AI-Based Segmentation to Enhance Aortic Planning for Endovascular Repair and Surveillance

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- Professor, Vascular and Endovascular Surgery
- Complex Aortic Program Co-Director

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What is AI?

We Need MORE DATA!

Natural Progression

It's Just "Simple" Math… Learned on Data

Logistic Regression

$$J(\theta) = -\frac{1}{m}\left[\sum_{i=1}^{m} y^{(i)} \log h_\theta(x^{(i)}) + (1 - y^{(i)}) \log(1 - h_\theta(x^{(i)}))\right] + \frac{\lambda}{2m}\sum_{j=1}^{n} \theta_j^2$$

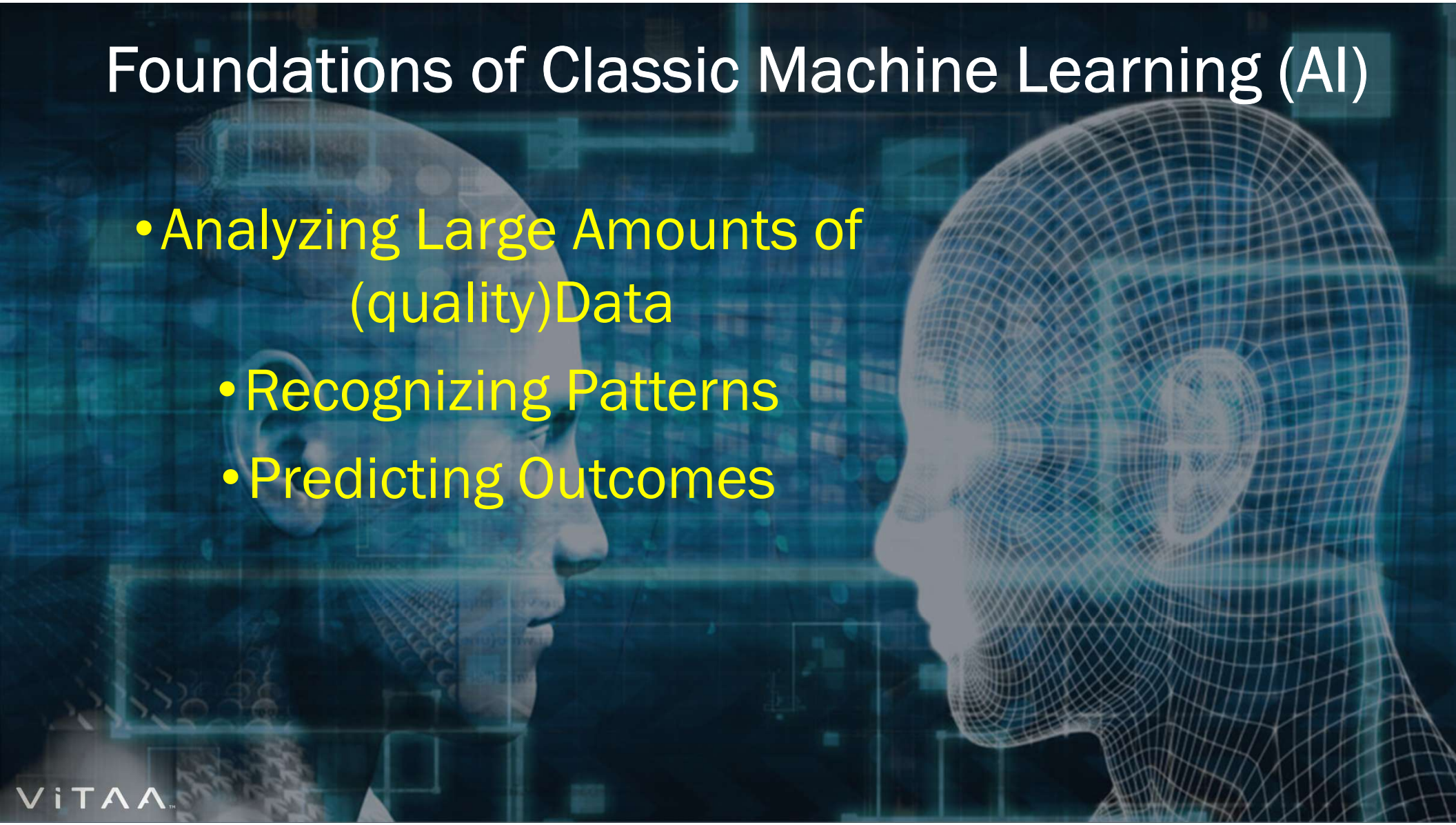
$$h_\Theta(x) \in \mathbb{R}^K \quad (h_\Theta(x))_i = i^{th} \text{ output}$$

Neural Regression

$$J(\Theta) = -\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{k=1}^{K} y_k^{(i)} \log((h_\Theta(x^{(i)}))_k + (1 - y_k^{(i)}) \log(1 - (h_\Theta(x^{(i)}))_k)\right]$$

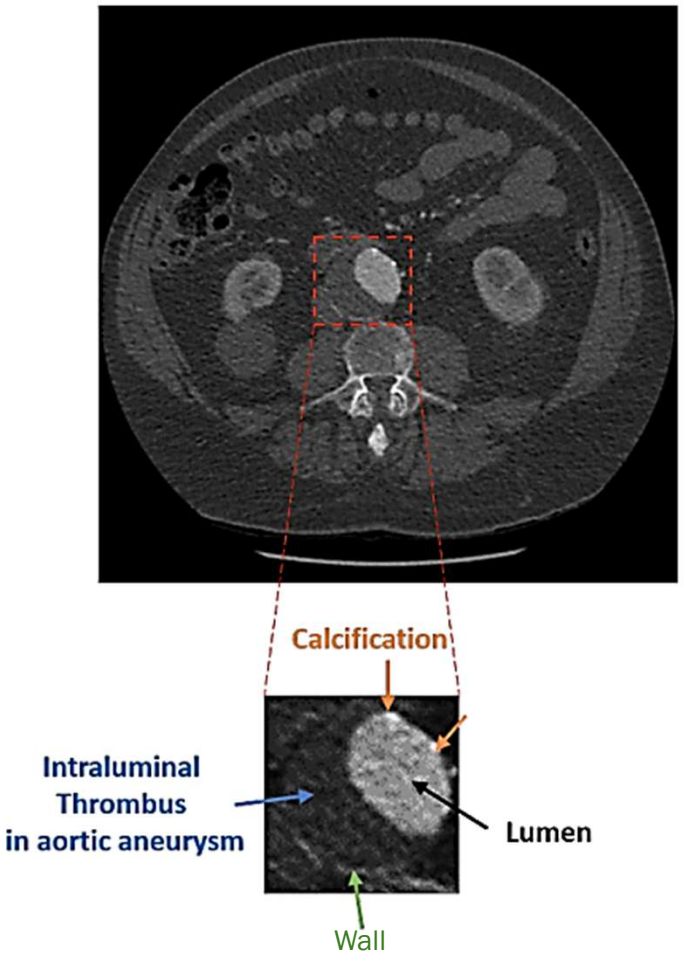
$$+\frac{\lambda}{2m}\sum_{l=1}^{L-1}\sum_{i=1}^{s_l}\sum_{j=1}^{s_{l+1}}(\Theta_{ji}^{(l)})^2$$

Foundations of Classic Machine Learning (AI)



- Analyzing Large Amounts of (quality)Data
- Recognizing Patterns
- Predicting Outcomes

ViTAA™



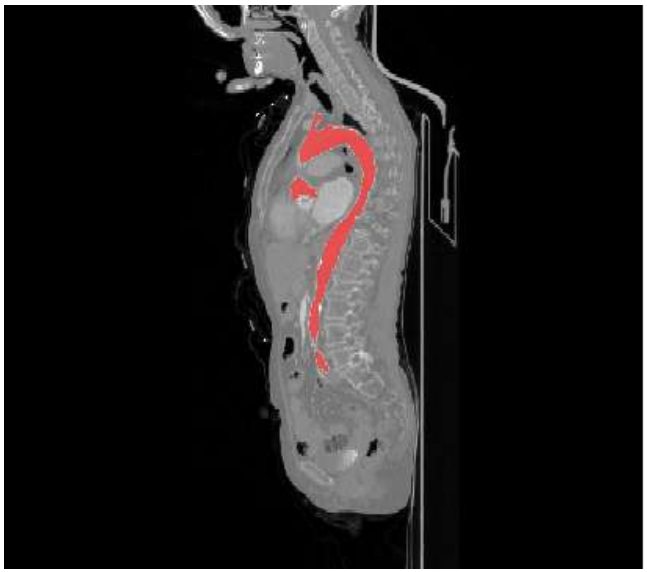
ELSEVIER

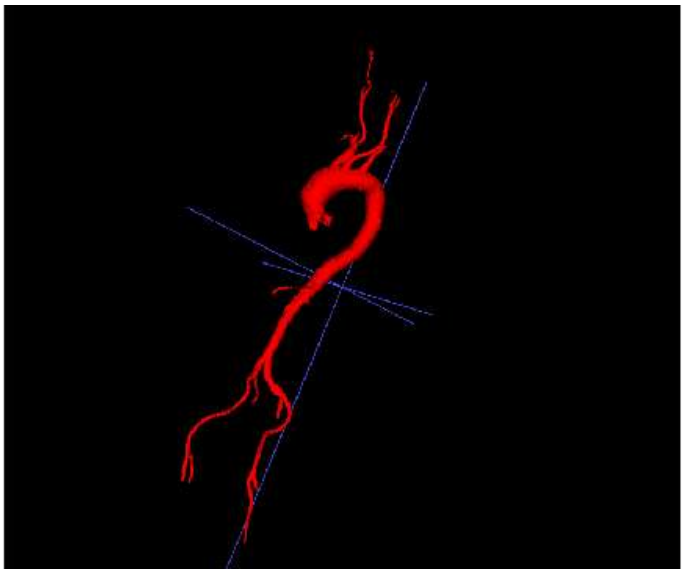
Medical Image Analysis

journal homepage: www.elsevier.com/locate/media

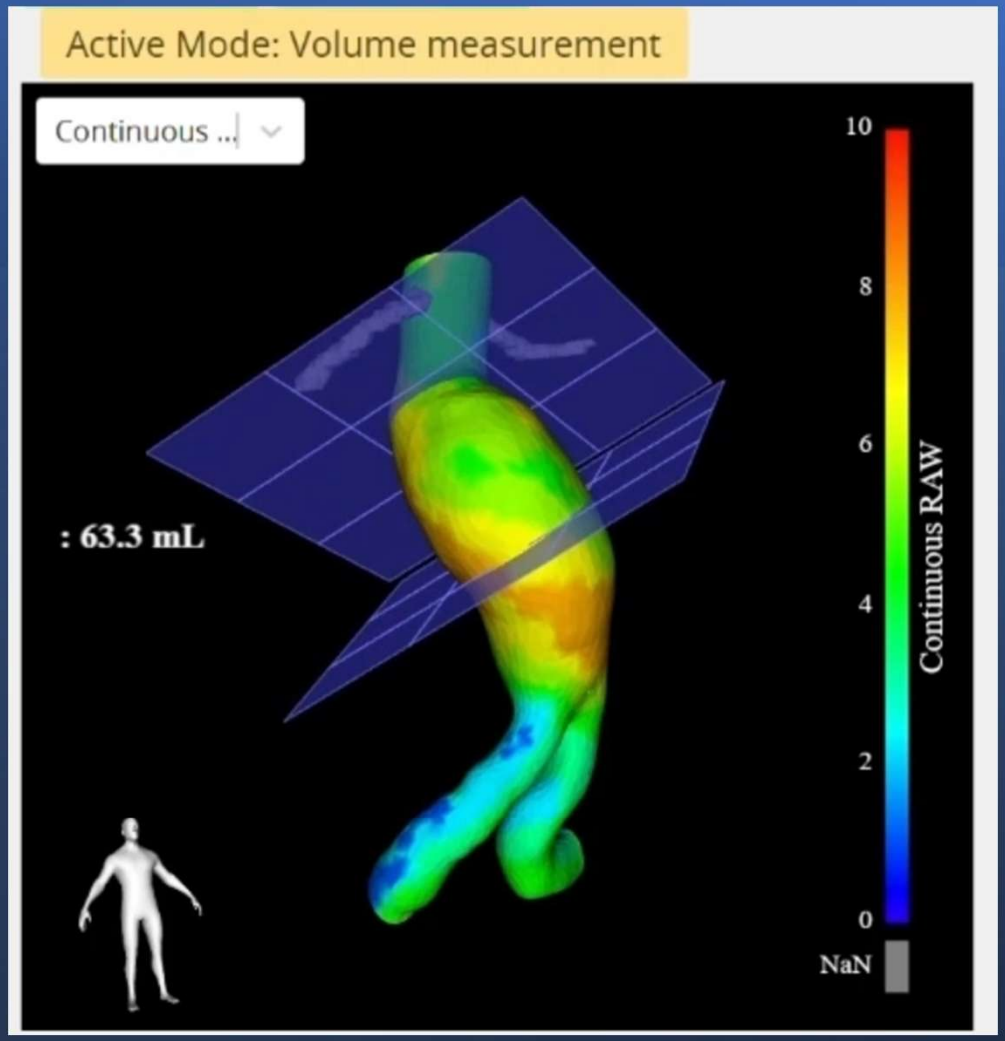
Fully automatic segmentation method to characterize abdominal aortic aneurysm tissues using Computed Tomography imaging

Atefeh Abdolmanafi[a,*], Arianna Forneris[a,b], Randy Moore[a,b], Elena Di Martino[a,b]





Front. Cardiovasc. Med., 05 January 2023 Sec. Cardiovascular Imaging, Volume 9 - 2022 | https://doi.org/10.3389/fcvm.2022.1040053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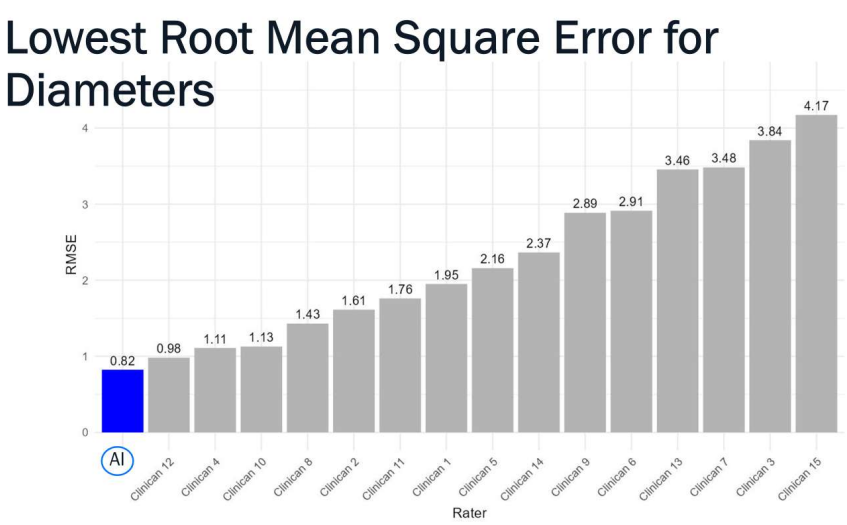
Continuous ...
: 63.3 mL
10
8
6
4
2
0
NaN
Continuous RAW

AI-based Aortic Segmentation is (more) accurate



Aorta and Major Branches

Eur J Vasc Endovasc Surg (2021) 62, 869–877

EJVES Open Access

Pre-surgical and Post-surgical Aortic Aneurysm Maximum Diameter Measurement: Full Automation by Artificial Intelligence

Chloé Adam [a], Dominique Fabre [b], Justine Mougin [b], Marc Zins [c], Arshid Azarine [c], Roberto Ardon [a], Gaspard d'Assignies [a], Stephan Haulon [b,*]

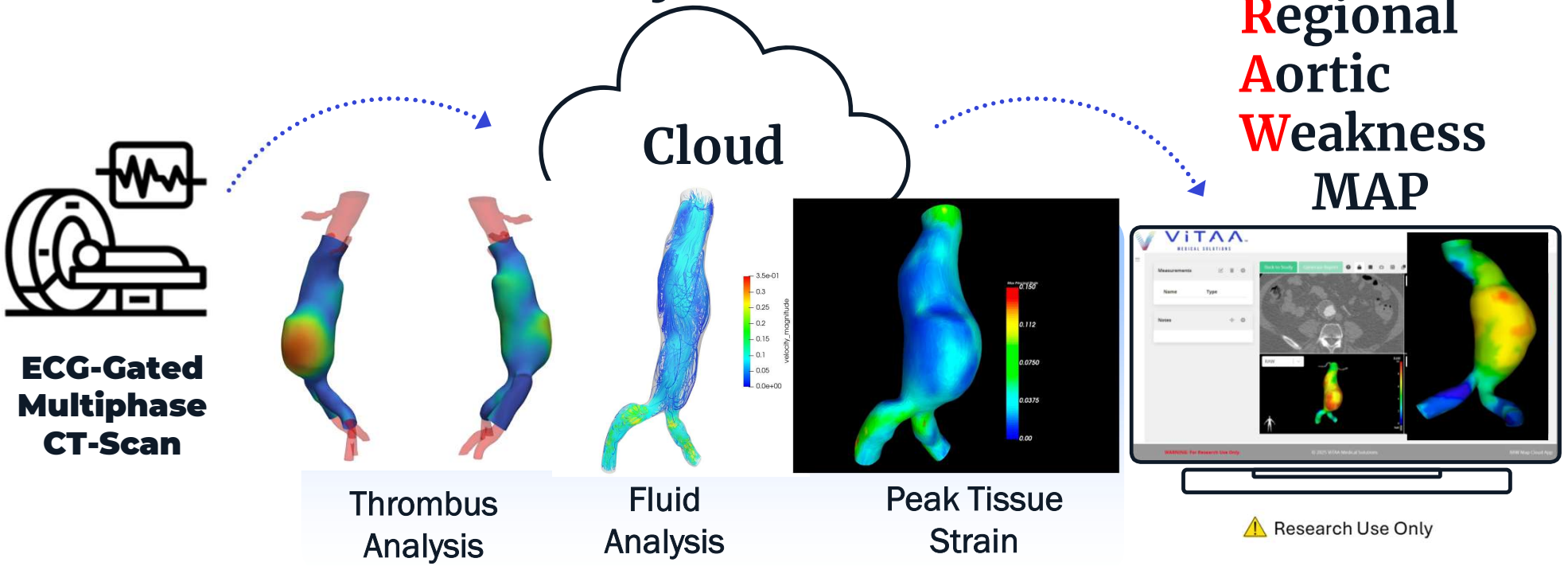
[a] Incepto Medical, Paris, France
[b] Aortic Centre, Hôpital Marie Lannelongue, Groupe Hospitalier Paris Saint Joseph, Université Paris Saclay, Paris, France
[c] Radiology Department, Groupe Hospitalier Paris Saint Joseph, Paris, France

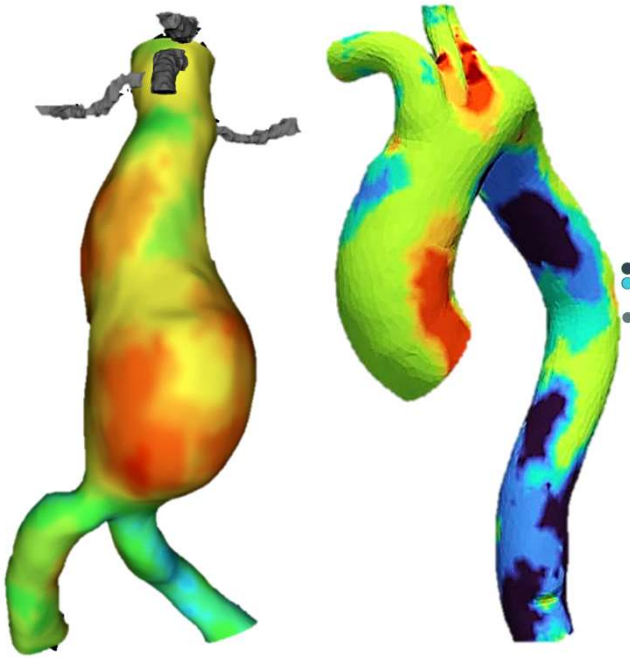
Multicentric clinical evaluation of a computed tomography-based fully automated deep neural network for aortic maximum diameter and volumetric measurements

Thomas J. Postiglione, MD,[a] Enora Guillo, MD,[b] Alexandre Heraud, MD,[b] Alexandre Rossillon, MD,[c] Michel Bartoli, MD,[c] Guillaume Herpe, MD, PhD,[d,e] Chloé Adam, PhD,[e] Dominique Fabre, MD, PhD,[a] Roberto Ardon, PhD,[e] Arshid Azarine, MD, MSc,[b] *and* Stéphan Haulon, MD, PhD,[a] *Paris, Marseille, and Poitier, France*

Adam C et al, Eur J Vasc Endovasc Surg 2021 and Postiglione TJ et al, J Vasc Surg 2024

Aortic Wall Analysis:





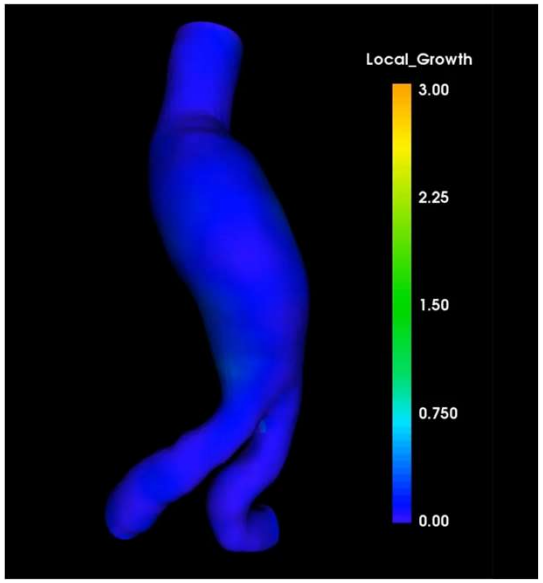
RAW Map

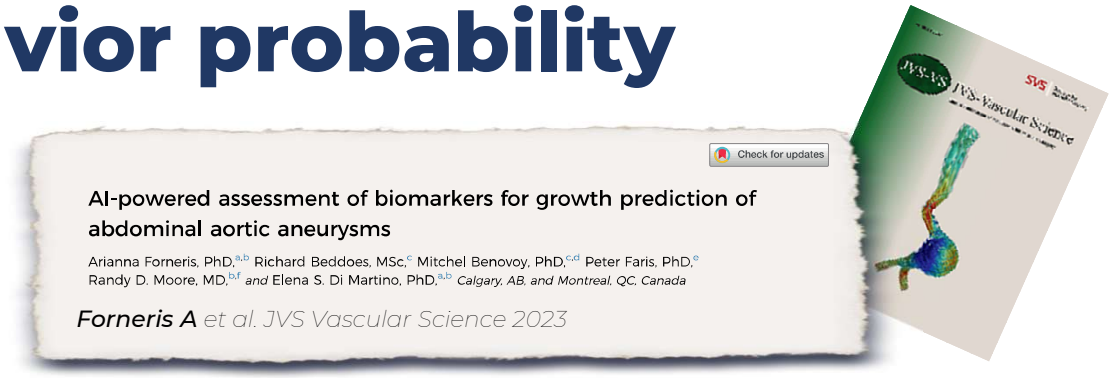
Aortic wall analysis that provides
wall tissue strength characteristics for the **individual** patient

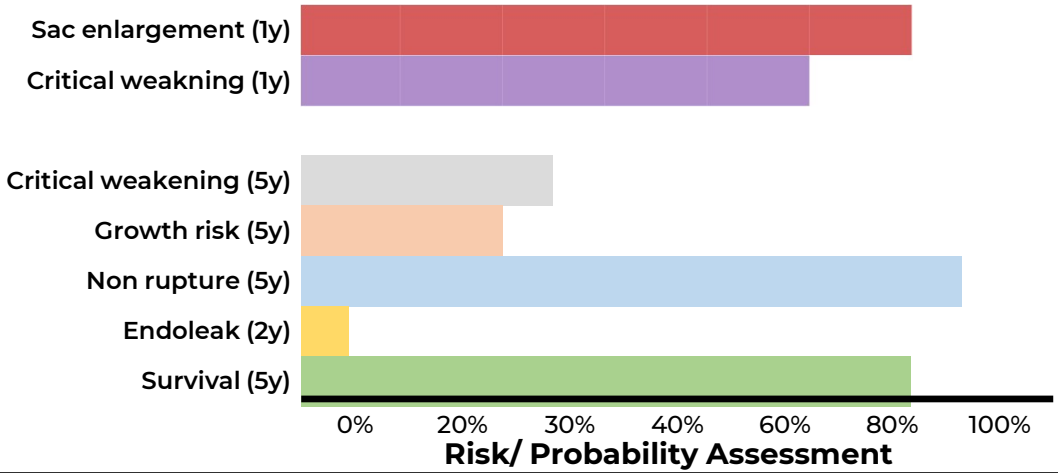
IRIS AI

Glassbox
Fully auditable
AI system

Aneurysm behavior probability







Functional and local characterization of aortic issue **(RAW score) resulted in superior prediction of growth compared to geometrical assessment**

⚠ Research Use Only

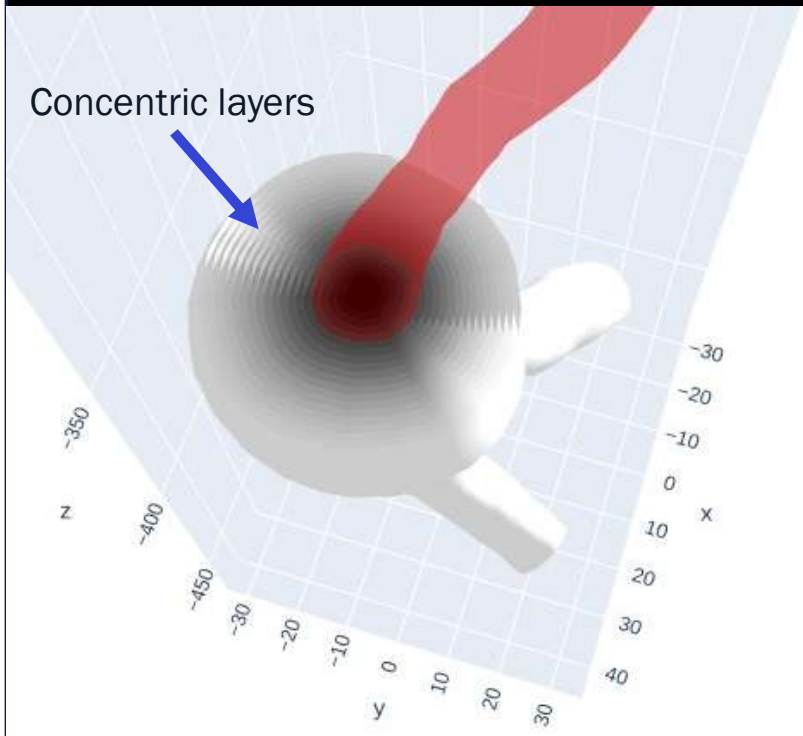
AiORTA Maps

RUPTURE PREDICTION

- Standard static scans
  - Radiomics & CFD
- N = 106
- Unique *matched "twins"* cohort
  - Equal diameter, age, sex
- Time-to-rupture range: **6-364 days**

Parametric meshing

"Onion-Ring" Layering



AiORTA Maps

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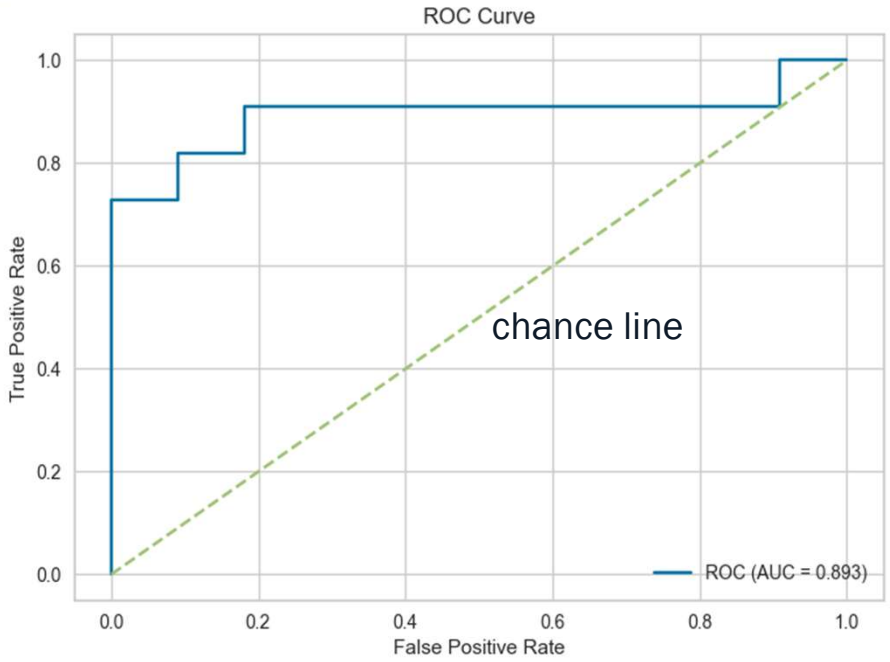
ViTAA Iris

AUC	89.3%
Accuracy	87.0%
Sensitivity	91.0%
Specificity	83.5%



AiORTA Maps

RUPTURE PREDICTION

AI

91% Rupture
Probability at Baseline

Ruptured 20 Days Later

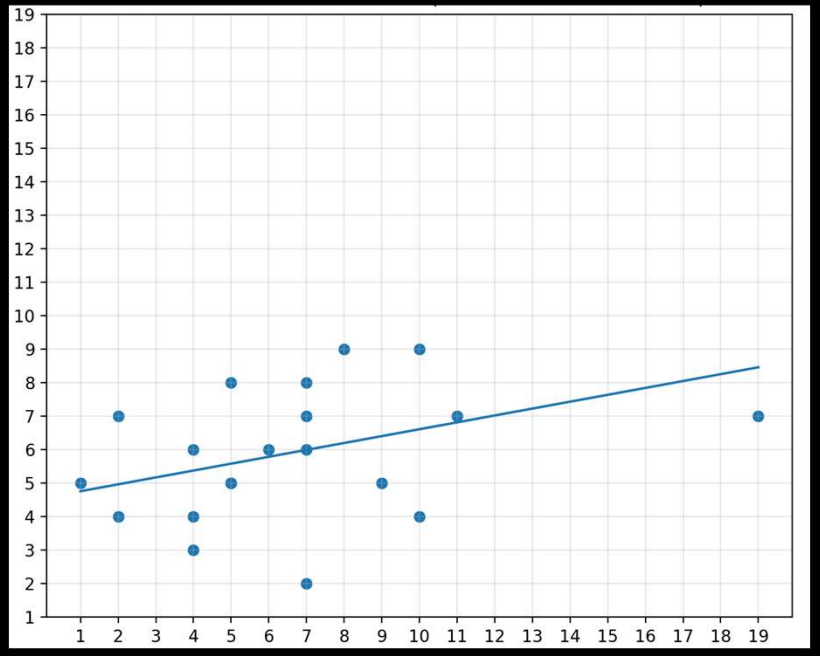
AiORTA Maps

RUPTURE PREDICTION

- Can we predict when they will rupture?
- Time-to-rupture range: 6-364 days
  - Binned in 20 days periods

ViTAA Iris

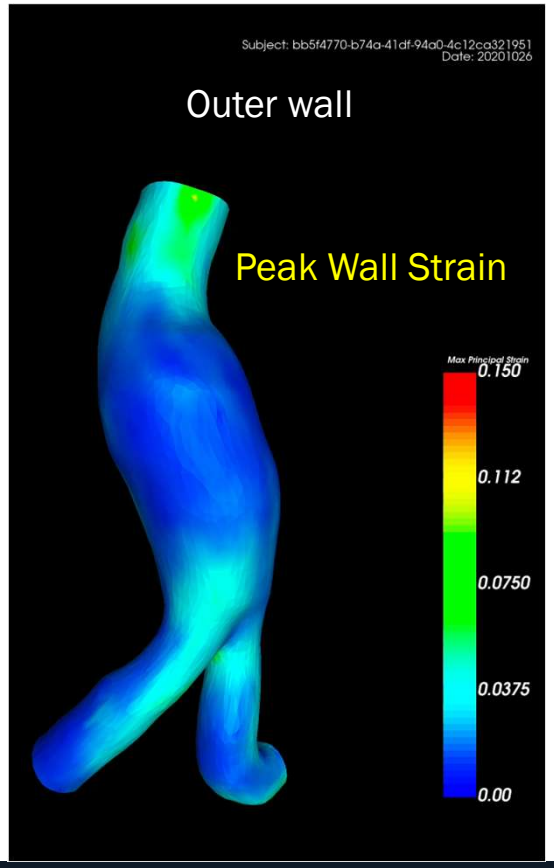
AUC	89.3%
Accuracy	87.0%
Sensitivity	91.0%
Specificity	83.5%

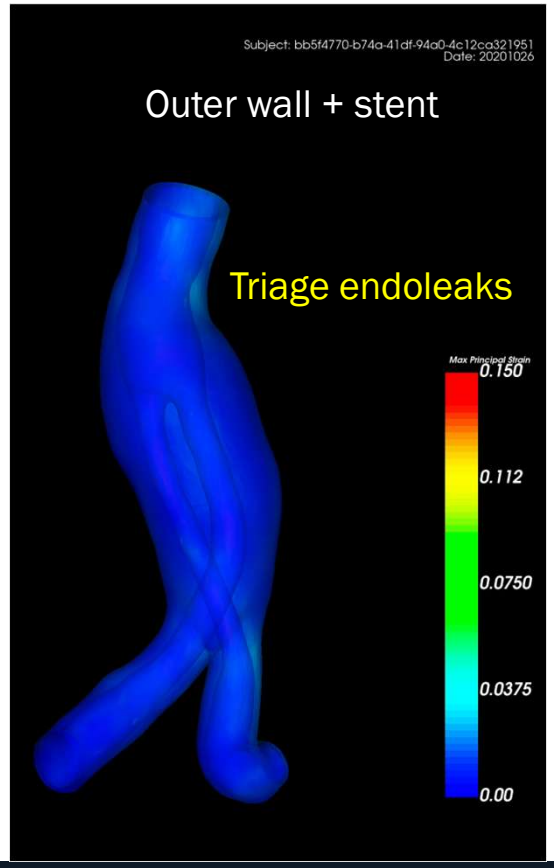


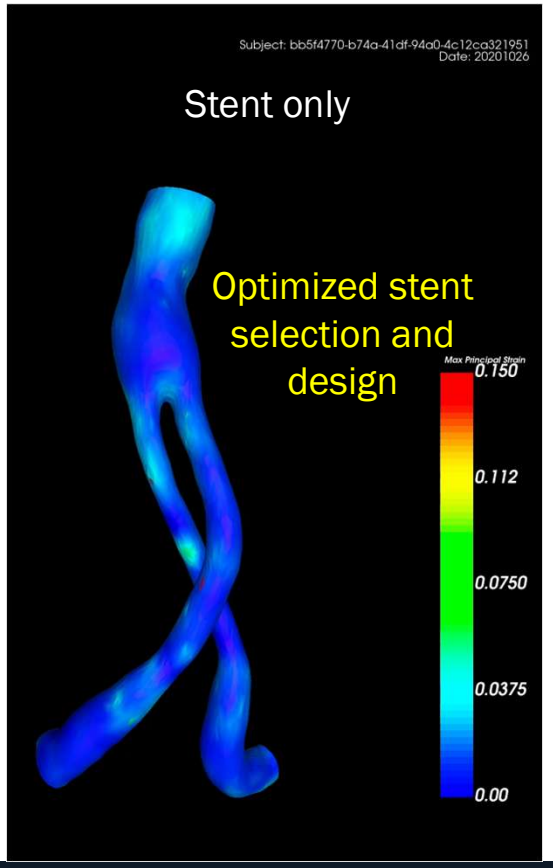
20 days bins

AiORTA Watch

POST-OP SURVEILLANCE







Allows for complete (AI)ortic analysis:

The Future of Artificial Intelligence

Number of Search Parameters?

Traditional Search Models

10s

Classic AI Models

1,000s

Generative AI Models

1,000,000,000s

Generative (pre-trained) Transformers

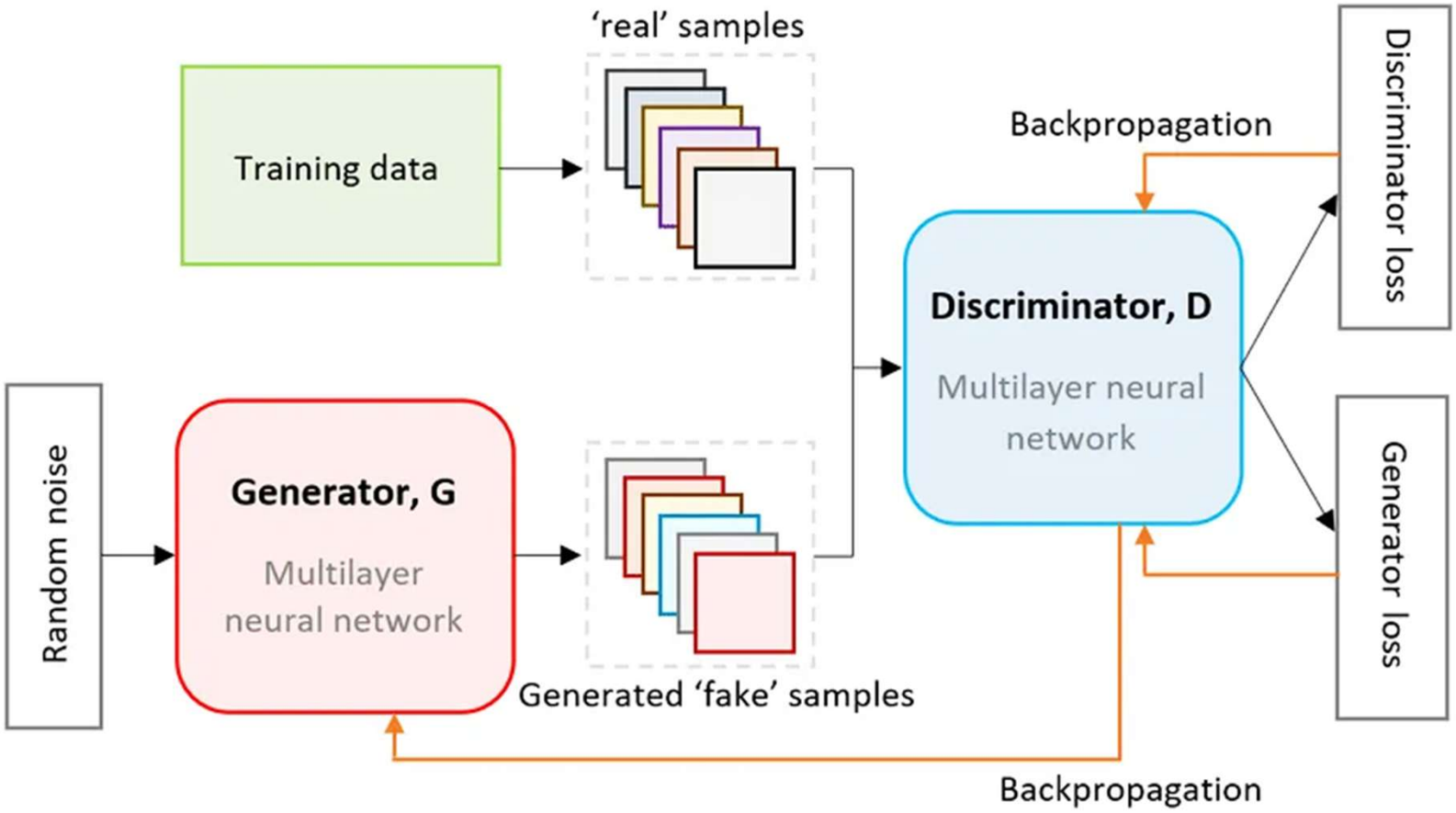
Diffusion models

Generative AI TECHNOLOGY

Umbrella term that encompasses any AI system designed to create new content:

e.g. These people do not exist

Generative Adversarial Network (GAN)



The “synthetic” patient (aorta)

Human aortic characteristics without actually including any back traceable real-patient data.

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AI TECHNOLOGY

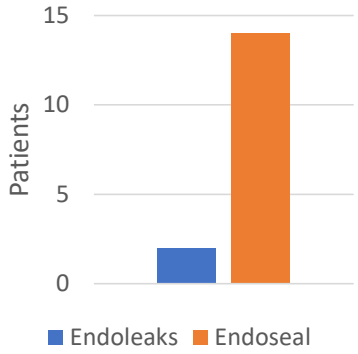
The artificial aorta

Use Case: We need more endoleaks

Original database

16 post-EVAR patients

- 2 Type-I endoleaks
- 14 with Endoseal
- **Mean 2-year follow-up**



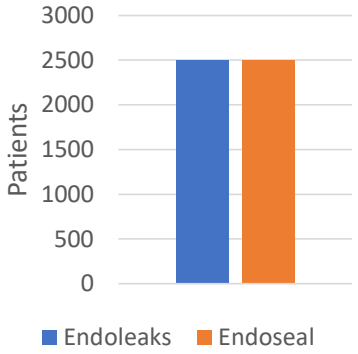
- Hugely imbalanced
- Diminutive target class size

Impossible to train AI

Synthetic database

5000 post-EVAR patients

- 2500 Type-I endoleaks
- 2500 with Endoseal
- **6 mins** to synthesize (laptop)



- Perfect class balance
- Large cohort size

Ideal to train AI

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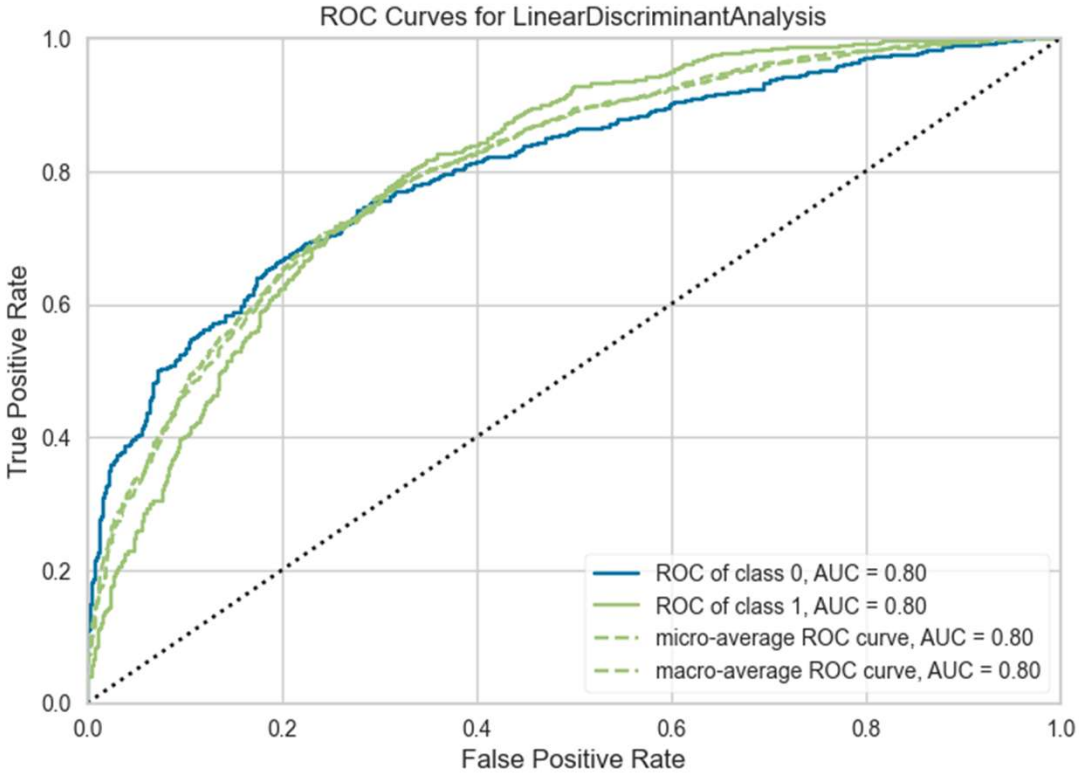
AI TECHNOLOGY

The artificial aorta

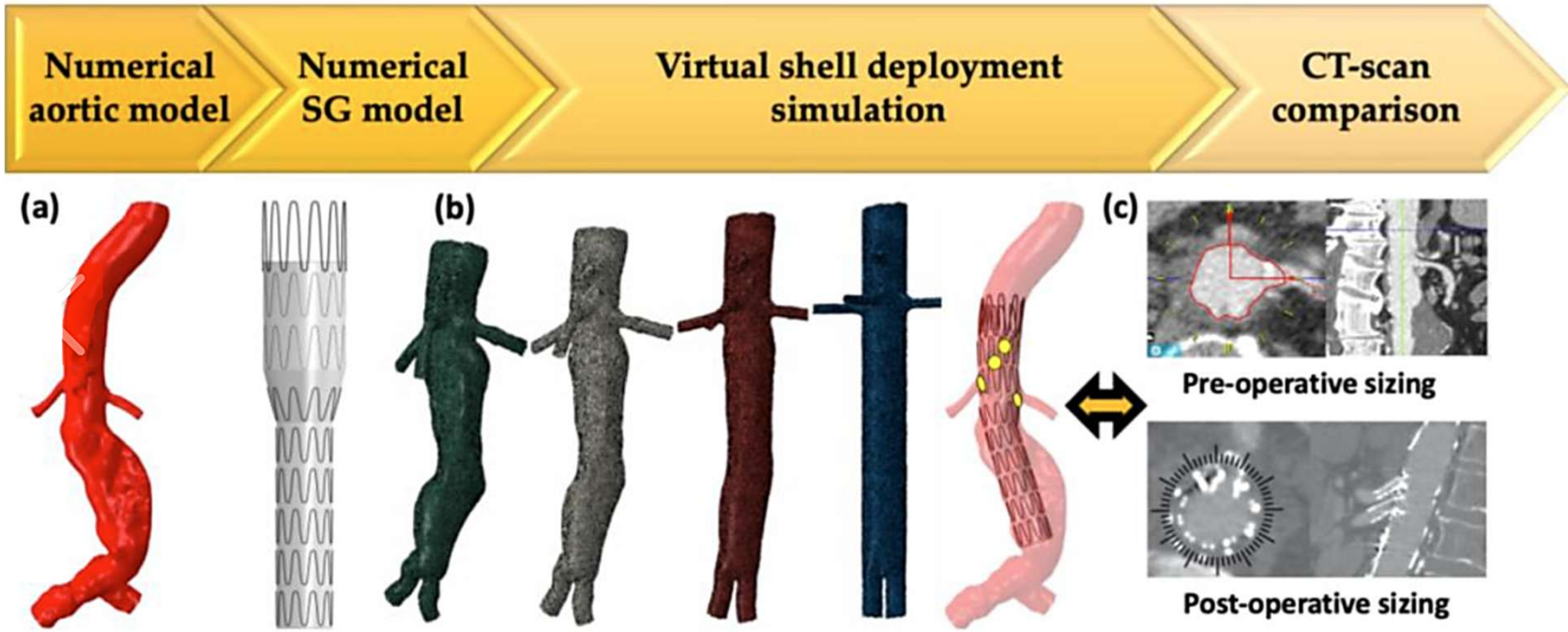
Use Case: We ~~need~~ have more endoleaks



Type-I Endoleak Prediction

Mean AUC = 0.80

Digital twin technology: Virtual Repair



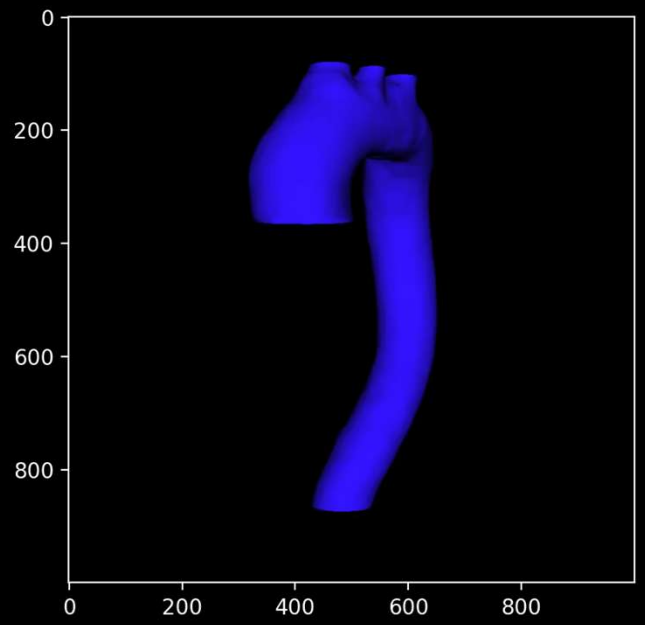
Open Access Review

Patient-Specific Numerical Simulations of Endovascular Procedures in Complex Aortic Pathologies: Review and Clinical Perspectives

by Lucie Derycke [1,2], Stephane Avril [2] and Antoine Millon [3,*]

J. Clin. Med. **2023**, *12*(3), 766; https://doi.org/10.3390/jcm12030766

Summary:



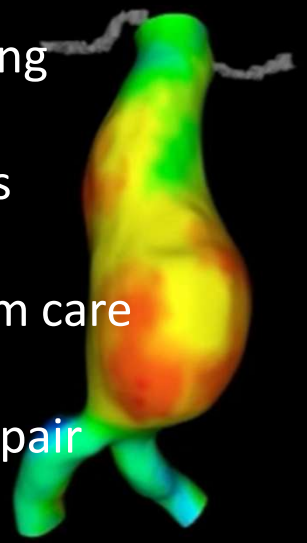
AI-Based Segmentation Critical:

Increased accuracy of planning

Patient-Specific Wall Analysis

Outcome Prediction to inform care

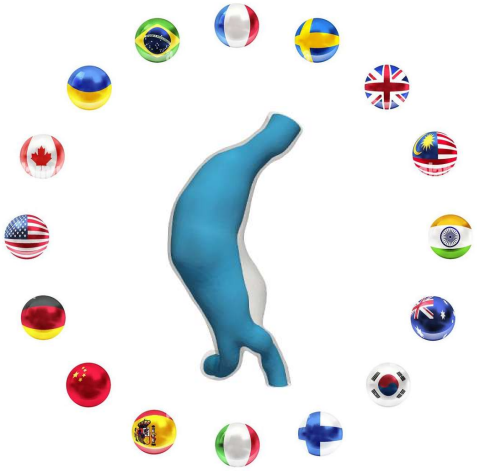
Synthetic datasets/Virtual repair



Thank you

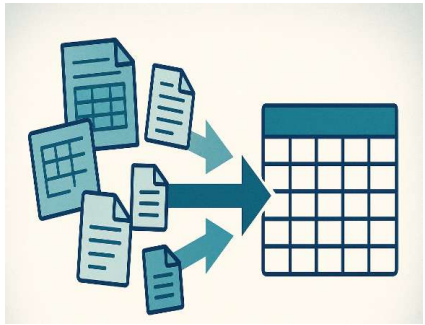
CLINICAL AI APPLICATIONS

How do we craft real-world **clinical** AI?



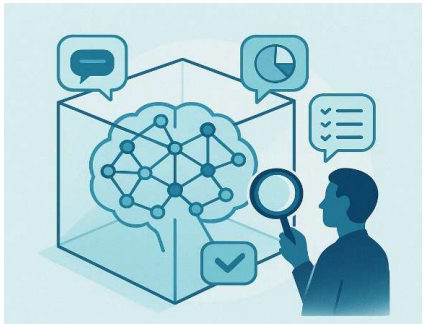
Data sourcing

- Multi-centric, wide spectrum demographics
- Acquired under real-world conditions



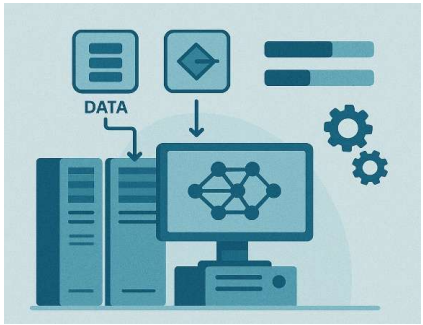
Data standardization

Glassbox AI



Deep phenotyping

Human understanding
of the pathophysiology



Model design
+ Training
+ Validation