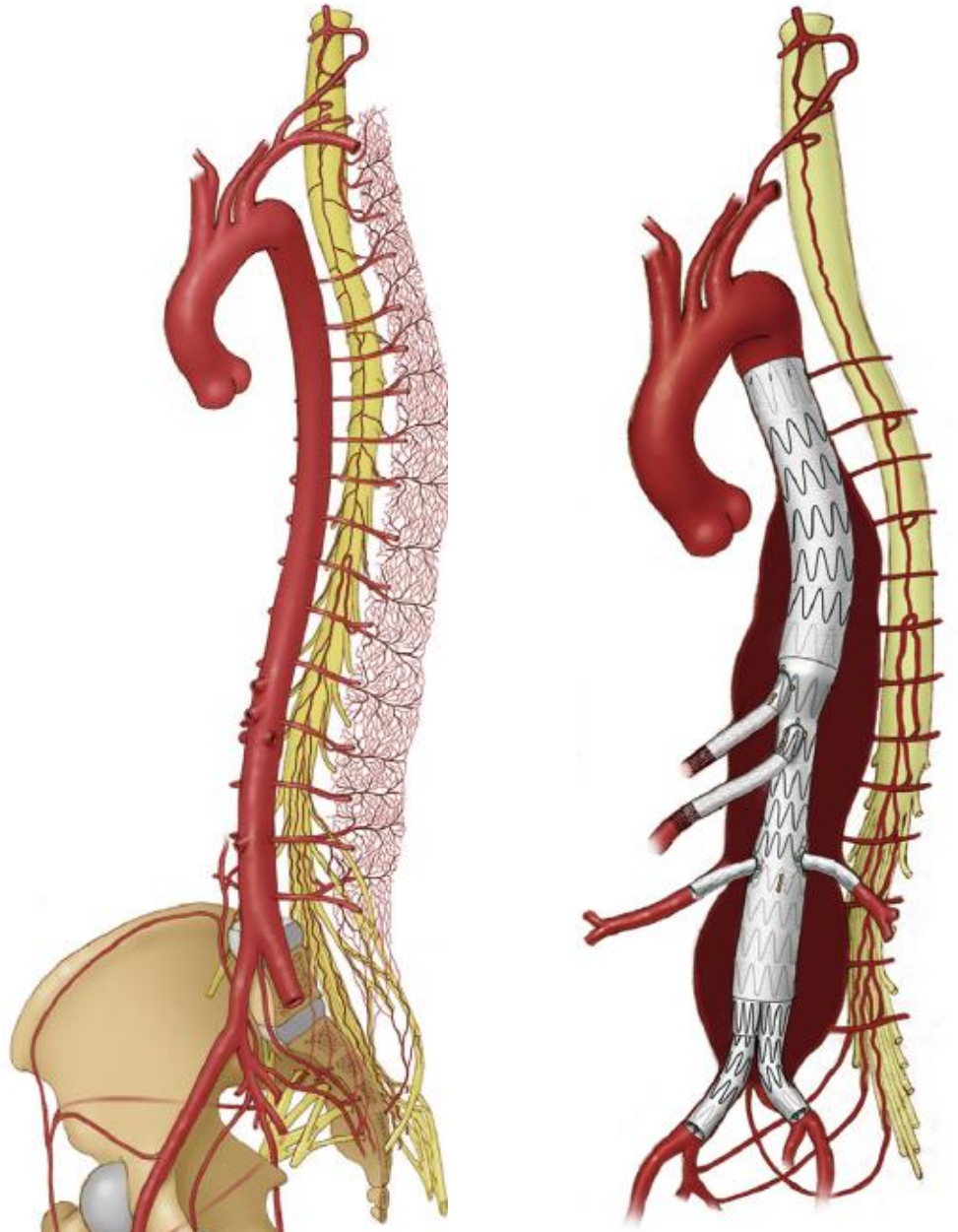
- Insufficient perfusion
- Sensory and motortic deficits
- After extensive endovascular aortic repair
  - Descending thoracic aorta
  - Thoraco-abdominal
- Collateral network
  - Left subclavian artery
  - Intercostal arteries
  - Lumbar arteries
  - Internal iliac arteries



Oderich, JVS (2021)

Spinal Cord Ischemia

- Risk factors
  - Extent of disease, length of aortic coverage, collateral network coverage, LSA coverage, reduced spinal cord perfusion pressure, prior aortic repair, etc.
  - Multifactorial
- Preventive measures
  - CS-bypass, augmentation of spinal cord perfusion, CSF drainage, staging of repair, etc.



Oderich, JVS (2021)

Staging of procedures

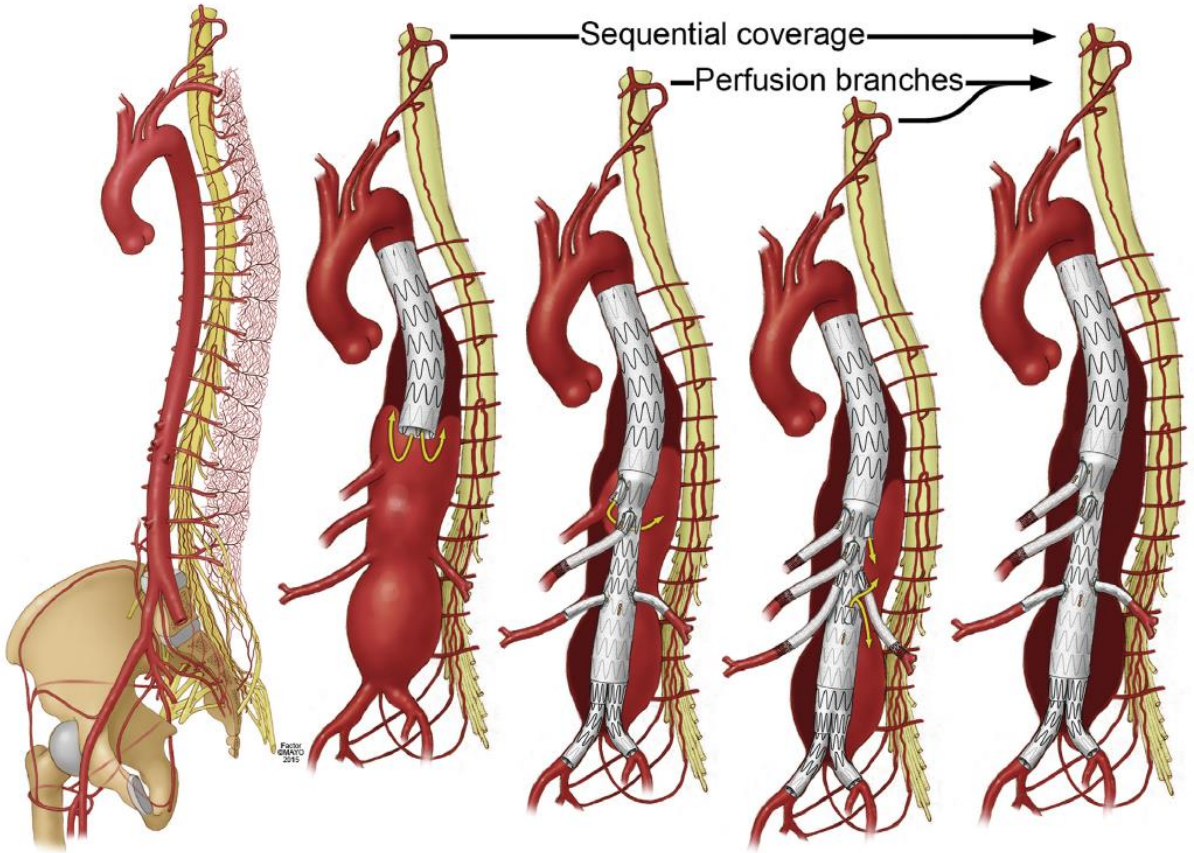


Fig 17. Strategies for staged endovascular repair of thoracoabdominal aortic aneurysms (TAAAs), including sequential thoracic coverage and use of temporary aneurysm sac perfusion by incomplete repair or perfusion branches. (Reproduced by permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

Comparison of single and multistage strategies during fenestrated-branched endovascular aortic repair of thoracoabdominal aortic aneurysms

Marina Dias-Neto • Emanuel R. Tenorio • Ying Huang • ... Sinead Gormley • Gustavo S. Oderich • On behalf of The International Aortic Research Consortium • Show all authors

Published: January 30, 2023 • DOI: https://doi.org/10.1016/j.jvs.2023.01.188

Table IV. 30-Day after elective FB-EVAR using single- or multi-stage approaches.

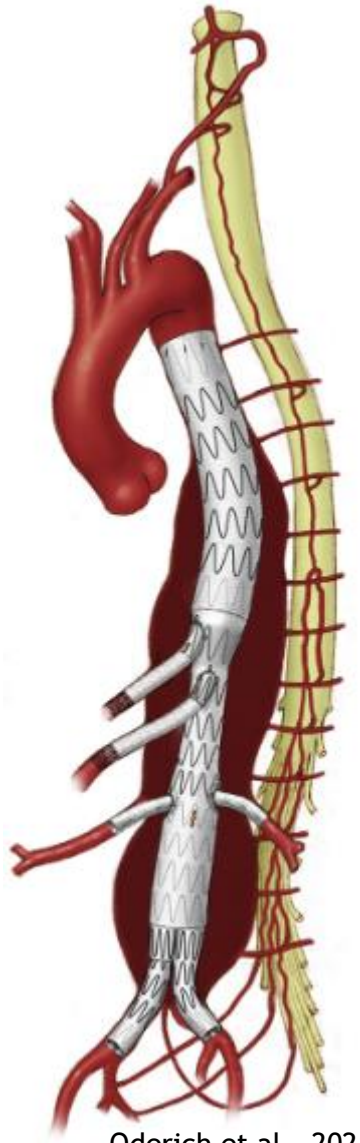
	N	Single-stage (n = 713)	Multi-stage (n = 884)	Total	P value
		Values are Number (Percent)			
Death or permanent paraplegia	1502	92 (13.7)	52 (6.3)	144 (9.6)	**<.001**
Any SCI	1597	108 (15.1)	92 (10.4)	200 (12.5)	**.004**
Permanent SCI	1501	59 (8.8)	33 (4.0)	92 (6.1)	**<.001**
Permanent paraplegia	1500	56 (8.3)	25 (3.0)	81 (5.4)	**<.001**

Oderich, JVS (2021)

Preoperative AI-based prediction of Spinal Cord Ischemia

"Prediction and prevention of spinal cord ischemia after complex EVAR using artifical intelligence on pre-operative imaging"

- Our project:
  - Use of pre-operative imaging for better risk prediction of spinal cord ischemia
  - Use of AI for automatic extraction of imaging-based features on large data sets
  - Combination of imaging features and clinical data to predict SCI



Oderich et al., 2021

Investigating the association between sarcopenia and spinal cord ischemia after Branched and Fenestrated EVAR

Investigating the association between sarcopenia and spinal cord ischemia after Branched and Fenestrated EVAR

- Sarcopenic patients have an increased risk of early mortality after EVAR and FB-EVAR
  [Meta-analysis by Bradley et al., Sci Reports 2022]

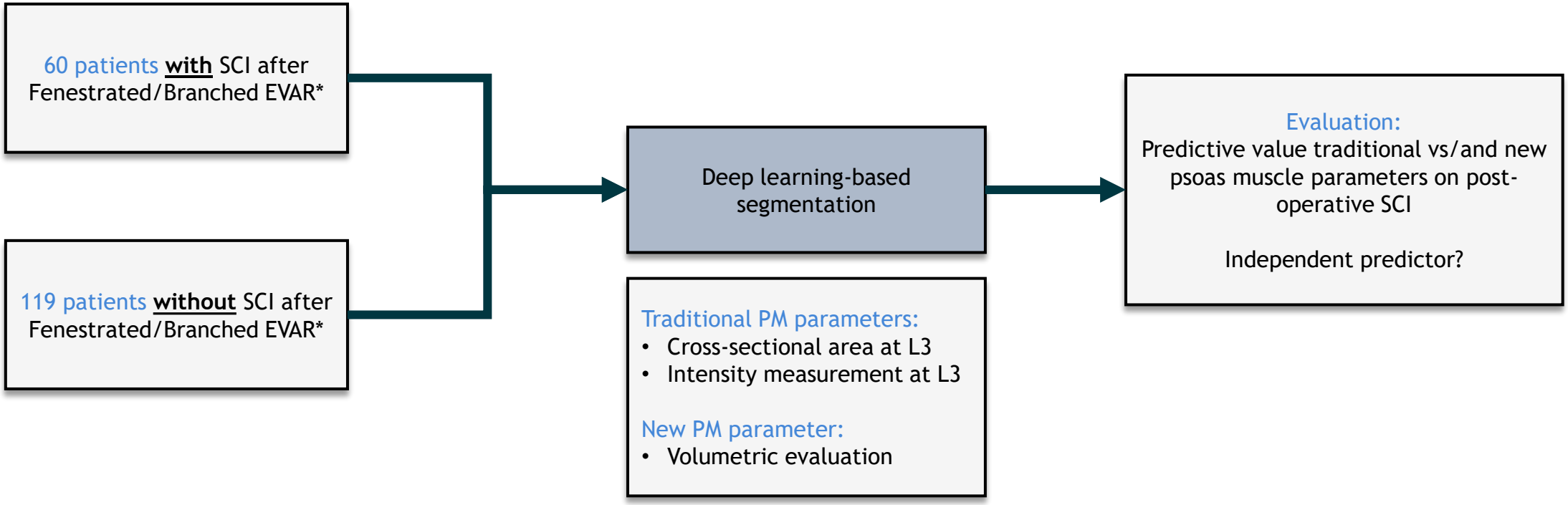
- Single study evaluating psoas muscle as prognostic factor for SCI
  [Kölbel, et al., JEVT 2023]
  - Only predictive combined with ASA score
  - Limited by the number of patients (12 SCI patients vs 68 non-SCI patients)

Goal:

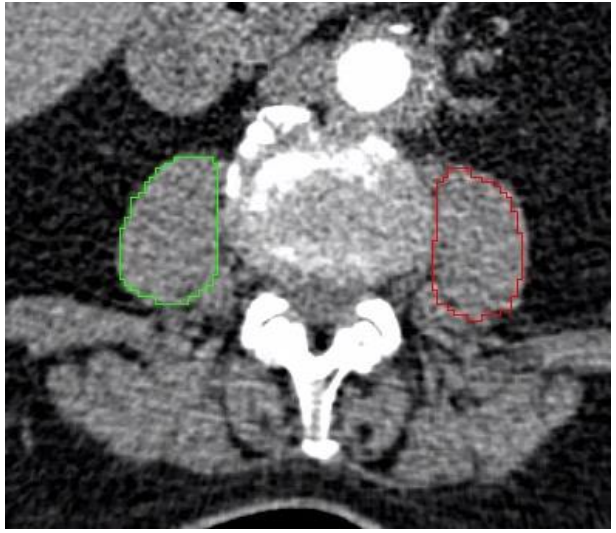
Investigate the predictive value of psoas muscle parameters for SCI after Fenestrated and Branched EVAR

Methods

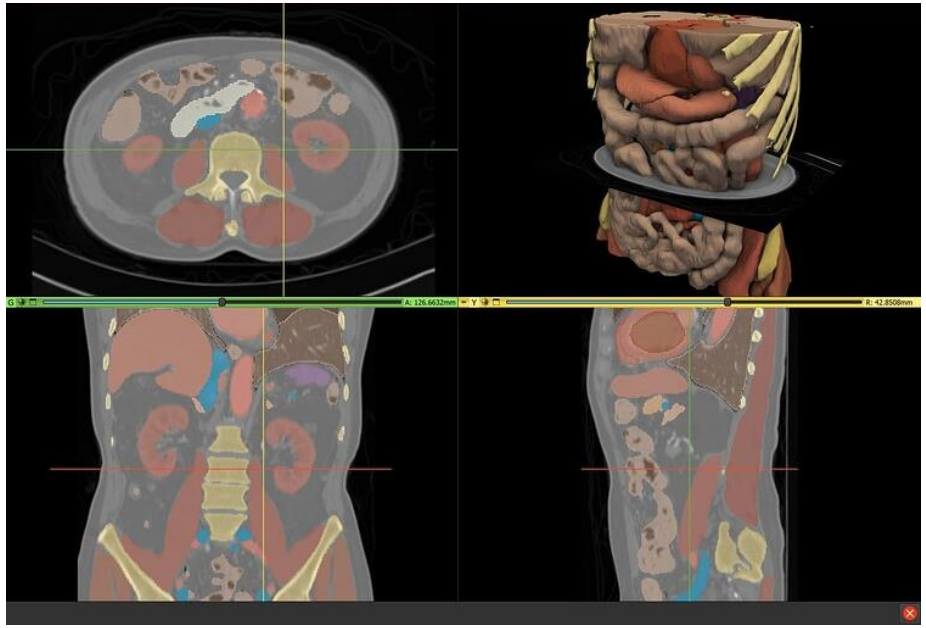
- Measurement based on preoperative CTA
- Primary outcome: post-operative SCI



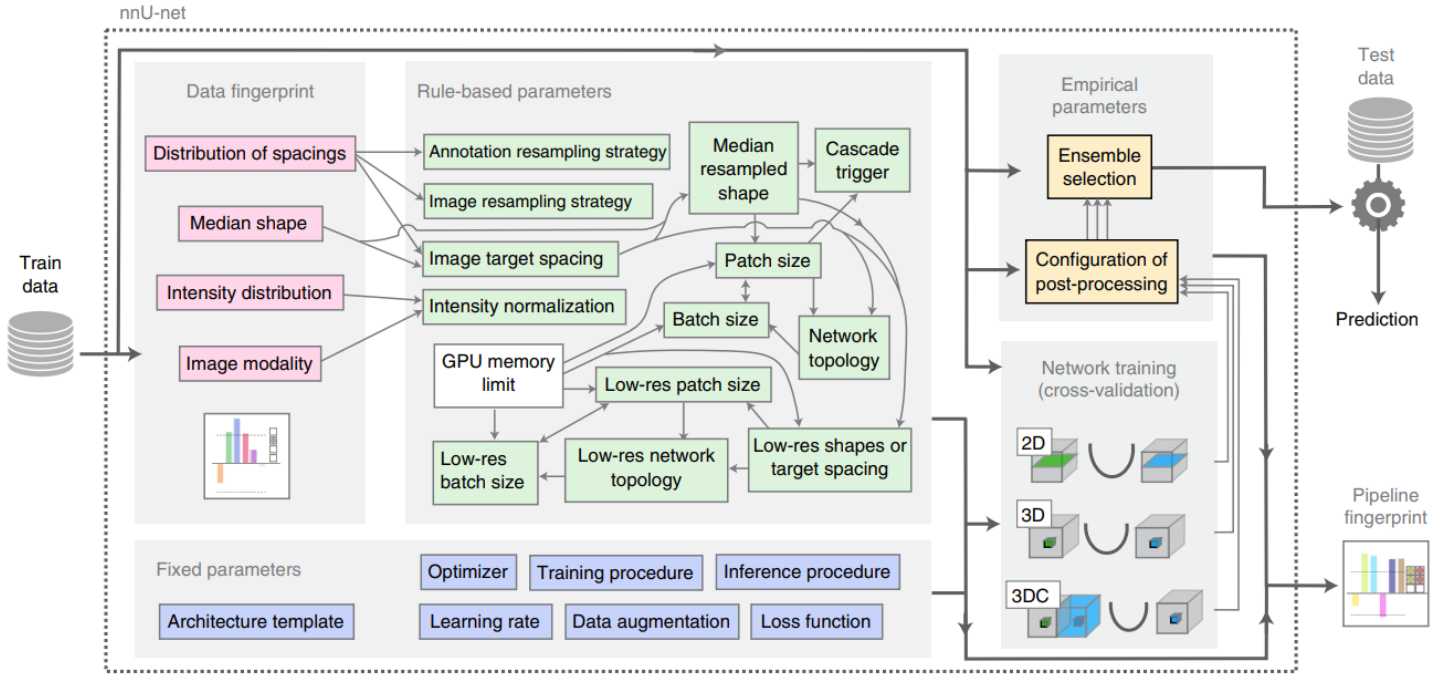
Automated Segmentation



Total Segmentator



nnU-Net



Wasserthal J, Breit H-C, Meyer MT, Pradella M, Hinck D, Sauter AW, et al. TotalSegmentator: Robust Segmentation of 104 Anatomic Structures in CT Images. Radiology: Artificial Intelligence. 2023;5(5):e230024

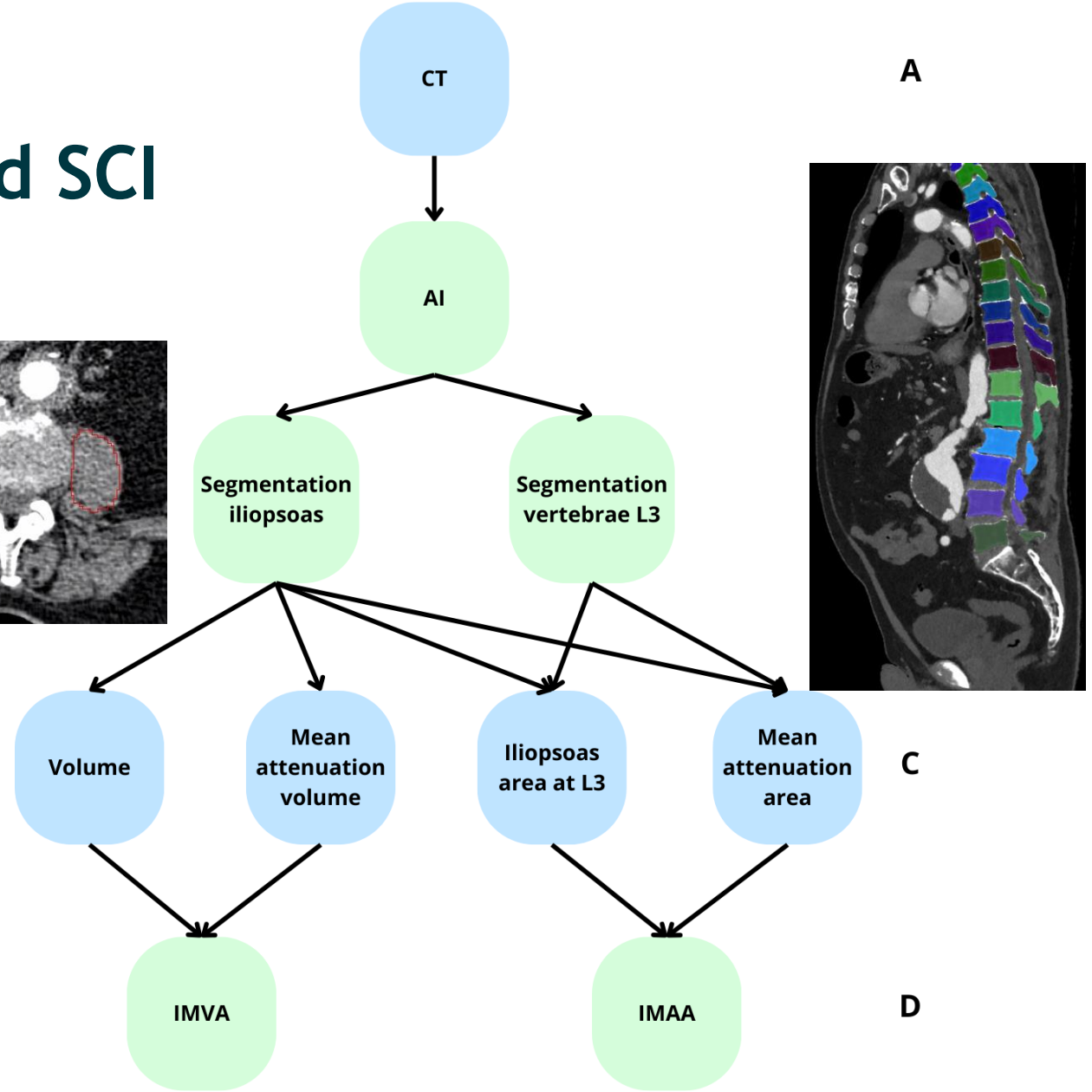
Isensee F, Jaeger PF, Kohl SAA, Petersen J, Maier-Hein KH. nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation. Nat Methods. 2021;18(2):203-11

Association Sarcopenia and SCI

Outcomes:

- Iliopsoas Muscle Volume Attenuation (IMVA)
- Iliopsoas Muscle Area Attenuation (IMAA)

Compare SCI vs non-SCI



Methods

Iliopsoas muscle segmentation

- Fully automated pipeline, including:
  - Post-processing to obtain different measurements
  - Volume, area and intensity values
- 179 patients including 60 SCI patients

Classic approach:

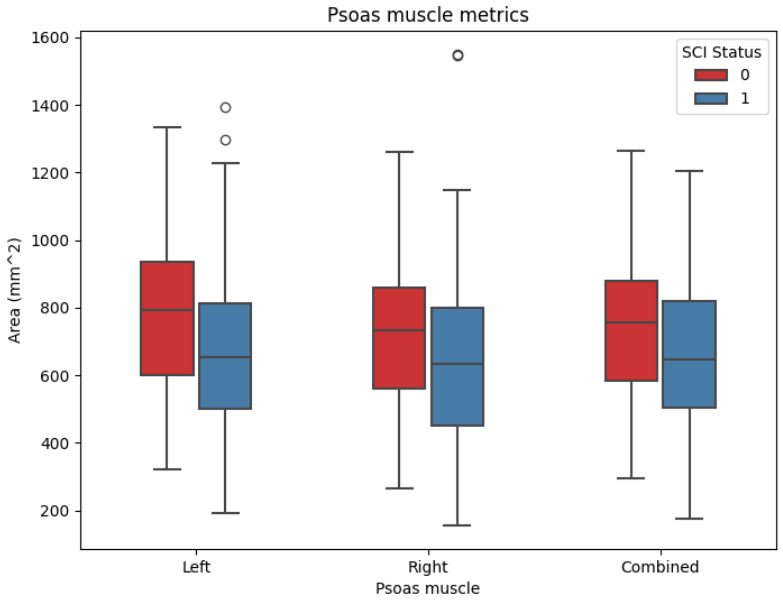
- Area at vertebra L3
- Intensity at vertebra L3
- Area x Intensity at L3

New approach including volume:

- Total Psoas volume
- Intensity of the volume
- Volume x Intensity

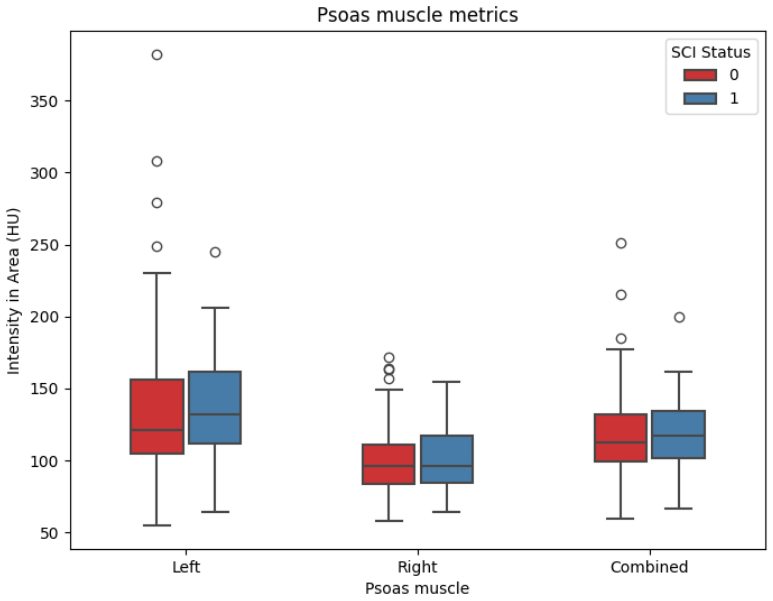
Classical approach

Psoas area



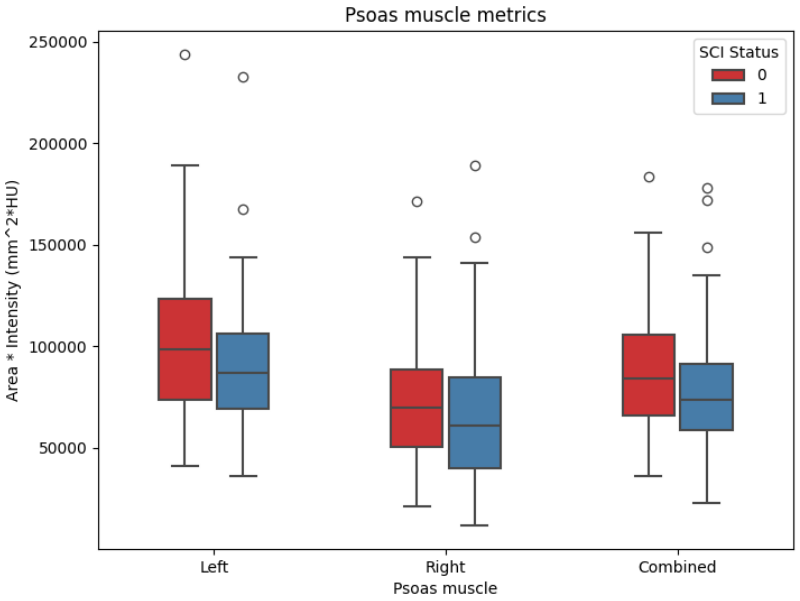
P=0.014

Intensity of Psoas area



P=0.352

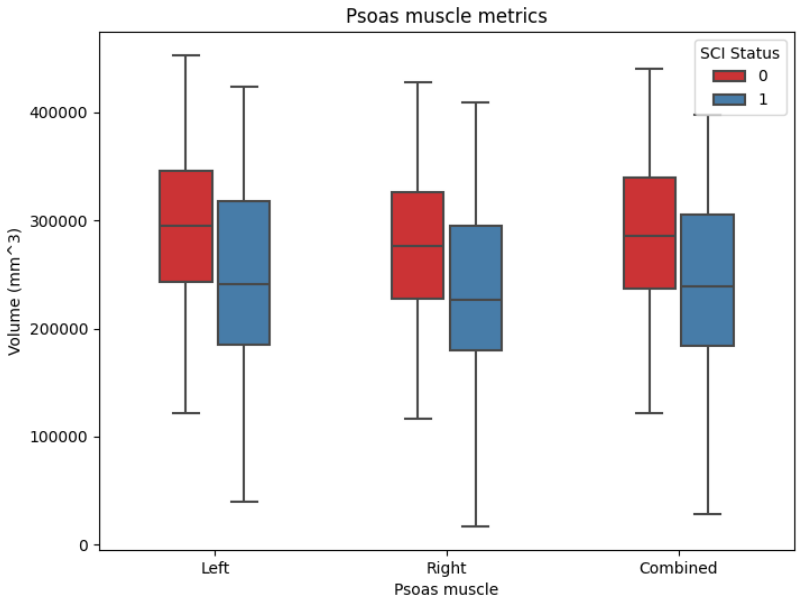
Psoas area x intensity



P=0.034

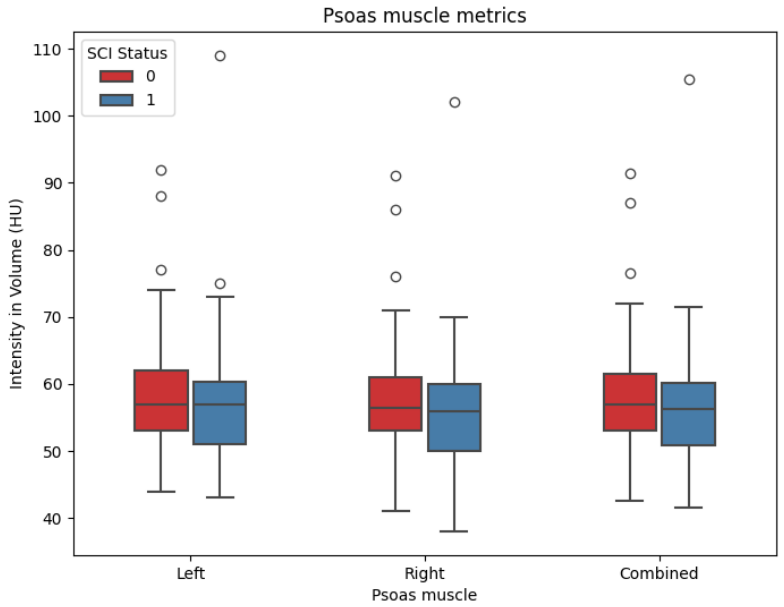
New approach including volume measurements

Iliopsoas volume



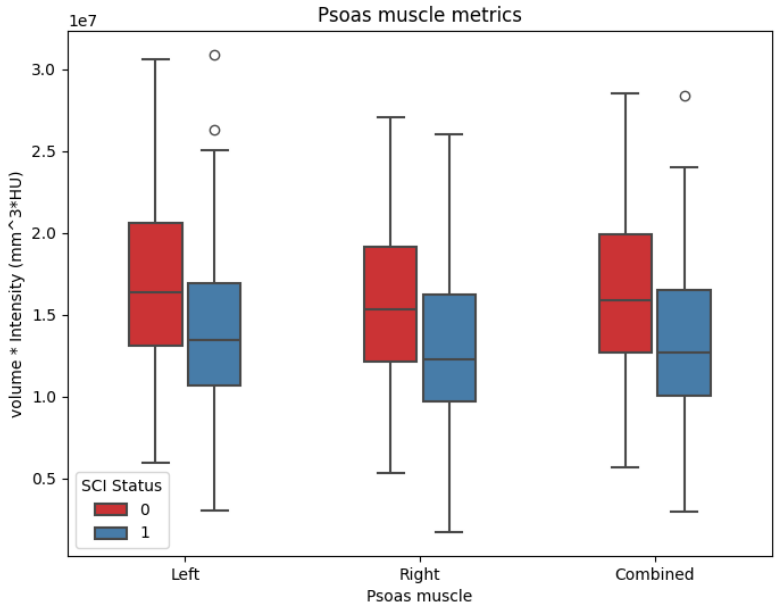
P=0.001

Intensity of Iliopsoas volume

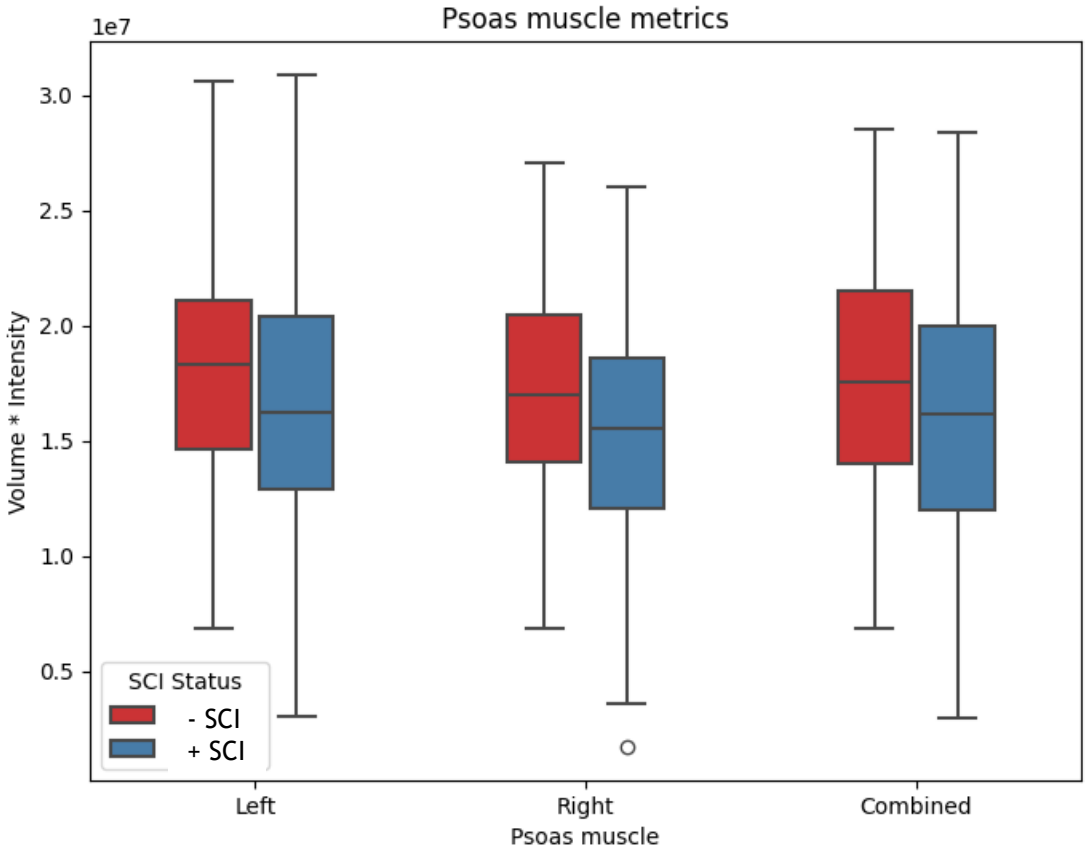


P=0.204

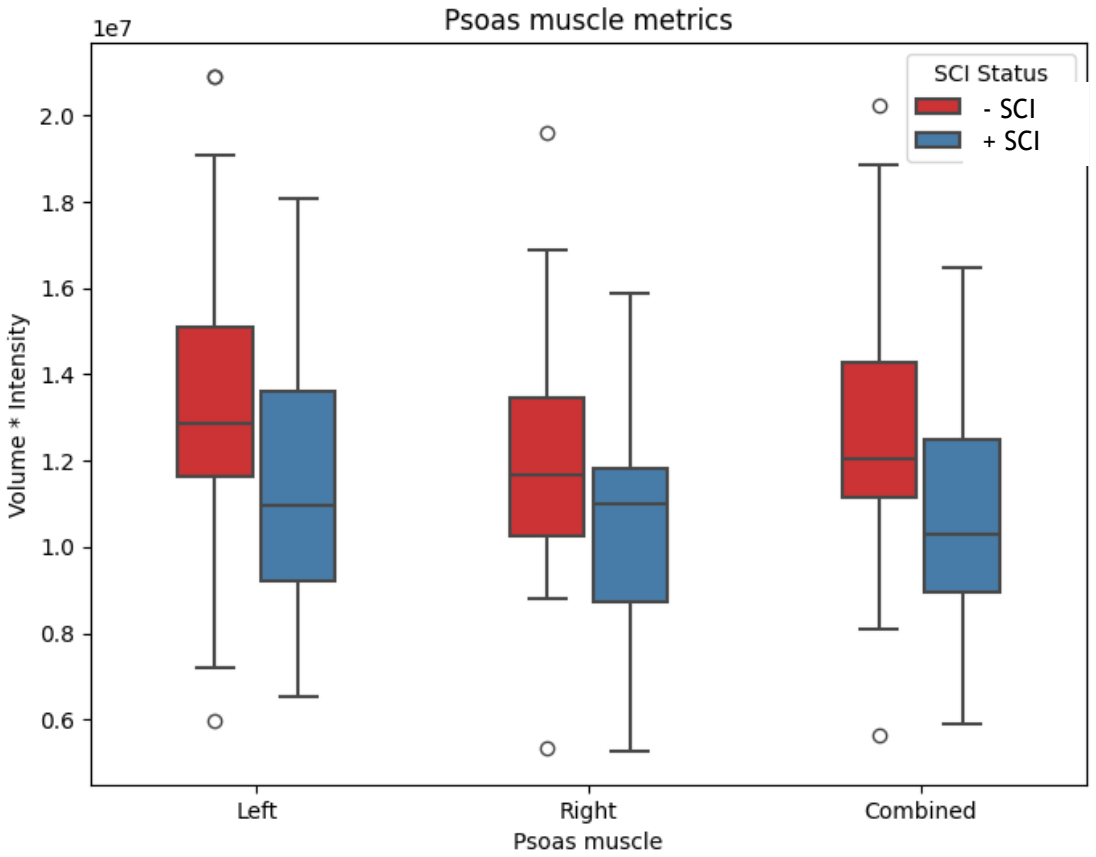
Iliopsoas volume x intensity



P<0.001


Psoas muscle metrics
1e7
3.0
2.5
2.0
1.5
1.0
0.5
Volume * Intensity
SCI Status
- SCI
+ SCI
Left
Right
Combined
Psoas muscle

Men


Psoas muscle metrics
1e7
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
Volume * Intensity
SCI Status
- SCI
+ SCI
Left
Right
Combined
Psoas muscle

Women

Conclusions regarding psoas volume

The area at level L3 and the area and total iliopsoas volume combined with the intensity is statistically different between SCI and non-SCI patients.

Next Goal:

- Combining clinical patient data with automatically imaging-derived features to predict postoperative SCI
- Enhanced clinical decision making and shared decision making with the patient
  - Balancing risks and benefits of preventive measures

Goal:

Investigate the feasibility of using machine learning approaches for the prediction of spinal cord ischemia after F/B-EVAR

Methods

Patient/clinical input parameters:

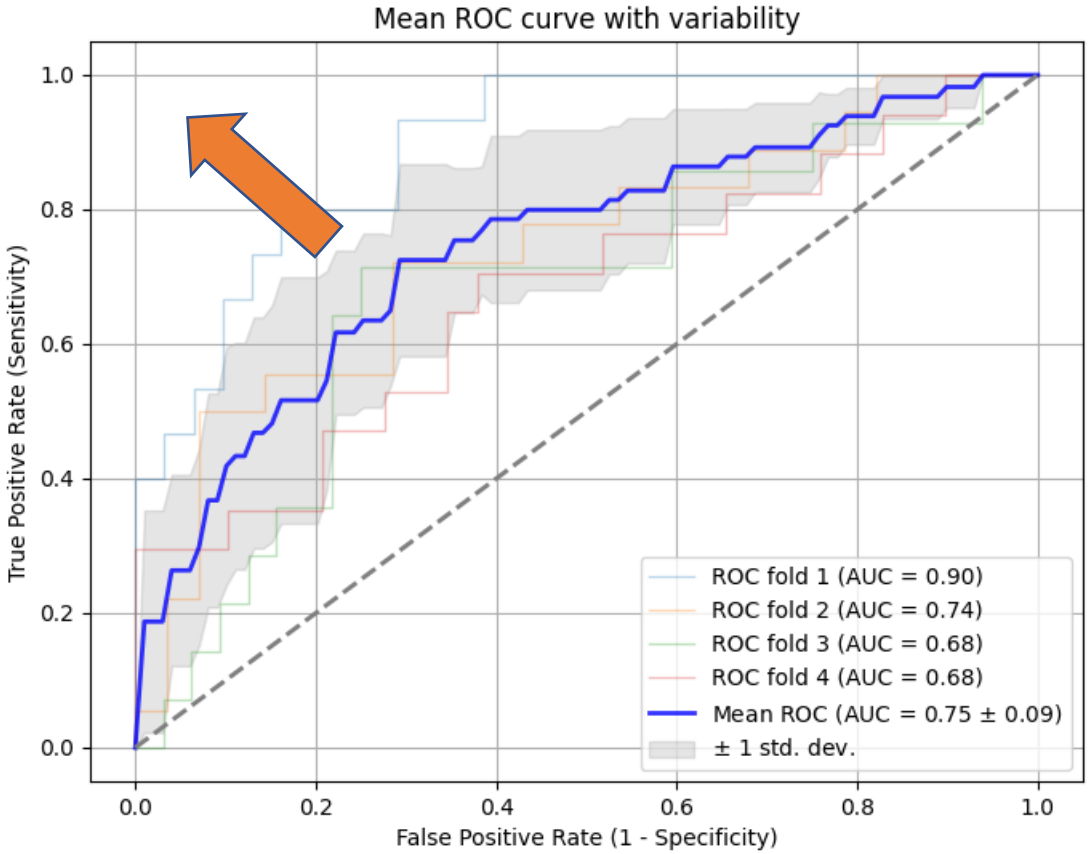
- Gender
- Age
- ASA Score
- Hypertension
- eGFR Stage

Imaging derived features:

- Maximum aneurysm diameter
- Iliopsoas Muscle Area Attenuation
- Iliopsoas Muscle Volume Attenuation

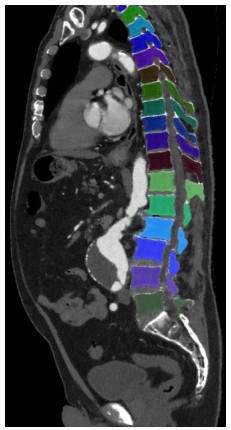
ROC of the prediction model

More data leads to better performance of classifiers



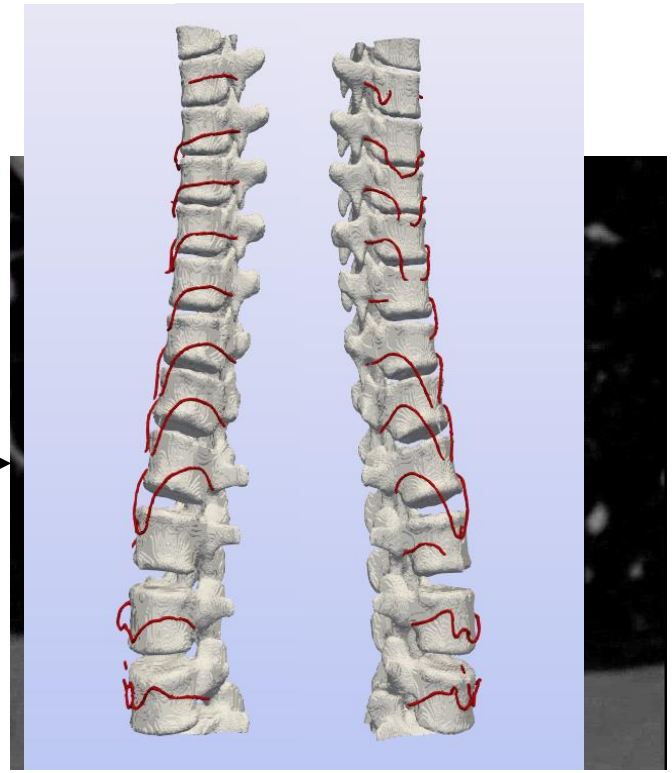
Gaussian Naives Bayes Classifier

Future studies include segmental artery detection using AI



ROI selection

Trained network (nnUNet)



Centerline tracking of segmental arteries:

- Current output serves as seedpoints for individual segmental ateries
- Scale-invariant vessel tracking system for centerline tracking (University of Twente)
- Feature extraction

Preliminary result

Precision of 94% for detection of detection of segmental arteries.

Discussion

- Preliminary results
- Cross-validation to optimize the use of limited data
- Addition of data → increase to > 300 patients from 5 different centers

Amsterdam
Hamburg
Houston
Rotterdam
Utrecht

Conclusion

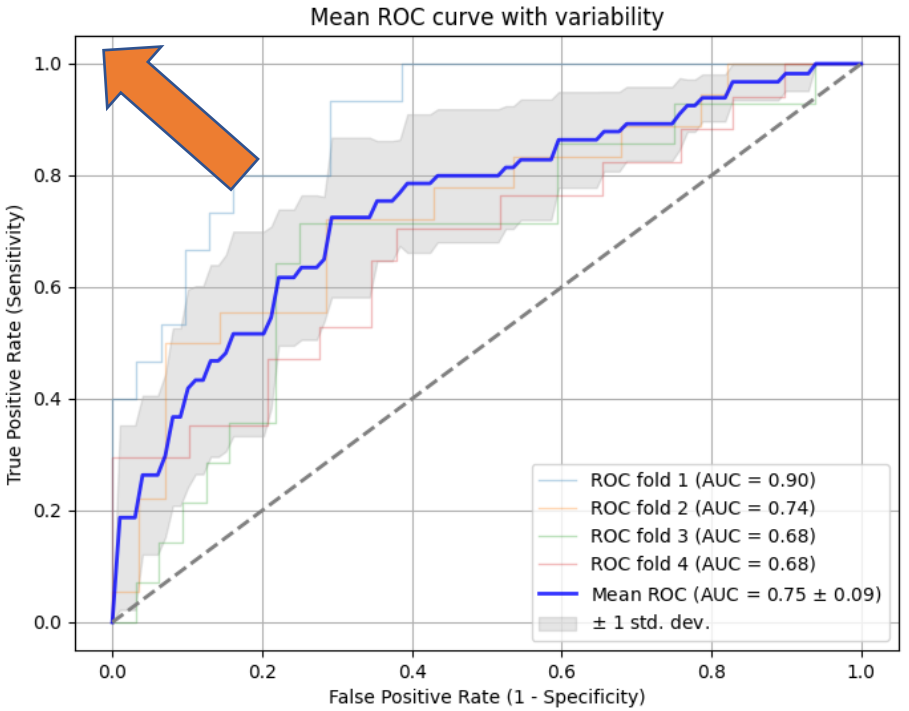
The use of machine learning based classifiers shows promising results for preoperative identification of patients at high risk of spinal cord ischemia after F/BEVAR

We are ready to include more data!
If interested please send me an email!

k.yeung@amsterdamumc.nl

- Kak Khee Yeung - Vascular surgeon, Associate professor - Amsterdam UMC
- Jelmer Wolterink - assistant professor University of Twente
- Vincent Jongkind - Vascular Surgeon - Amsterdam UMC
- Kaj Kappe - engineering physician (PhD-student)
- Investigators team / collaborations: Tilo Kölbel, Gustavo Oderich, Hence Verhagen, Joost van Herwaarden,

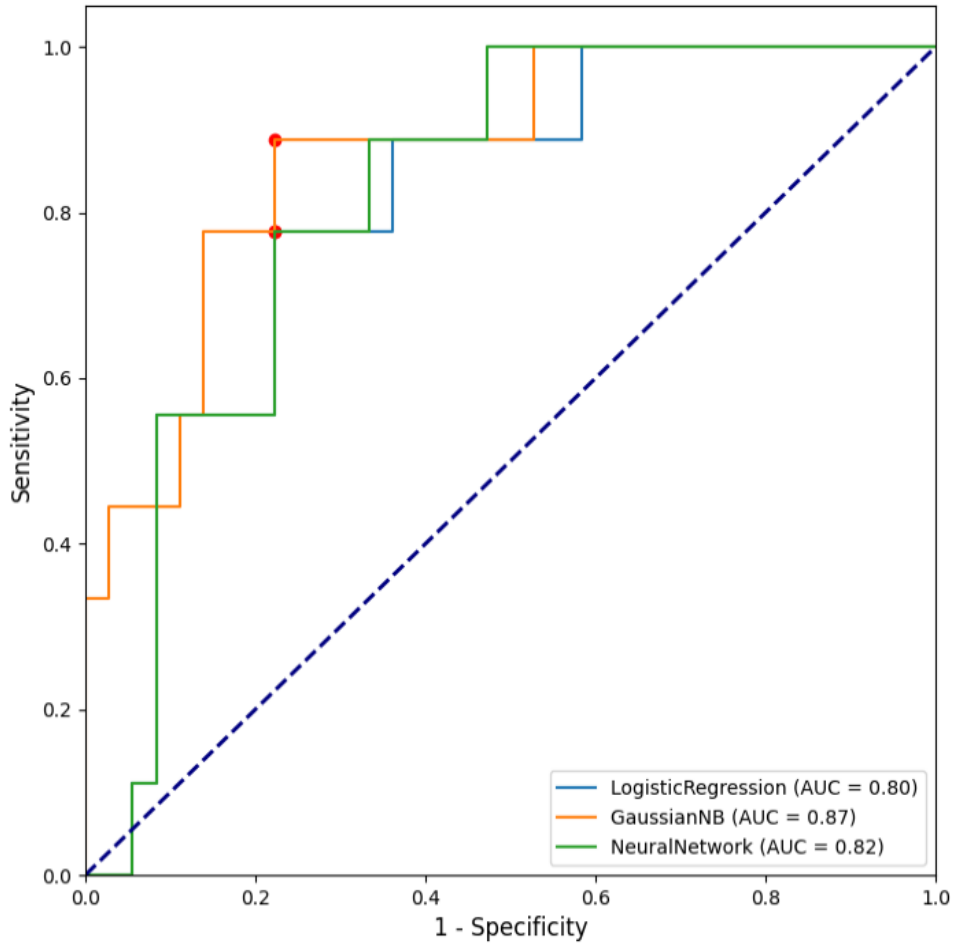


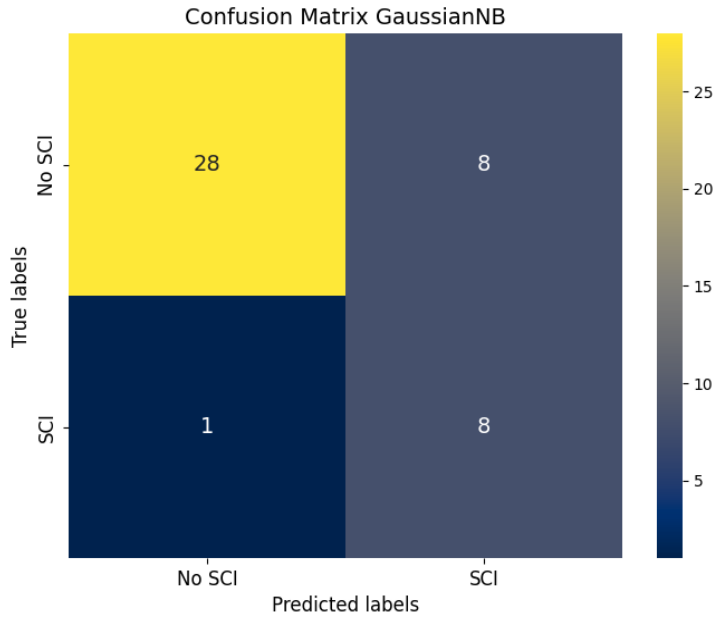



Amsterdam UMC University Medical Centers
AI VU CAMPUS CENTER
VASCULAID

24

Preliminary results





Gaussian Naive Bayes Classifiers:

Sensitivity: 0.89

Specificity: 0.78