AI in Neuroradiology
Stroke Imaging

Dennis M. Hedderich

06 February 2023

No conflicts of interest

Outline

Patient case

Imaging in stroke

AI-based solutions in stroke imaging

Future directions

Source: streamlineicons.com

Case

79 year-old male presenting with sudden onset left-sided hemiplegia and dysarthria 2 hours prior to admission.

What‘s the diagnosis?

Stroke

- 2nd most common cause of death in Germany and worldwide
- 270,000 strokes per year in Germany
- **High mortality:** 25-33% die in first year after stroke
- **High morbidity:** 40% survivors with neurologic disability
- 85% ischemia; 15% hemorrhage
- 1.9 million neurons die per minute

➔Time is brain!

Stroke treatment

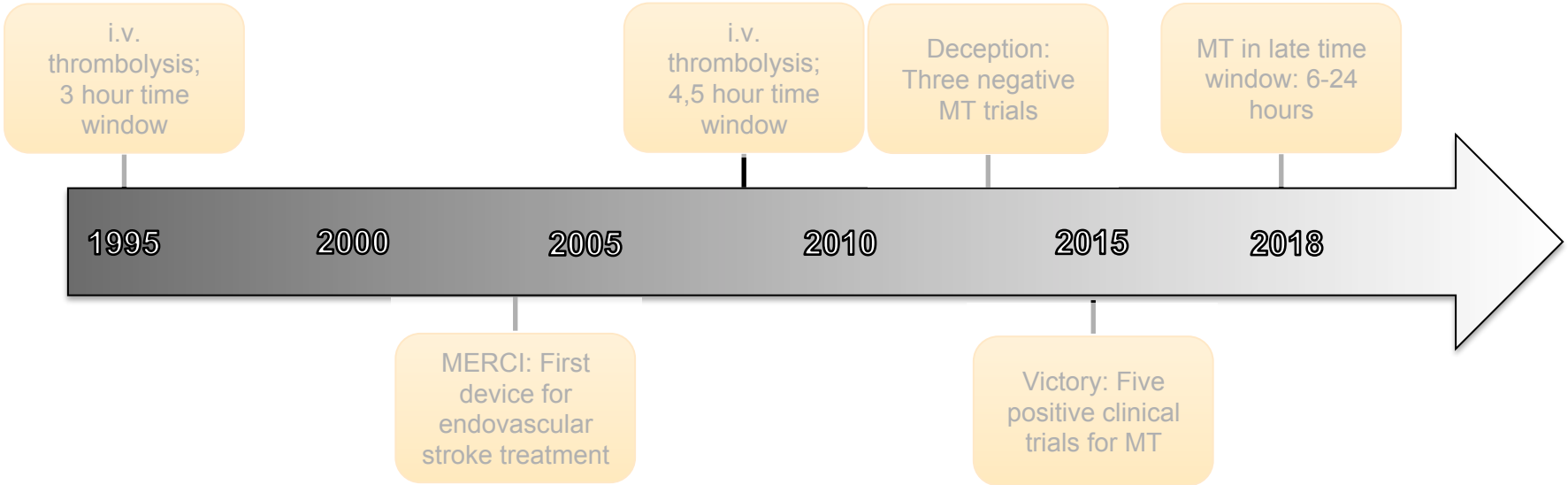
Best Medical Treatment

i.v. Thrombolysis

Mechanical Thrombectomy

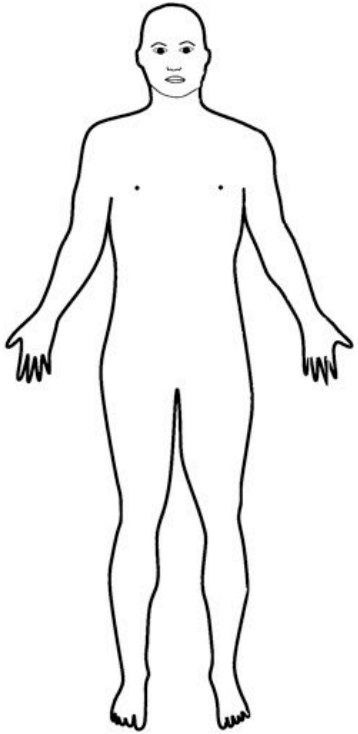
Only for ischemic stroke!

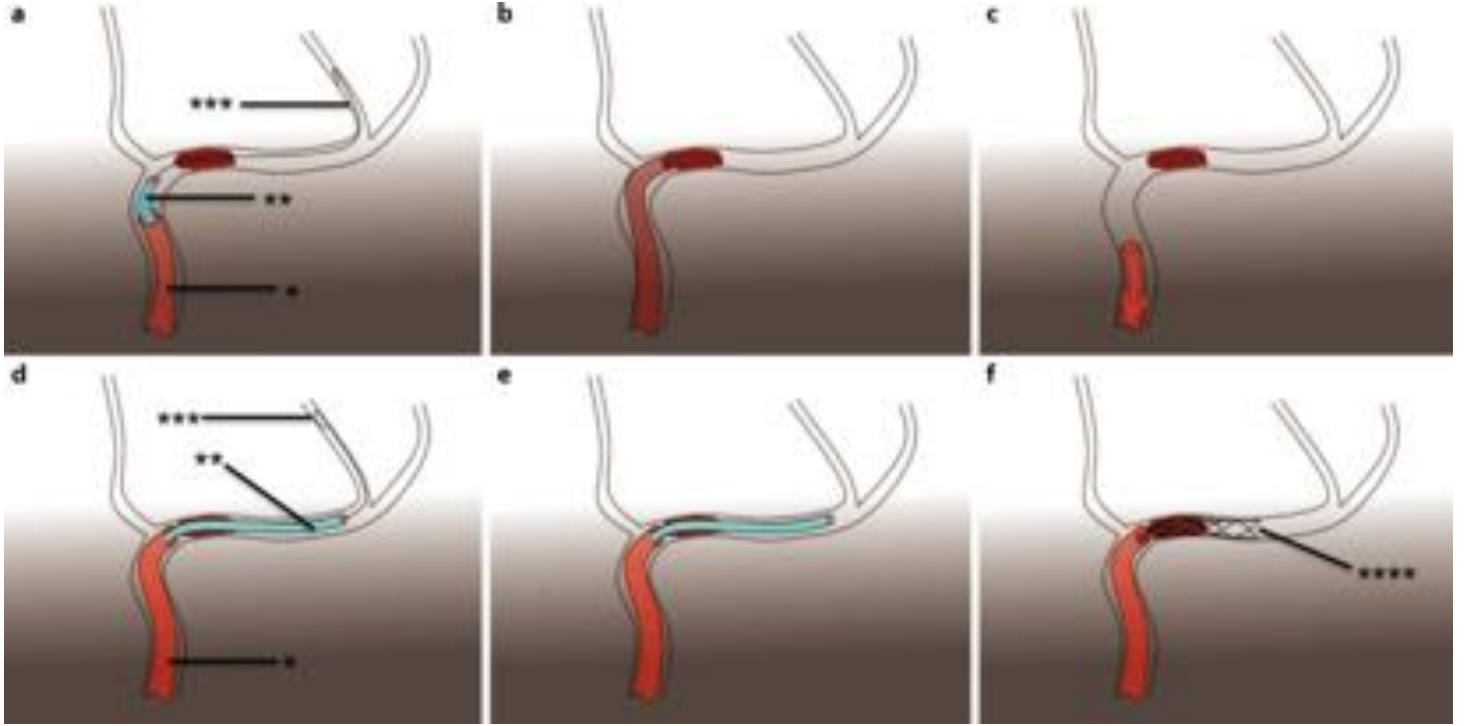
A brief history of stroke treatment



MT = Mechanical Thrombectomy

State of the art mechanical thrombectomy





Courtesy: Dr. Christian Maegerlein; wikipedia.org

Outline

Patient case

Imaging in stroke

AI-based solutions in stroke imaging

Future directions

Source: streamlineicons.com

Imaging guides stroke treatment decisions

Which modality?

CT

MRI

DSA

Source: Philips Healthcare, Siemens Healthineers

1st Imaging Decision:
Rule out hemorrhage

➔ **Intravenous Thrombolysis**

Ischemic vs. hemorrhagic stroke

2nd Imaging Decision:
Find large vessel occlusion

Right internal carotid artery

Right common carotid artery

Brachiocephalic trunk

Left middle cerebral artery

Left common carotid artery

Aorta

➔ Mechanical thrombectomy

3rd Imaging Decision:
Patient selection (late time window)

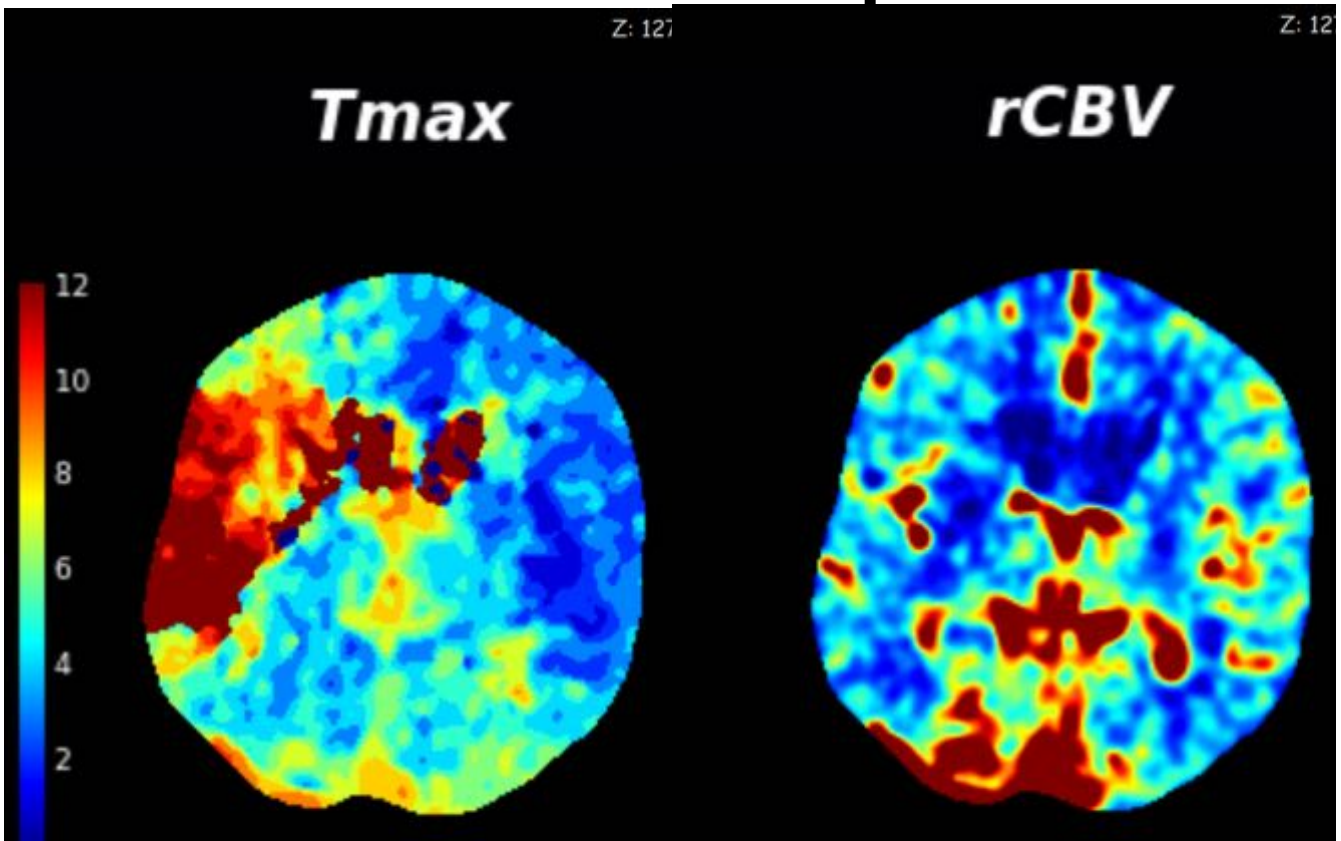
i.v. contrast administration

+

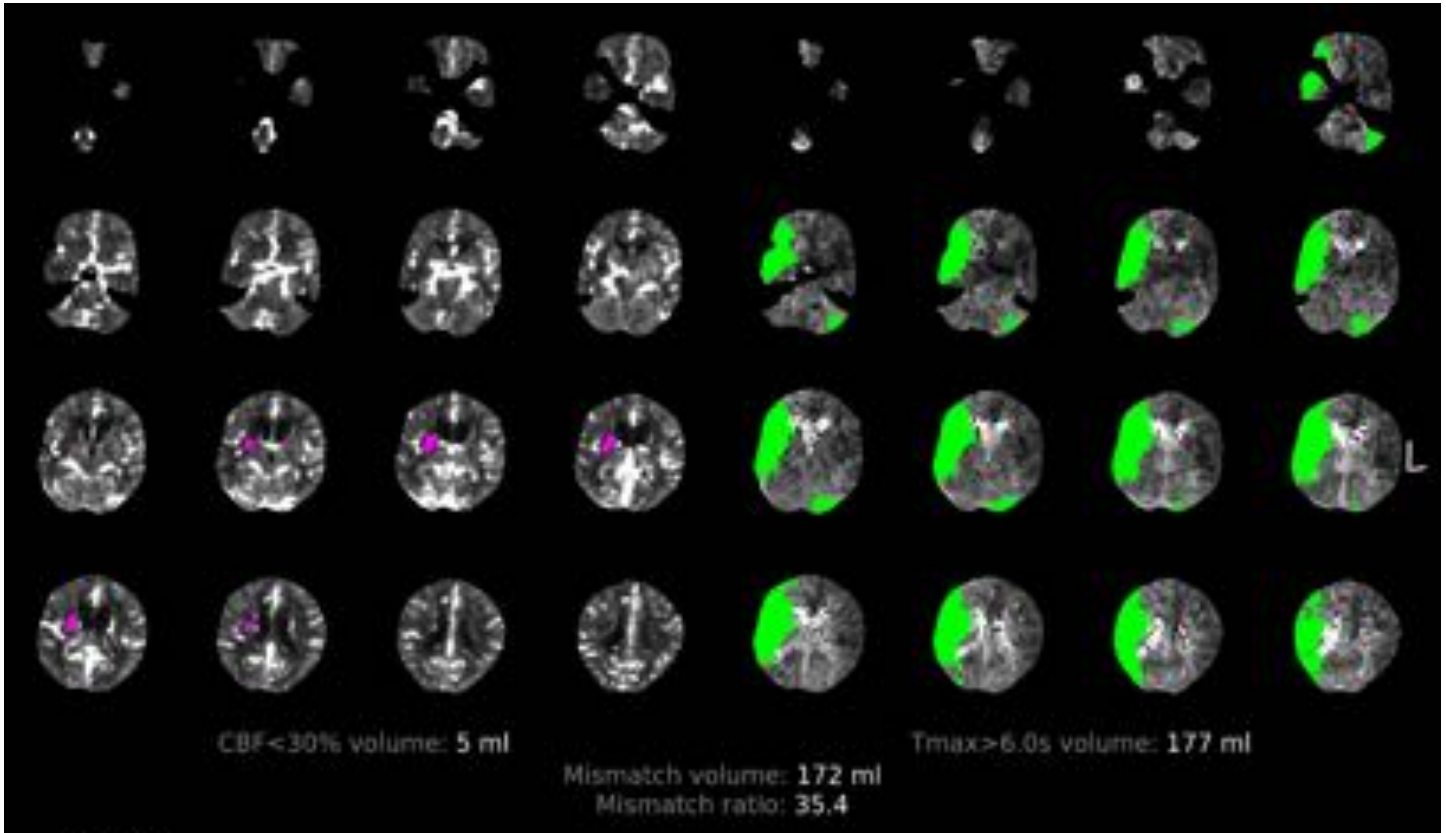
repeated CT scans

Tissue at risk? ➔ Mechanical thrombectomy

Perfusion maps

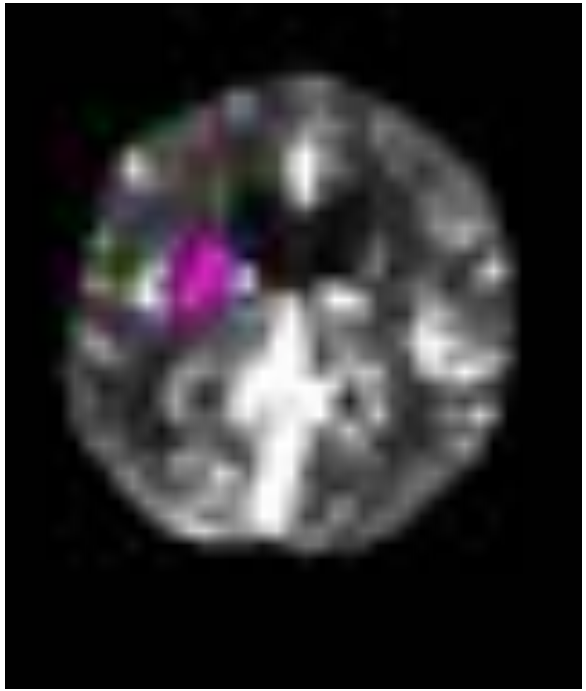


Perfusion summary



Perfusion summary

Infarct core



Penumbra

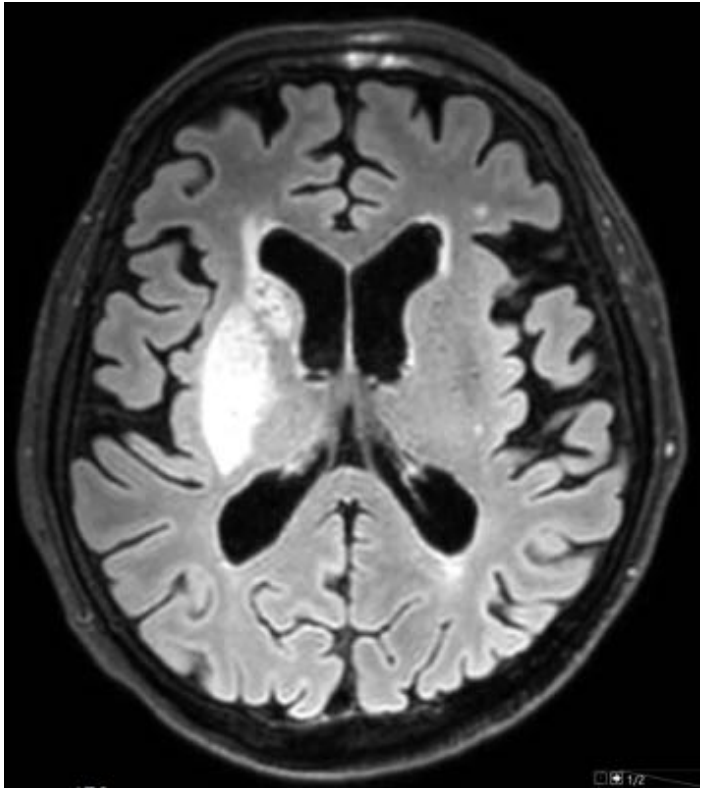
Mechanical thrombectomy

Before

After

Mechanical thrombectomy

Follow-up MRI



Outline

Patient case

Imaging in stroke

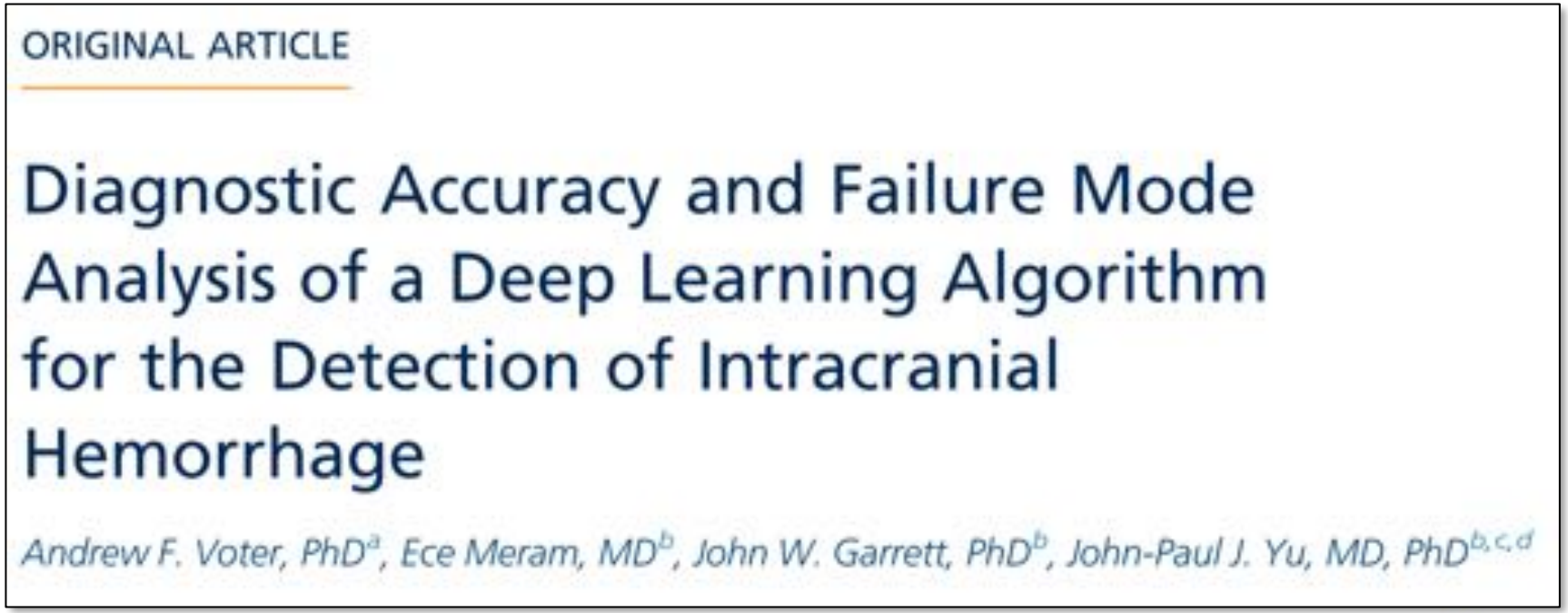
AI-based solutions in stroke imaging

Future directions

Source: streamlineicons.com

1st Imaging Decision:
Rule out hemorrhage

Detection of intracranial hemorrhage



ORIGINAL ARTICLE

Diagnostic Accuracy and Failure Mode Analysis of a Deep Learning Algorithm for the Detection of Intracranial Hemorrhage

Andrew F. Voter, PhD[a], Ece Meram, MD[b], John W. Garrett, PhD[b], John-Paul J. Yu, MD, PhD[b,c,d]

Quelle: Voter et al. J Am Coll Radiol 2021

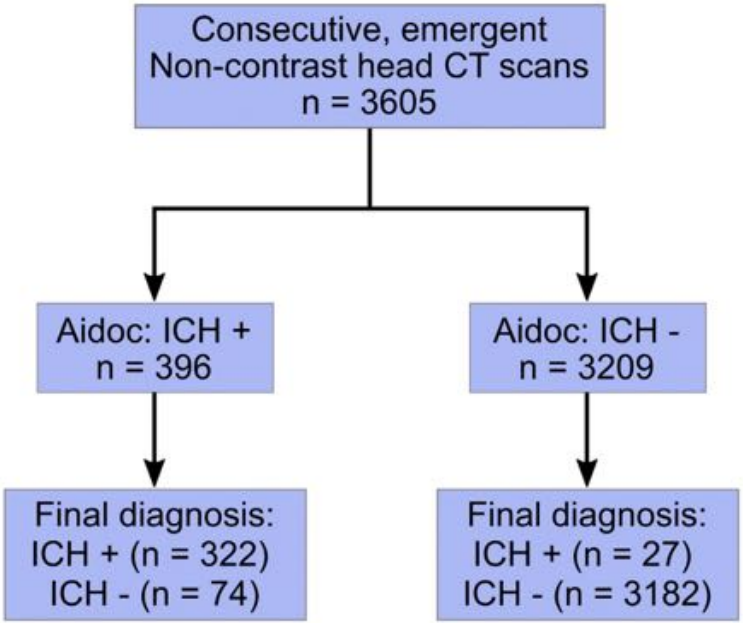
Detection of intracranial hemorrhage

Data	• Retrospective, concsecutive single center cohort • n = 3605; ICH+: 349 / ICH -: 3256 • Nonenhanced cranial CT, 7 scanners
Reference-standard	• 1 + 1 Neuroradiologists • Consensus reading in case of deviation
Technique	• Aidoc • „FDA-cleared neural network algorithm“

aidoc

Quelle: Voter et al. 2021; www.aitrends.com

Detection of intracranial hemorrhage

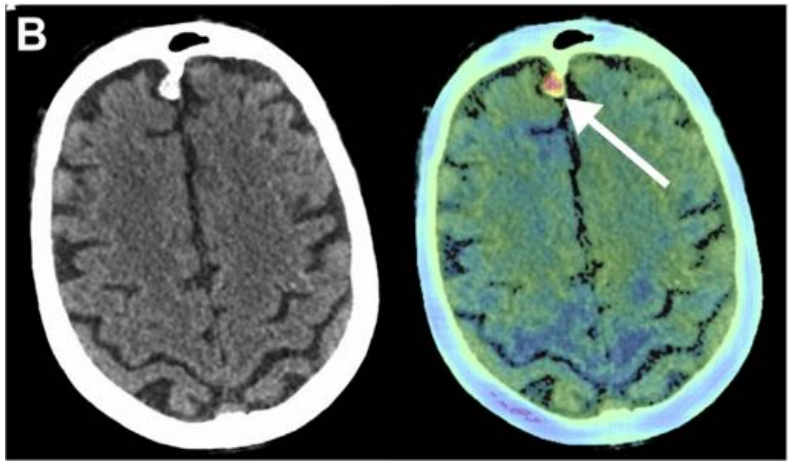


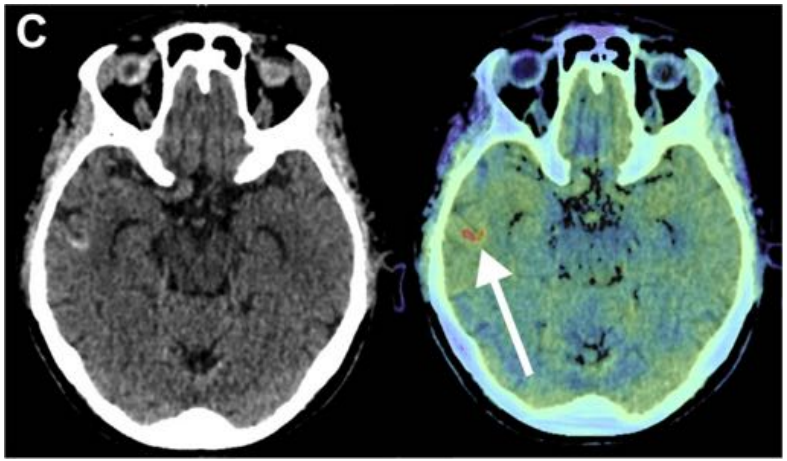
		Referenzstandard	
		ICH +	ICH -
Aidoc ICH	ICH +	322	74
	ICH -	27	3182

Sensitivity	92% [89% – 95%]
Specifity	98% [97% – 98%]
PPV	81% [78% – 85%]
NPV	99% [99% – 99%]

Quelle: Voter et al. 2021

False positive findings





Miscellaneous hyperdense findings in ¾ of cases

Quelle: Voter et al. 2021

2nd Imaging Decision:
Find large vessel occlusion

Large vessel occlusion detection

ORIGINAL RESEARCH
ADULT BRAIN

Evaluation of Artificial Intelligence–Powered Identification of Large-Vessel Occlusions in a Comprehensive Stroke Center

A. Yahav-Dovrat, M. Saban, G. Merhav, I. Lankri, E. Abergel, A. Eran, D. Tanne, R.G. Nogueira, and R. Sivan-Hoffmann

Quelle: Yahav-Dovrat et al. 2021

viz.ai

Large vessel occlusion detection

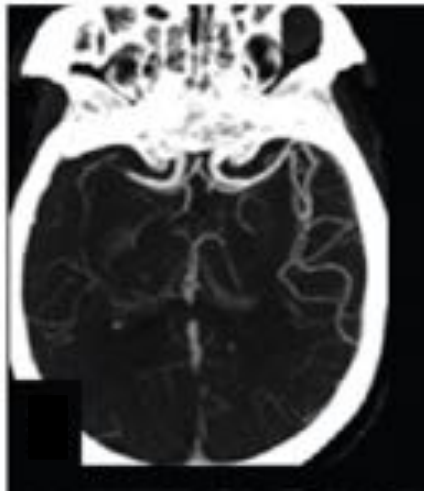
Data	• Retrospective, consecutive single center cohort • n = 1167; LVO+ = 75 (6,4%) • CTA: all indications, n = 404 stroke
Reference-standard	• Written radiology report
Technique	• Viz.ai LVO • Vessel length • Predefined threshold • Distal ACI, M1, (M2)

Quelle: Yahav-Dovrat et al. 2021

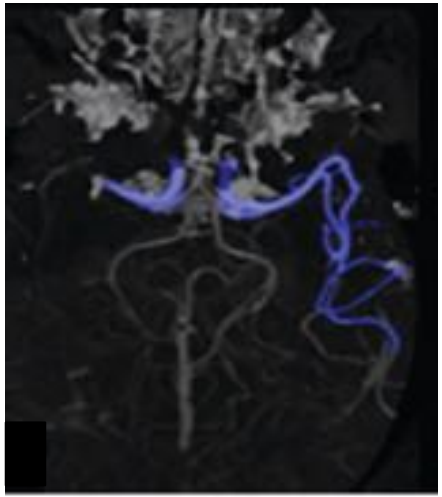
- Registration
- Cropping
- Vessel segmentation

- Bounding box
- Information to NRAD

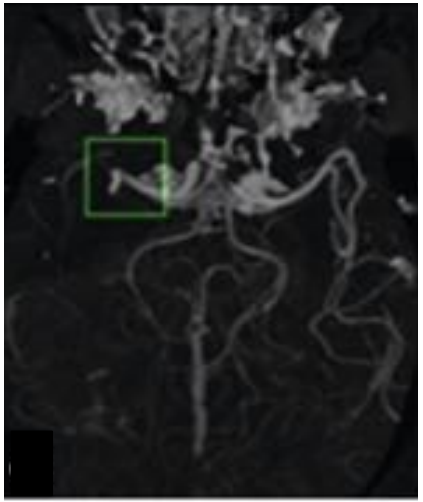
viz.ai



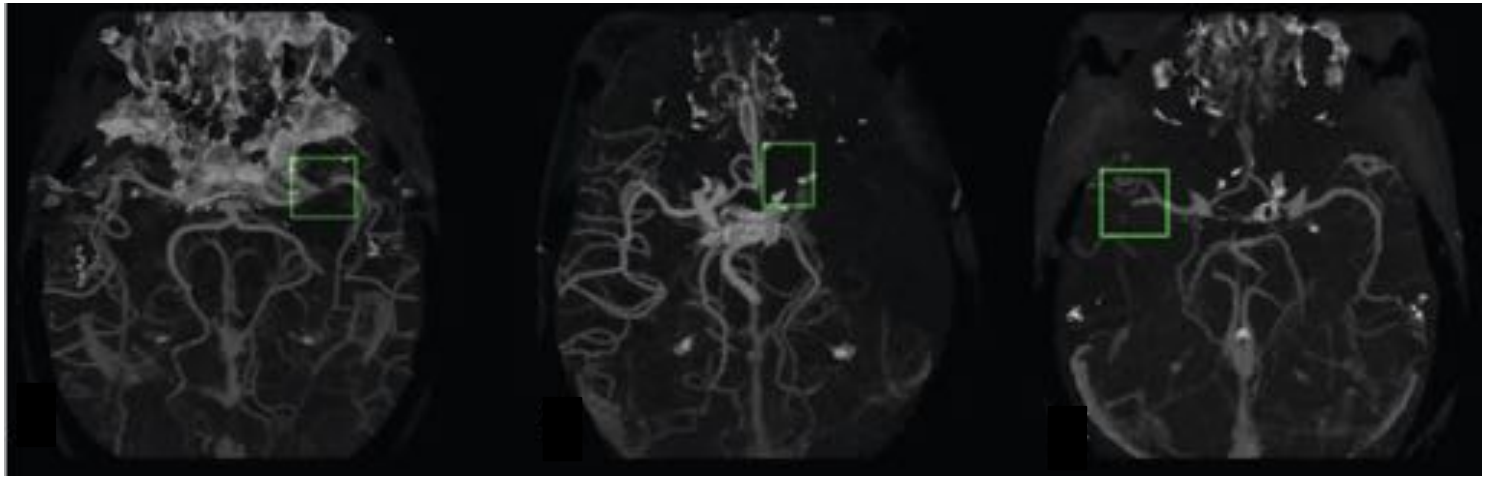
CTA? – Metadata
i.v. contrast?
metal present?



Vessel length
below threshold?



Quelle: Yahav-Dovrat et al. 2021



		Referenzstandard	
		LVO +	LVO -
Viz LVO	LVO +		
	LVO -		

Sensitivity	81% [74% – 91%]
Specifity	96% [95% – 97%]
PPV	65% [55% – 74%]
NPV	99% [98% – 99%]

Quelle: Yahav-Dovrat et al. 2021

LVO-Detection

NICOLAB

Original research

Diagnostic performance of an algorithm for automated large vessel occlusion detection on CT angiography

Sven P R Luijten ,[1] Lennard Wolff,[1] Martijne H C Duvekot,[2,3] Pieter-Jan van Doormaal,[1] Walid Moudrous,[4] Henk Kerkhoff,[3] Geert J Lycklama a Nijeholt,[5] Reinoud P H Bokkers,[6] Lonneke S F Yo,[7] Jeannette Hofmeijer,[8] Wim H van Zwam ,[9] Adriaan C G M van Es,[10] Diederik W J Dippel ,[2] Bob Roozenbeek,[1,2] Aad van der Lugt,[1] on behalf of the MR CLEAN Registry and PRESTO investigators

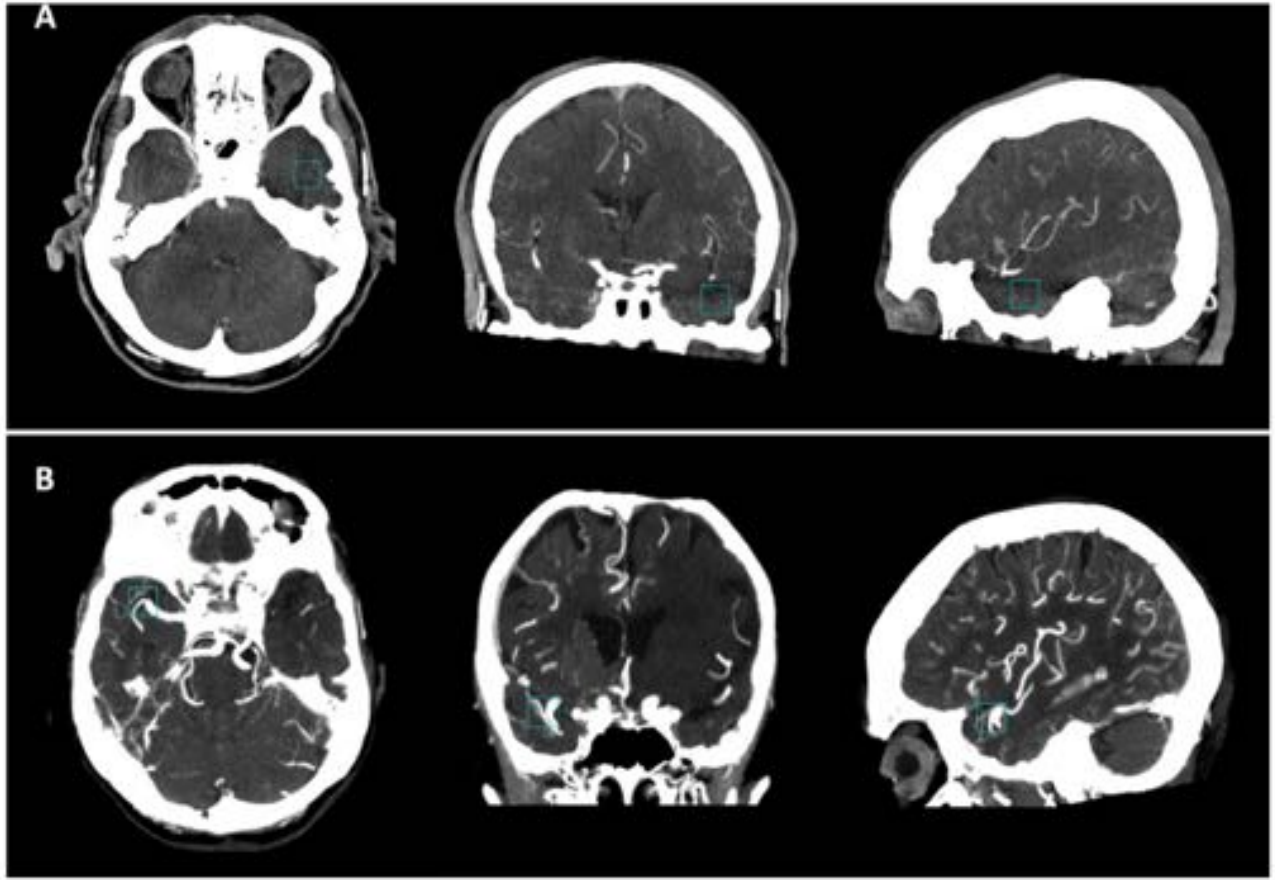
Quelle: Luijten et al. 2022

LVO-Detection

NICOLAB

Data	• Retrospective study • MR CLEAN (n=1110) & • PRESTO (n=646; 141 LVO+)
Reference standard	• Core lab assessment
Methods	• NICO LAB • Bounding Box • Distal ACI, M1, M2

Quelle: Luijten et al. 2022



Quelle: Luijten et al. 2022

MR CLEAN		Reference standard	
		LVO +	LVO -
NicoLab	LVO +	992	0
	LVO -	118	0

Sensitivity	89% [87% – 92%]

PRESTO		Reference standard	
		LVO +	LVO -
NicoLab	LVO +	102	113
	LVO -	39	392

Sensitivity	72% [64% – 80%]
Specifity	78% [74% – 81%]
PPV	47% [41% – 54%]
NPV	91% [88% – 93%]

Quelle: Dehkharghani et al. 2021

What can we learn from these studies?

- Don‘t expect perfect results
- The scenario matters
- Examples of false positive and false negative findings
- Guide clinical deployment
- Weird output can happen

3rd Imaging Decision:
Patient selection (late time window)

Lots of automated solutions....

... but not AI

Outline

Patient case

Imaging in stroke

AI-based solutions in stroke imaging

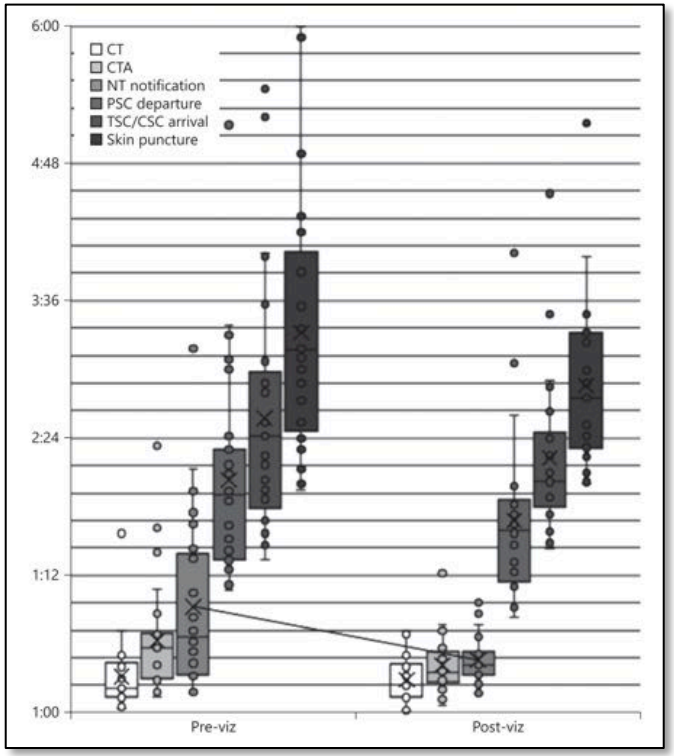
Future directions

Source: streamlineicons.com

Decreasing time to treatment through mobile apps

Reference: Murray et al. JNIS 2019

Mobile stroke apps impact on turnover times



Time to notification:

Before implementation: 40 min

After implementation: 25 min

viz.ai

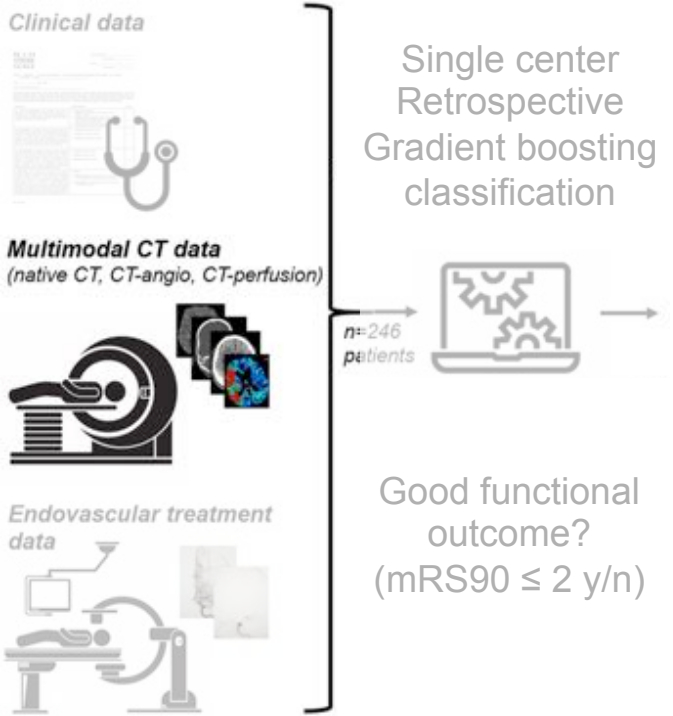
RAPIDAI

VEOcore

Olea medical

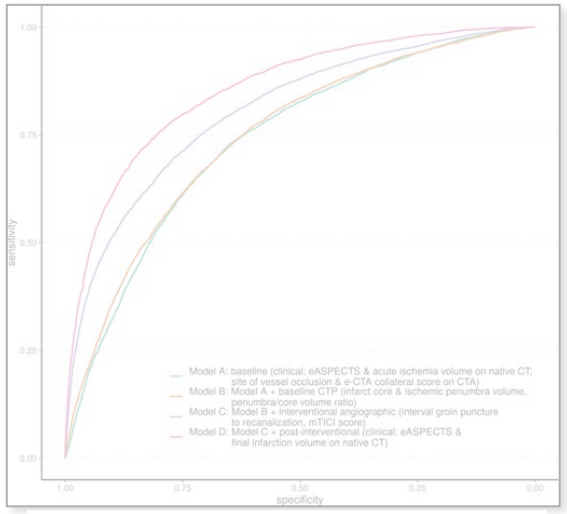
Reference: Morey et al. Cerebrovascular Diseases 2021

Machine learning for outcome prediction



Single center
Retrospective
Gradient boosting classification

Good functional outcome?
(mRS90 ≤ 2 y/n)



Four models
Improvement with treatment data
(not CT-P)

Most important predictors:

1) NIHSS after 24hrs
2) Premorbid mRS
3) Final infarct volume (NCCT)
4) Groin to recanalization
5) Baseline infarct volume (NCCT)

Reference: Brugnara et al. Stroke 2020

Summary

Stroke is common and serious
Time is brain

Three image-guided treatment decisions
Image-guided thrombectomy

AI-based solutions are available for dedicated imaging questions, room for improvement

Workflow streamlining
Outcome prediction

Source: streamlineicons.com

Thank you very much for your attention

dennis.hedderich@tum.de