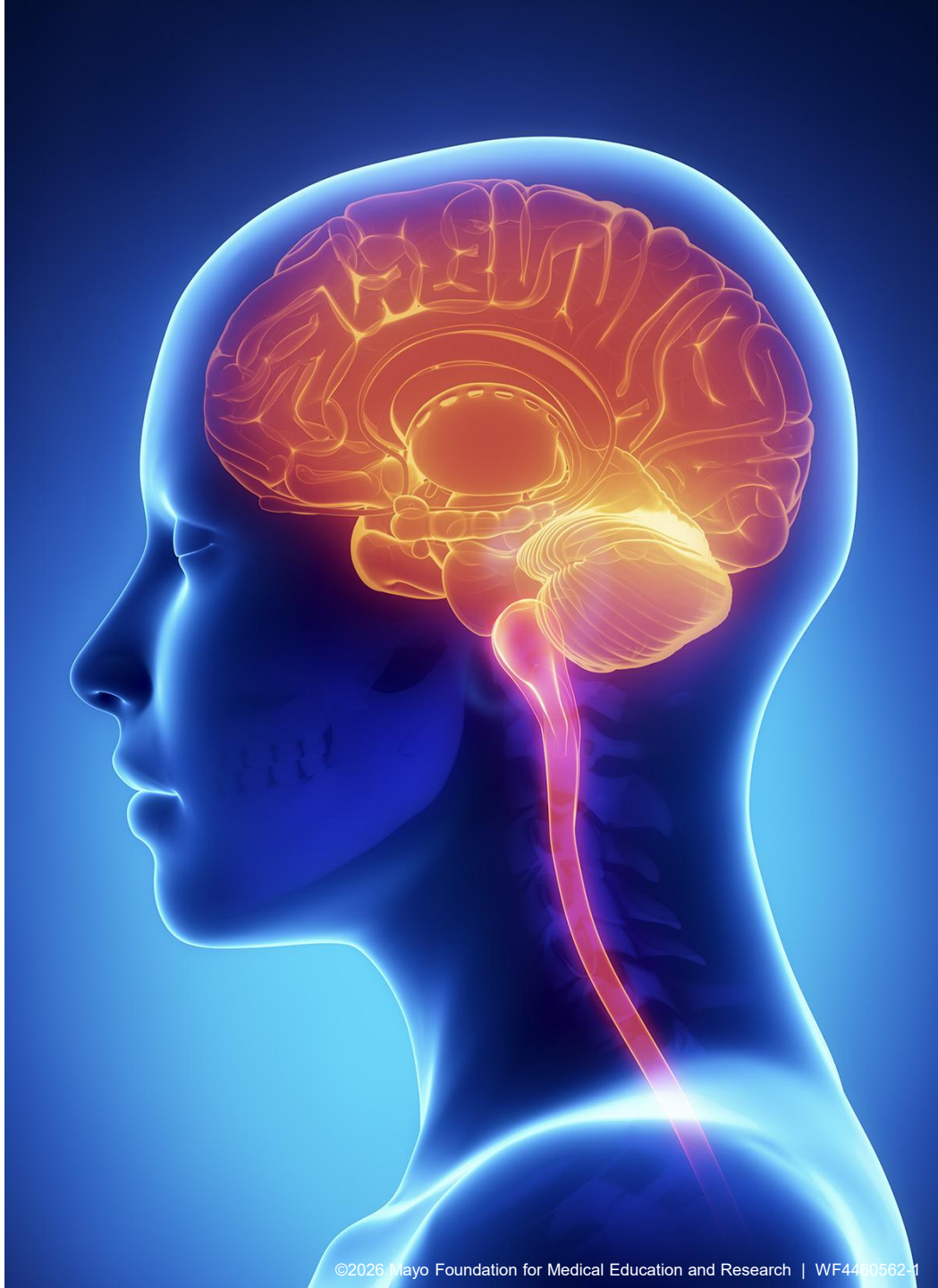
MAYO CLINIC | School of Continuous Professional Development

ASN 2026 ANNUAL MEETING

Jan 17, 2026



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NEW TECHNOLOGIES IN TCD/CAROTID

ARE ROBOTS TAKING OVER?

Gyan Kumar
M.B.B.S.,M.D.,RPNI, FASN, CPAHA, FAAN

DISCLOSURE OF RELEVANT FINANCIAL RELATIONSHIP(S)

Name	Nature of relationship	Company
Gyan Kumar	Employee	Mayo Clinic
Gyan Kumar	Served as Consultant	Oculus Imaging
Gyan Kumar	Consultant	AZMB

All relevant financial relationships have been mitigated.

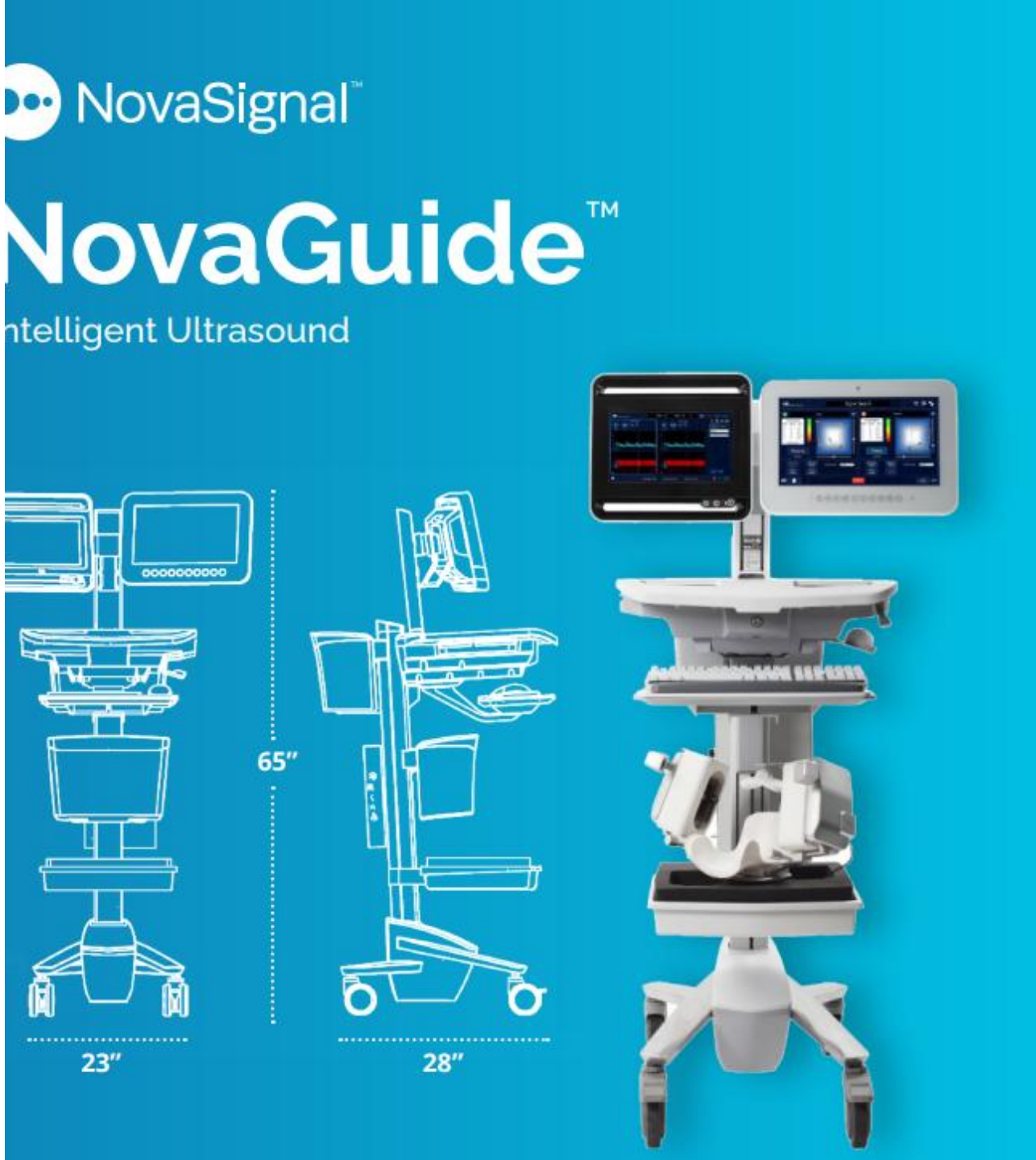
LEARNING OBJECTIVE

- Describe the capabilities and clinical applications of robotic-assisted TCD systems and AI integration
- Review clinical evidence on detection rates and diagnostic accuracy of robotic-assisted TCD
- Analyze impact on clinical workflow, access, and implementation
- Evaluate applications in neurocritical care and stroke management
- Recognize current limitations in traditional TCD and carotid ultrasound practice, and consider future directions

ROBOTIC ASSISTED TCD

TECHNOLOGY OVERVIEW

- Automated probe positioning/vessel geo location
- Hands-Free monitoring
- AI driven data acquisition
- AI driven data interpretation



Clare K. Sci Rep 2022 Feb 10;12(1):2266
Vitt JR. Front Neurol. 2023 Apr 20;14:1155986

ROBOTIC ASSISTED TCD

FEASIBILITY, SAFETY, ACCURACY

Enables prolonged, hands-free monitoring

Reduces operator dependence

Feasibility rates for RA TCD exceed 85% and MV measurements are equivalent to manual TCD

continuous neuro monitoring in neurovascular care

Maintains agreement with gold standard imaging for vasospasm detection

In SAH RA TCD achieved strong concordance with CTA for vasospasm (Cohen's kappa = 0.74)

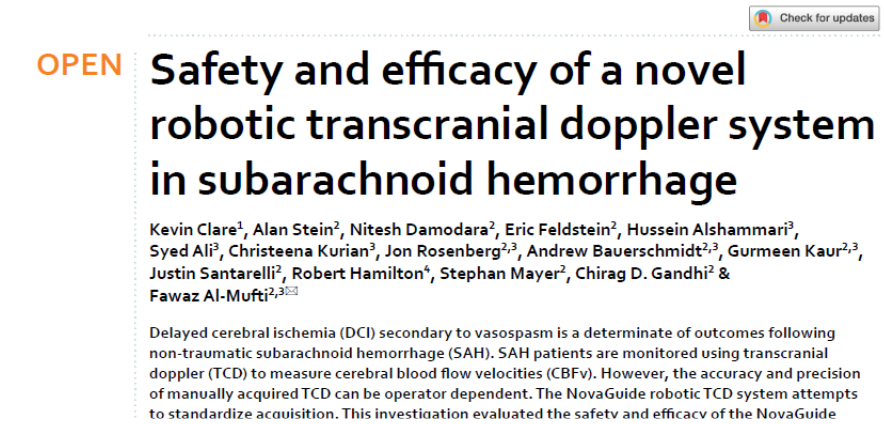
No adverse effects in those with central lines or EVD

Salimbeni AF. NCC 2025 Apr;42(2):457-464.
Clare K. Sci Rep 2022 Feb 10;12(1):2266

ROBOTIC ASSISTED TCD

VASOSPASM IN SAH

scientific reports



OPEN

Safety and efficacy of a novel robotic transcranial doppler system in subarachnoid hemorrhage

Kevin Clare[1], Alan Stein[2], Nitesh Damodara[2], Eric Feldstein[2], Hussein Alshammari[3], Syed Ali[3], Christeena Kurian[3], Jon Rosenberg[2,3], Andrew Bauerschmidt[2,3], Gurmeen Kaur[2,3], Justin Santarelli[2], Robert Hamilton[4], Stephan Mayer[2], Chirag D. Gandhi[2] & Fawaz Al-Mufti[2,3]✉

Delayed cerebral ischemia (DCI) secondary to vasospasm is a determinate of outcomes following non-traumatic subarachnoid hemorrhage (SAH). SAH patients are monitored using transcranial doppler (TCD) to measure cerebral blood flow velocities (CBFv). However, the accuracy and precision of manually acquired TCD can be operator dependent. The NovaGuide robotic TCD system attempts to standardize acquisition. This investigation evaluated the safety and efficacy of the NovaGuide

Clare K. Sci Rep 2022 Feb 10;12(1):2266

a)

NovaGuide Mean CBFv ≥ 86 cm/s	CT Angiogram: Positive	CT Angiogram: Negative
Positive	0	0
Negative	12	21

b)

NovaGuide Max CBFv ≥ 120 cm/s	CT Angiogram: Positive	CT Angiogram: Negative
Positive	10	2
Negative	2	19

c)

	Mean CBFv MCA	Max CBFv MCA
Cohen's Kappa Value	N/A	0.74
Sensitivity	0	83%
Specificity	1	90%
Positive Predictive Value	N/A	84%
Negative Predictive Value	0.63	90%
Positive Likelihood Ratio	N/A	8.75
Negative Likelihood Ratio	N/A	0.11

ROBOTIC ASSISTED TCD

RLS DETECTION

In a multicenter prospective trial, RA TCD detected RLS in 64% of patients versus 20% with TTE (absolute difference 43.4%, p<0.001)

large shunts were identified in 27% versus 10% respectively

RA TCD enables non expert operators to achieve known high sensitivity of TCD for RLS detection without specialized training

The RA TCD bubble study follows standard TCD technique with agitated saline injection during Valsalva maneuver

MES detection in MCAs

grading with SLS /ICC

clinical decision making with RoPE score and PASCAL score

Rubin M. Stroke. 2023 Nov;54(11):2842-2850
Chang I. Front Neurol 2025 Feb 13:15:1481817

ROBOTIC ASSISTED TCD

RLS DETECTION

Stroke

CLINICAL AND POPULATION SCIENCES

Robot-Assisted Transcranial Doppler Versus Transthoracic Echocardiography for Right to Left Shunt Detection

Mark N. Rubin, MD, RPNI, NVS; Ruchir Shah, MD; Thomas Devlin, MD, PhD; Teddy S. Youn, MD, RPNI; Michael F. Waters, MD, PhD; John J. Volpi, MD; Aaron Stayman, MD; Colleen M. Douville, RVT, NVS; Ted Lowenkopf, MD; Georgios Tsivgoulis, MD, PhD, MSc, RVT; Andrei V. Alexandrov, MD, RPNI, RVT, NVS

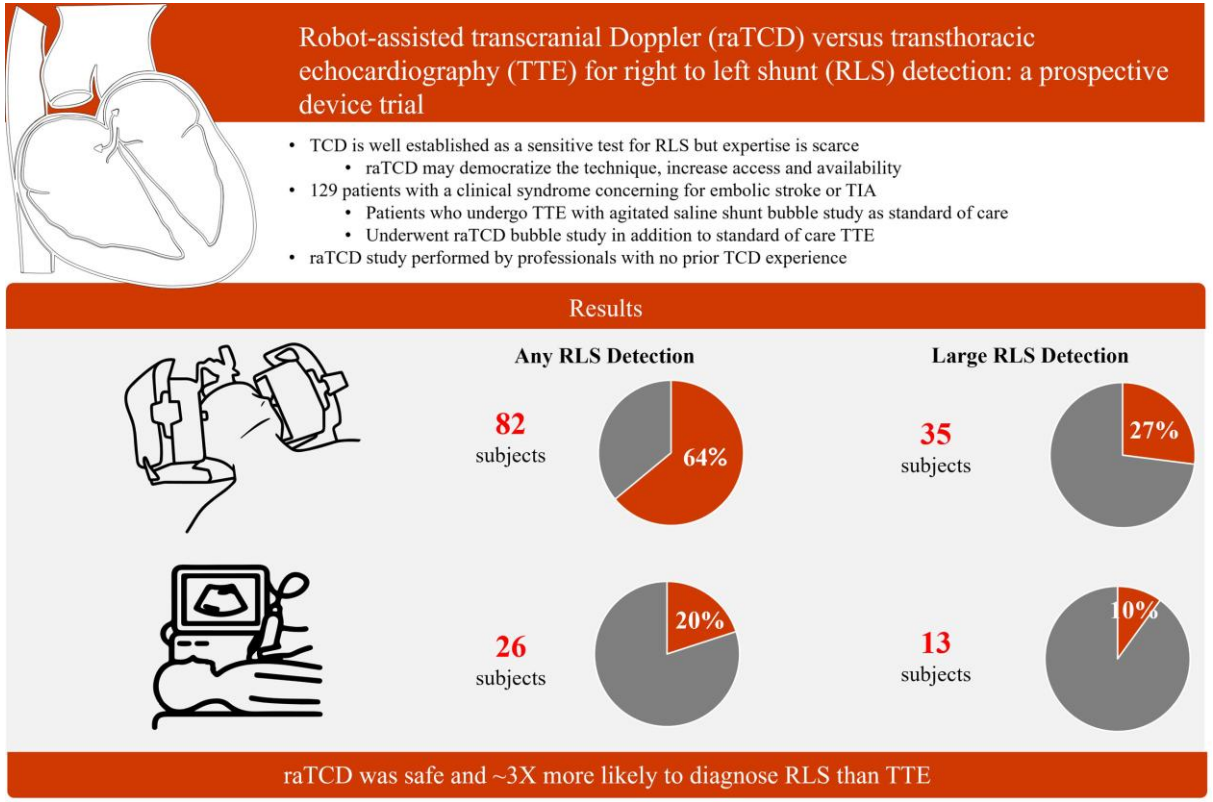
Ra-TCD vs TTE

TTE (ITS)	Positive	Negative	Total	TTE (PP)	Positive	Negative	Total
raTCD				**raTCD**			
Positive	24 (18.6%)	58 (45.0%)	82 (63.6%)	Positive	22 (18.2%)	52 (43%)	74 (61.2%)
Negative	2 (1.6%)	45 (34.8%)	47 (36.4%)	Negative	2 (1.6%)	45 (37.2%)	47 (38.8%)
Total	26 (20.2%)	103 (79.8%)		**Total**	24 (19.8%)	97 (80.2%)	
Difference	43.4% (95% CI, 35.2%-52.0%) **P<0.001**			41.4% (95% CI, 32.9%-50.2%) **P<0.001**			

Rubin M. 2023 Oct 5;54(11):2842–2850

ROBOTIC ASSISTED TCD

RLS DETECTION



Mark N. Rubin. Stroke. Robot-Assisted Transcranial Doppler Versus Transthoracic Echocardiography for Right to Left Shunt Detection, Volume: 54, Issue: 11, Pages: 2842-2850, DOI: (10.1161/STROKEAHA.123.043380)

ROBOTIC ASSISTED TCD

RLS DETECTION

ra-TCD key advantages

- Noninvasive bedside testing with no serious adverse events
- High feasibility with 89% of patients able to perform Valsalva
- Detection of both cardiac and extra cardiac shunts unlike echo
- Ability to perform prolonged and repeat testing without operator fatigue
- raTCD ≈3 times more likely to diagnose RLS than TTE
- TTE completely missed or underdiagnosed two thirds of large shunts diagnosed by raTCD
- Health professionals with no prior TCD training can achieve the known sensitivity

Rubin M. Stroke. 2023 Nov;54(11):2842-2850
Chang I. Front Neurol 2025 Feb 13:15:1481817
Silvestry F. J Am Soc Echocardiogra.. 2015 Aug;28(8):910-58.

ROBOTIC ASSISTED TCD

RLS DETECTION

ra-TCD- clinical workflow integration

- Effective screening tool for RLS in cryptogenic stroke patients
- Positive findings warrant confirmatory TEE to visualize anatomy and guide closure decisions

Palazzo P. Stroke. 2024 Dec;55(12):2932-2941
Kent DM. JAMA 2025 Oct 28;334(16):1463-1473.

ROBOTIC ASSISTED TCD

IMPACT ON NEUROCRITICAL CARE MANAGEMENT

While direct evidence of improved patient outcomes is still emerging, literature supports RA-TCD in comprehensive neurocritical care with potential for earlier intervention and better risk stratification

- Enhanced detection of vasospasm
- Integration into Mmodal monitoring for
  - SAH
  - TBI
  - Acute stroke

Salimbeni AF. NCC 2025 Apr;42(2):457-464.
Clare K. Sci Rep 2022 Feb 10;12(1):2266
ACEP.org/ACEP emergency ultrasound guidelines 2023 policy statement

ROBOTIC ASSISTED TCD

IMPACT ON NEUROCRITICAL CARE MANAGEMENT

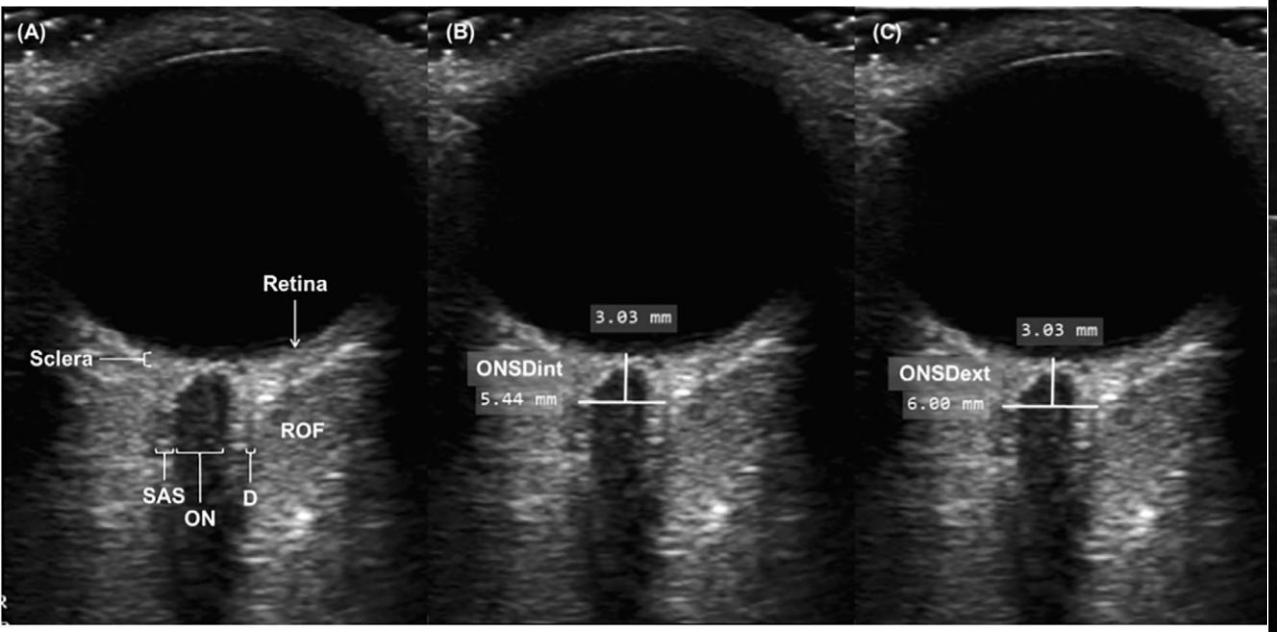
ONSD

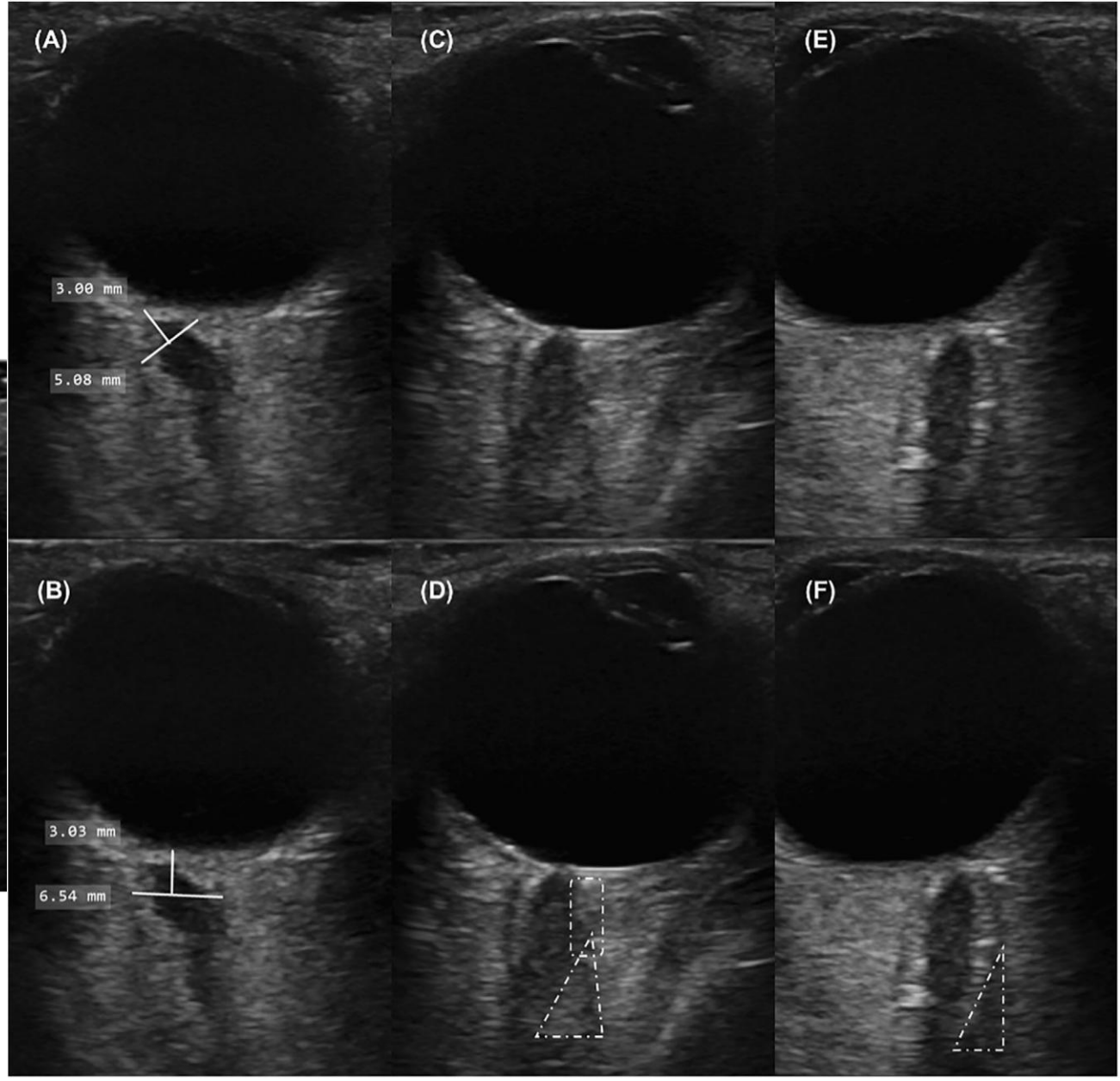
- The automated analysis and measurement of ONSD
  - Eliminate operator dependence and inconsistencies in image acquisition and measurement
  - Technology is rapidly evolving and in early stage
  - The automation of both image acquisition and measurement is necessary for fully independent ONSD measurement processing.
- In 20 patients with a SAH, ONSD correlated positively with invasive ICP, in those where basal cisterns had not been entered surgically
  - Clinically important noninvasive ICP monitor

Escamilla-Ocañas CE. J Neuroimaging 2025; 35:e70017.
Netteland DF. Neurocrit Care 2025; 42:1043–1053.

ROBOTIC ASSISTED TCD

ONSD

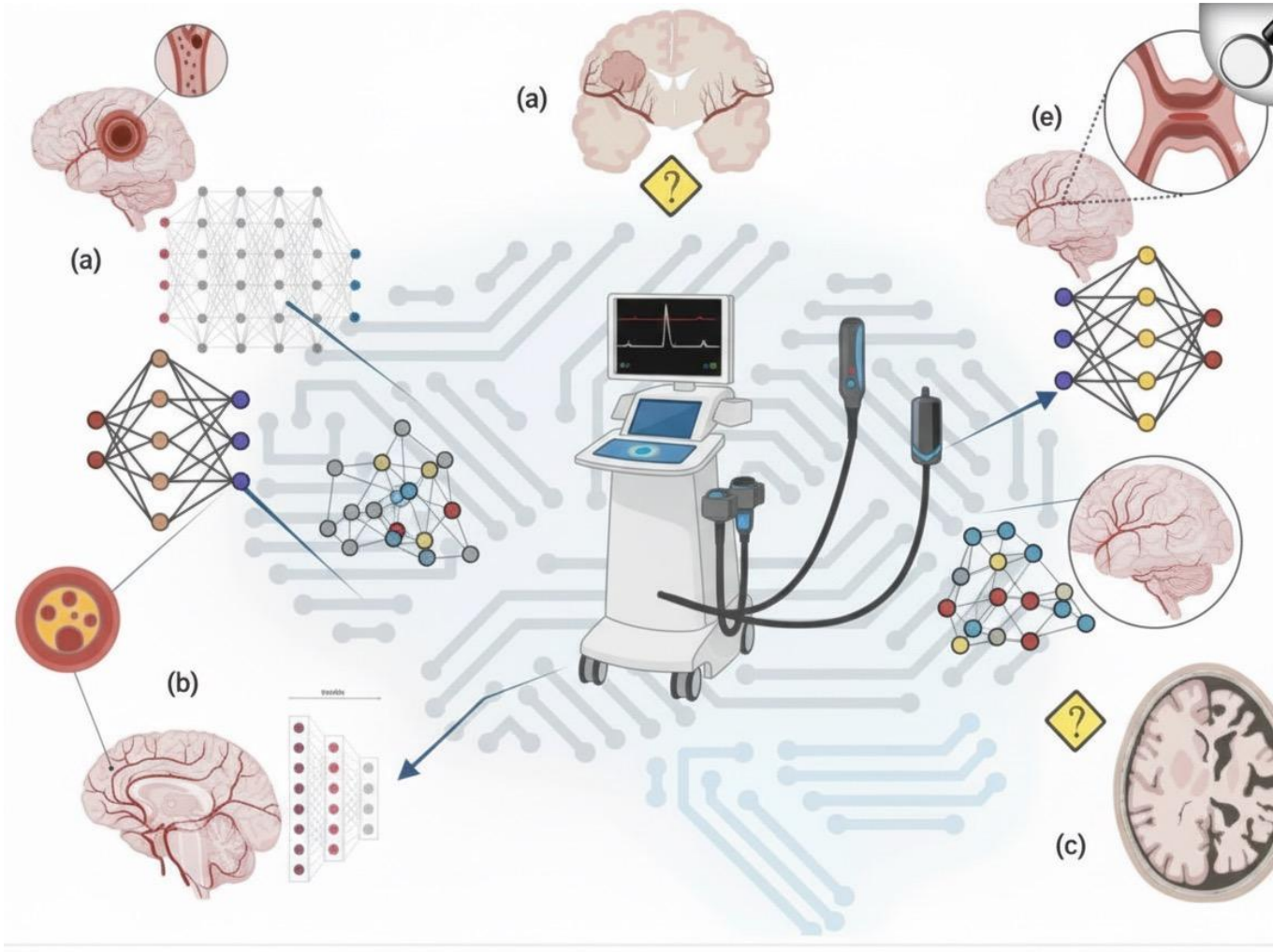




Escamilla-Ocañas CE. J Neuroimaging 2025; 35:e70017

AI INTEGRATION

- ML, DL, Convolutional NN algorithms have been applied
- For the diagnosis of MES, ICAS, RLS, Vasospasm in SAH
- Application to structural disease like dementia and SOL has not been explored
- Standardized datasets
- Novel digital Biomarkers

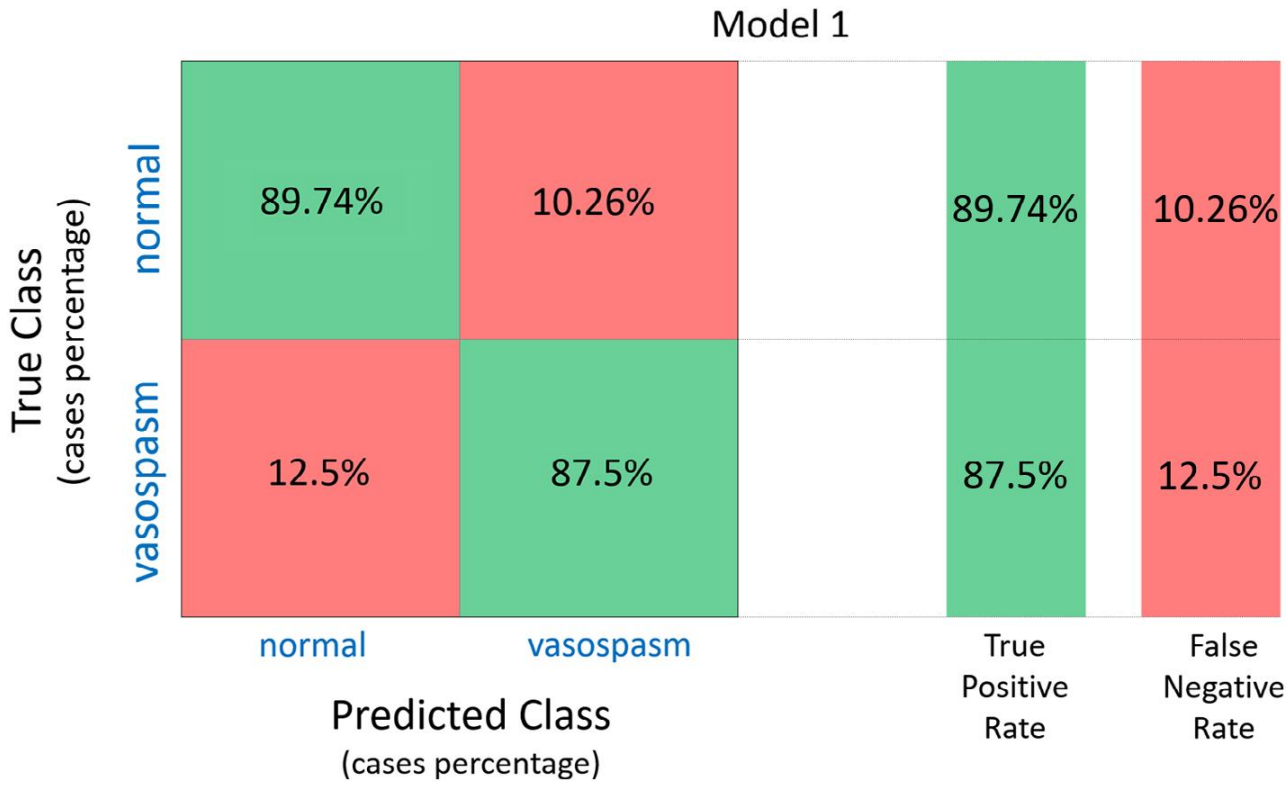


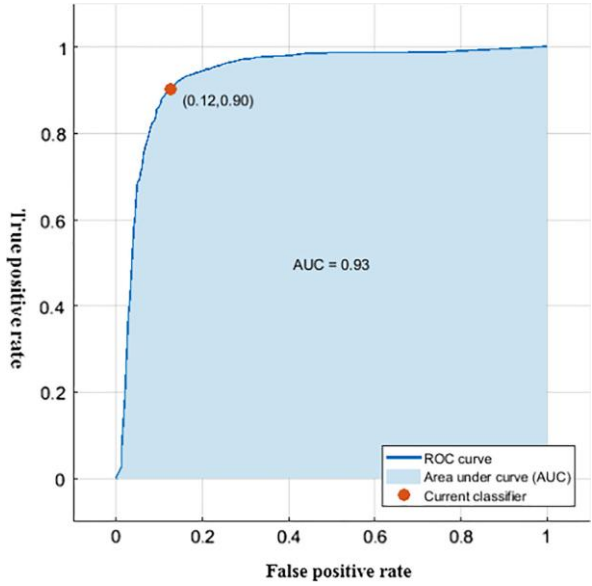
Giuseppe M. Bioengineering 2025, 12, 681
Elzaafarany K, Kumar G et al. Signal Image And Video Processing. 2018; 1-7
Elzaafarany K, Kumar G et al. J Ultrasound Med. 2019 Aug; 38 (8):2191-2202

AI INTEGRATION

Algorithm for automated vasospasm detection

- 268 TCD audio signals from BA and MCA
- Patients with aneurysmal SAH
- Between days 3 and 21
- Arteries in vasospasm (49) as well as those normal flow (219).
- The Doppler audio signals were acquired as wav files of 3-15 seconds in duration.

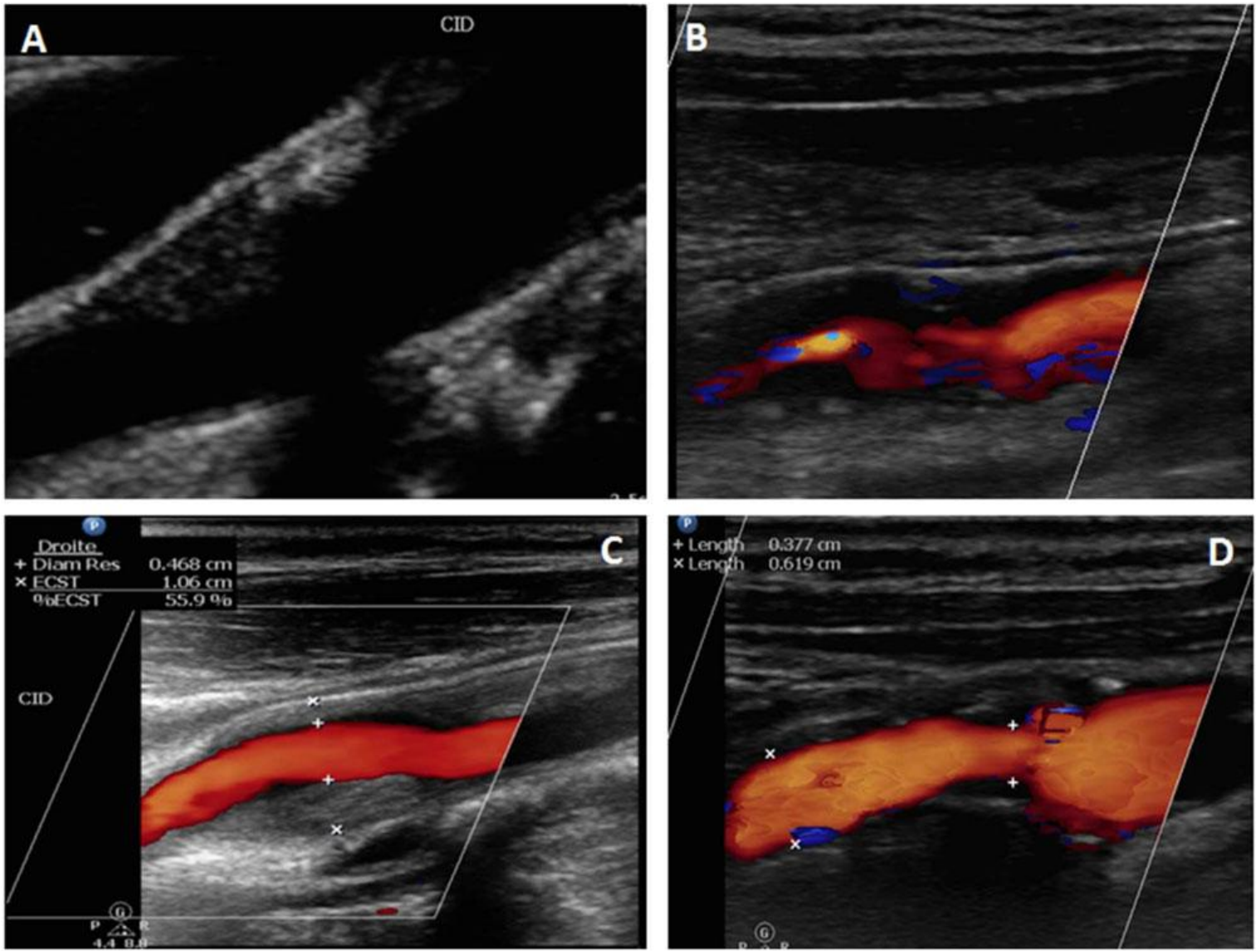




Elzaafarany K, **Kumar G** et al. Signal Image And Video Processing. 2018; 1-7
Elzaafarany K, **Kumar G** et al. J Ultrasound Med. 2019 Aug; 38 (8):2191-2202

CAROTID ULTRASOUND INTEGRATION

- Principles of automation, enhanced reproducibility, integration with the other imaging modalities are being explored
- Robotic automation is less well established in literature
- CUS for plaque, stenosis
- TCD complementing for collateral flow, emboli detection
- Plaque echogenicity can be estimated with semi-automated methods
- Semiautomated techniques have been used to evaluate neoangiogenesis



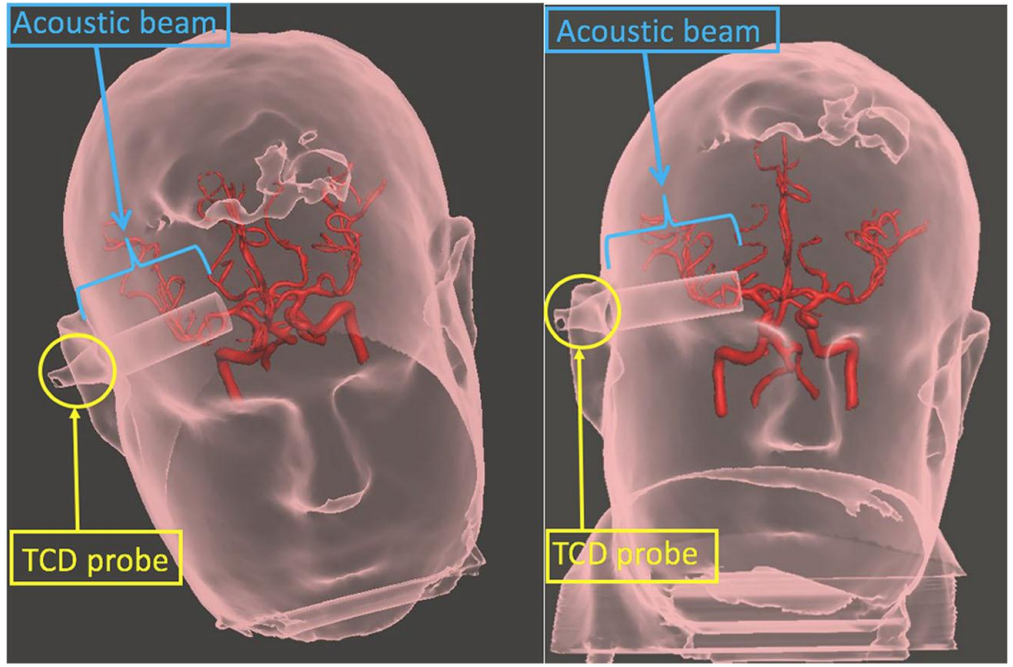
Kargiotis O. J Neuroimaging 2018;28:239-251..

SURFACE POINT CLOUD ULTRASOUND

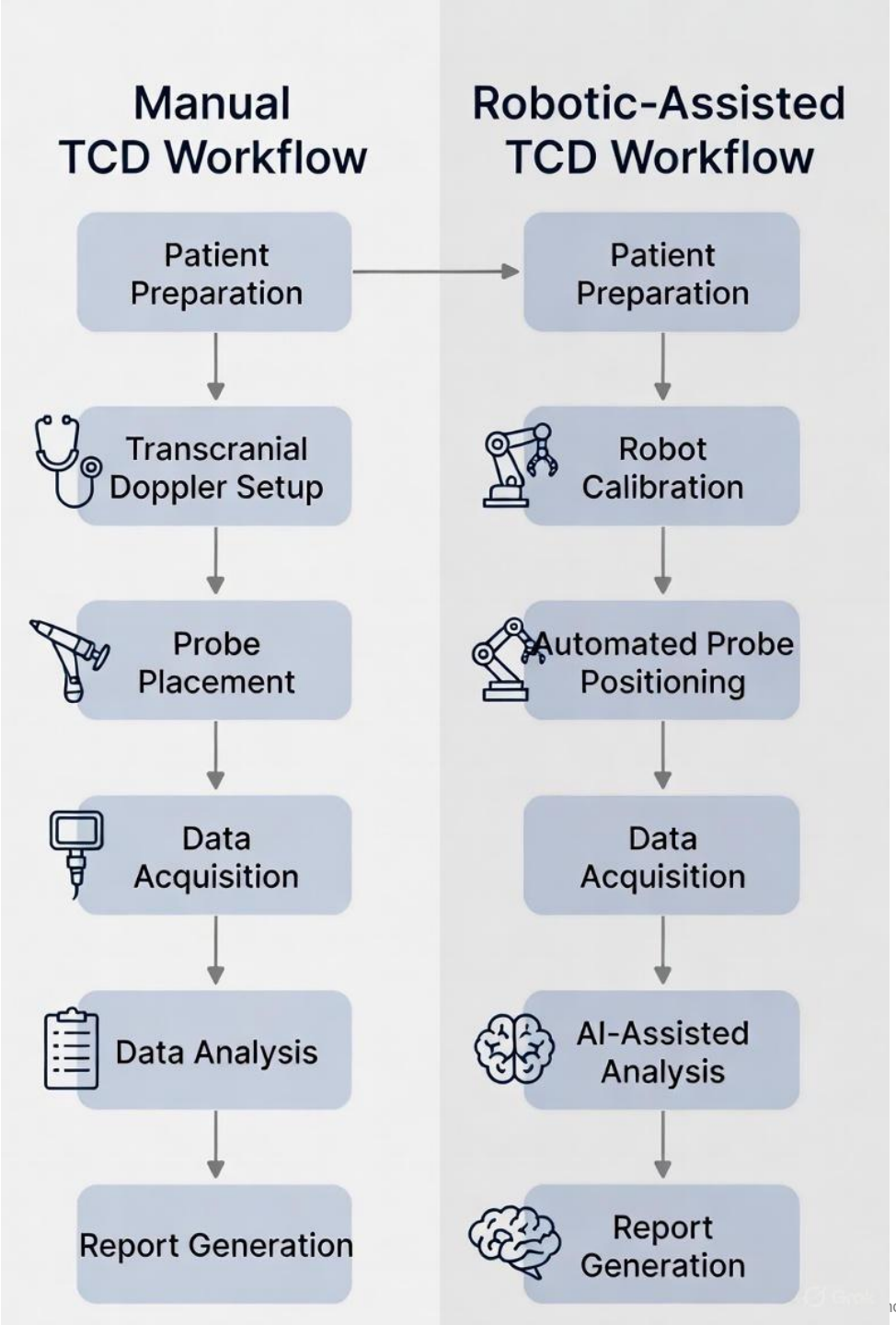
SPC-US

- Integration of SPC with TCD allows for 3D mapping and core registration with MR angiography
- This approach improves reproducibility, speed, accuracy of TCD exams by providing a 3D roadmap for probe navigation and vessel localization
- Facilitates semi automation and precise monitoring
- Future state - augmented reality glasses to overlay TOF MRA on the patient's head during TCD performance for probe navigation and vessel localization

Stember JN. Journal of Digital Imaging (2020) 33:930–936



ROBOTIC ASSISTED TCD WORKFLOW



ROBOTIC ASSISTED TCD

WORKFLOW EFFICIENCY

ACCESS TO TCD

- Ra-TCD expands access to TCD where expertise is limited
- Supports real-time dynamic feedback for time-critical interventions in TBI and other acute conditions.

Salimbeni AF. NCC 2025 Apr;42(2):457-464.
Mainali S. NCC. 2022 Aug;37(Suppl 2):267-275.

ROBOTIC ASSISTED TCD

CHALLENGES

Challenges with technology include MT and CEA:

- Novaguide's head cradle design and its radiopacity hindered its use during carotid endarterectomy and mechanical thrombectomy.

Challenges with non-imaging doppler

- While robotics improve probe positioning, the lack of real-time imaging limits anatomical context and reproducibility
- Vessel localization and interpretation can be affected by brain shift or mass effect
- Robotic assistance allows hands-free monitoring, but still requires a skilled neurosonologist for interpretation
- Impediment in the development of large-scale standardized datasets

Salimbeni AF. NCC 2025 Apr;42(2):457-464.
Mainali S. NCC. 2022 Aug;37(Suppl 2):267-275.
Mathur B. SPIE. 2024 Apr;13412:134120A.

FUTURE DIRECTIONS

- Expanded access
- Real time feedback
- Clinical trials to assess patient outcomes and impact
- Automations, robotic and AI, in Carotid duplex ultrasound are needed