Amsterdam UMC
Universitair Medische Centra

Progress in the prevention and treatment of spinal cord ischemia (SCI) associated with the treatment of thoracic, thoracoabdominal and complex abdominal aneurysms

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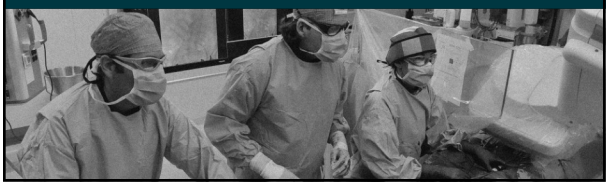
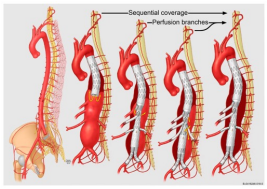


Disclosures

- Research grants:
  - **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

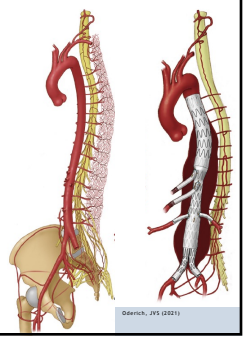


[2] Griepp EB, Di Luozzo G, Schray D, Stefanovic A, Geisbüsch S, Griepp RB. The anatomy of the spinal cord collateral circulation. Ann Cardiothorac Surg. 2012;1(3):350-7

[3] Diaz-Heto M, Tinnirello ER, Huang Y, Jakimovico T, Mendes BC, Rötzel T, et al. Comparison of single- and multistage strategies during fenestrated-branched endovascular aortic repair of thoracoabdominal aortic aneurysms. J Vasc Surg. 2023;77(5):1588-97.e4

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.

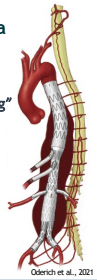


Oderich, JVS (2021)

Preoperative AI-based prediction of Spinal Cord Ischemia

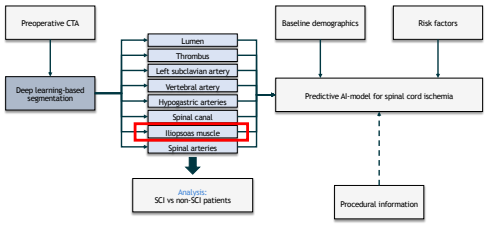
"Prediction and prevention of spinal cord ischemia after complex EVAR using artifical intelligence on pre-operative imaging"

- 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

Project overview



Update on data collection

Setting up Castor – electronic data capture system
- Harmonized data collection across centers

castor

Collection of:
- Demographics
- Medical history
- Laboratory values
- Medication use
- Surgical aortic history
- Aneurysm characteristics

Imaging bank
- Preoperative CTA
- Postoperative CTA

- Stent-graft information
- Staging details
- F/B-EVAR procedural information
- Early outcomes
- Spinal cord ischemia details

Update on data collection

Data currently available:

• Amsterdam:	162 patiënten – 10 SCI (prospective)
• Hamburg (Tilo Kölbel):	130 patiënten – 60 SCI
• Houston (Gustavo Oderich):	20 patiënten – 10 SCI
• Rotterdam (Hence Verhangen, Jorg de Bruin):	10 patiënten – 5 SCI

Expected data in near future:

• Trieste (Mario D'Oria)	Approved
• Innsbruck (Florian Enzmann)	Approved by EC, awaiting legal
• Nantes (Blandine Maurel)	Approved by EC, awaiting legal
• Leiden (Carla van Rijswijk)	Submitted to EC
• Genua (Giovanni Pratesi)	Verbal approval
• München (Nikolaos Tsilimparis)	Verbal approval
• Utrecht (Stijn Hazenberg)	Working on submission to EC

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

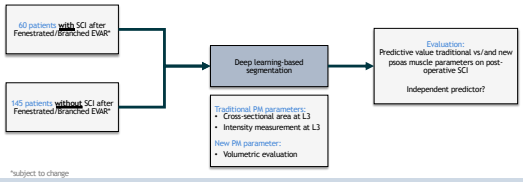
Investigating the association between sarcopenia and spinal cord ischemia after Branched and Fenestrated EVAR

- 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

Psoas Muscle as a Prognostic Factor for SCI after FEVAR and BEVAR

- Measurement based on preoperative CTA
- Primary outcome: post-operative SCI (all serverities)



*subject to change

Methods

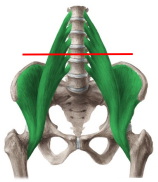
Iliopsoas muscle segmentation
- Fully automated pipeline, including:
  - Using TotalSegmentator based on nnUNet
  - Post-processing to obtain different measurements

Included patients
- 205 patients including 60 SCI patients (AUMC and UKE)

2D approach
- Area at vertebra L3
- Intensity at vertebra L3
- Area x Intensity at L3

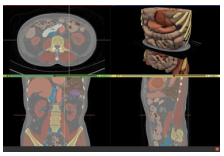
3D approach
- Total Iliopsoas muscle volume
- Intensity of the volume
- Volume x Intensity

Analysis → stratified by sex

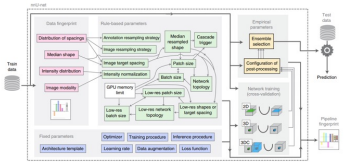


Automated Segmentation

Total Segmentator



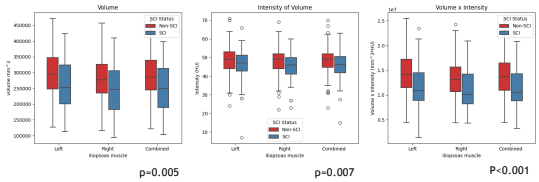
nnU-Net



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

Lower psoas volume in patients with SCI



p=0.005 p=0.007 P<0.001

Results - stratified by sex

Men

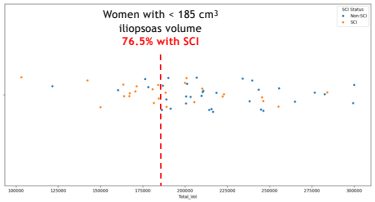
	SCI (n=35)	Non-SCI (n=112)	p-value
Area cm^2	8.2	8.3	0.776
Intensity area HU	36.2	40.0	**0.045**
Area x Intensity cm^2HU	301.6	336.7	0.146
Volume cm^3	304.3	311.1	0.541
Intensity volume HU	43.3	48.3	**0.005**
Volume x Intensity cm^3HU	13318.9	15107.1	**0.019**

Women

	SCI (n=25)	Non-SCI (n=33)	p-value
Area cm^2	4.6	5.7	**0.004**
Intensity area HU	39.2	41.8	0.275
Area x Intensity cm^2HU	183.0	238.6	**0.006**
Volume cm^3	192.1	218.7	**0.013**
Intensity volume HU	48.2	49.1	0.648
Volume x Intensity cm^3HU	9315.6	10720.6	**0.034**

Parameters for input in the SCI prediction model

Predictive value for investigated parameters?



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

Classification of SCI and non-SCI in patients after complex EVAR

Aim: Development of a classification model to predict SCI in patients after complex EVAR.

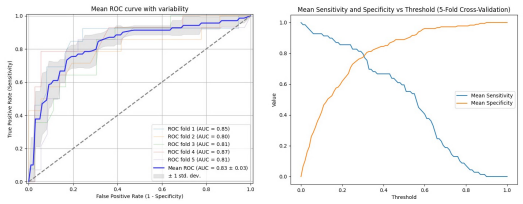
250 patients
- 181 non-SCI – 69 SCI

Training of multiple classifiers
- Input: imaging and clinical data
- Output: prediction of SCI

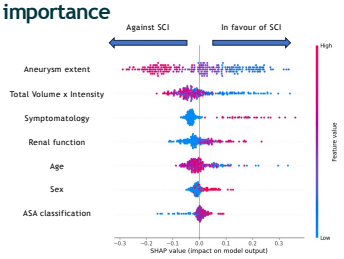
Performance evaluation using a 5-fold cross-validation
- AUC ROC-curve

Input parameters:
Age
Sex
ASA
Renal function
Symptomatology
Aneurysm extent
Iliopsoas volume x intensity

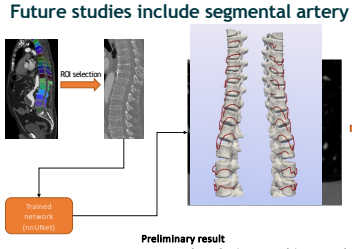
Random Forest Classifier



Feature importance



Future studies include segmental artery detection using AI



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 SCI patients from different centers

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

Thank you team

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- **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: special thanks to Tilo Kölbel**