# Pre-Hospital Stroke Detection Technologies: Visors, Sensors, and AI – Oh my!

Northeast Cerebrovascular Consortium
14th Annual Summit
October 24th, 2019

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Mount Sinai

# Disclosures

| | |
|---|---|
| Metis Innovative | Ownership Interest |
| Penumbra | Educational Grant |
| | Site PI of INVEST and MIND |
| Siemens | Research Grant |
| Cerebrotech | National PI of VITAL and VIGOR |
| Minnetronix | Site PI of PILLAR |

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# Agenda

Theories of Time in Ischemic Stroke

The Detrimental Effect of Lost Time

Prehospital Triage Scales

New Technology for Portable Brain Scanning

Future Directions

# 2015 - 2017

## Endovascular Stroke Therapy Trials

2015

Jan — MR CLEAN
OR 2·05, 95% CI 1·36–3·09

Feb — EXTEND IA / ESCAPE
EXTEND IA: OR 3.75, 95% CI 1·38–10.17
ESCAPE: OR 2.73, 95% CI 1·71–4.37

Jun — SWIFT PRIME / REVASCAT
SWIFT PRIME: OR 2·98, 95% CI 1·61–5·83
REVASCAT: OR 1·98, 95% CI 1·11–3.53

2016

Feb — HERMES
(5 trials; 1287 patients)
ADJUSTED cOR 2·49, 95% CI 1·76–3·53; p<0·0001
NNT 2.6

Aug — THRACE
OR 1·55, 95% CI 1·05–2·30

Sep — THERAPY

2017

Aug — ASTER
$1^0$ - TICI 2b/3 85.4% ADAPT vs 83.1% SR

2018

2019

# Time Is Brain—Quantified

Jeffrey L. Saver, MD

***Conclusions***—Quantitative estimates of the pace of neural circuitry loss in human ischemic stroke emphasize the time urgency of stroke care. The typical patient loses 1.9 million neurons each minute in which stroke is untreated. (***Stroke*. 2006;37:263-266.**)

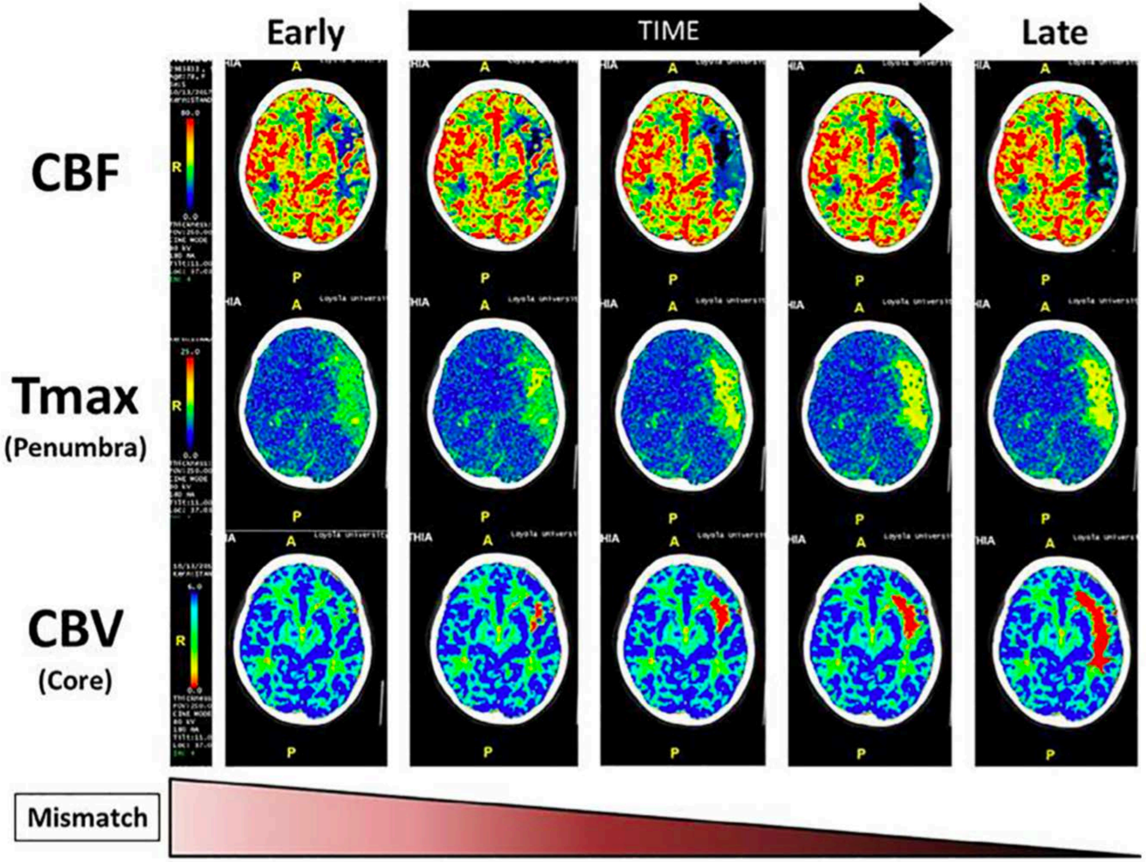
1.9 million neurons
14 billion synapses
12 km of myelinated fibers

# Time Is Brain:
# The Stroke Theory of Relativity

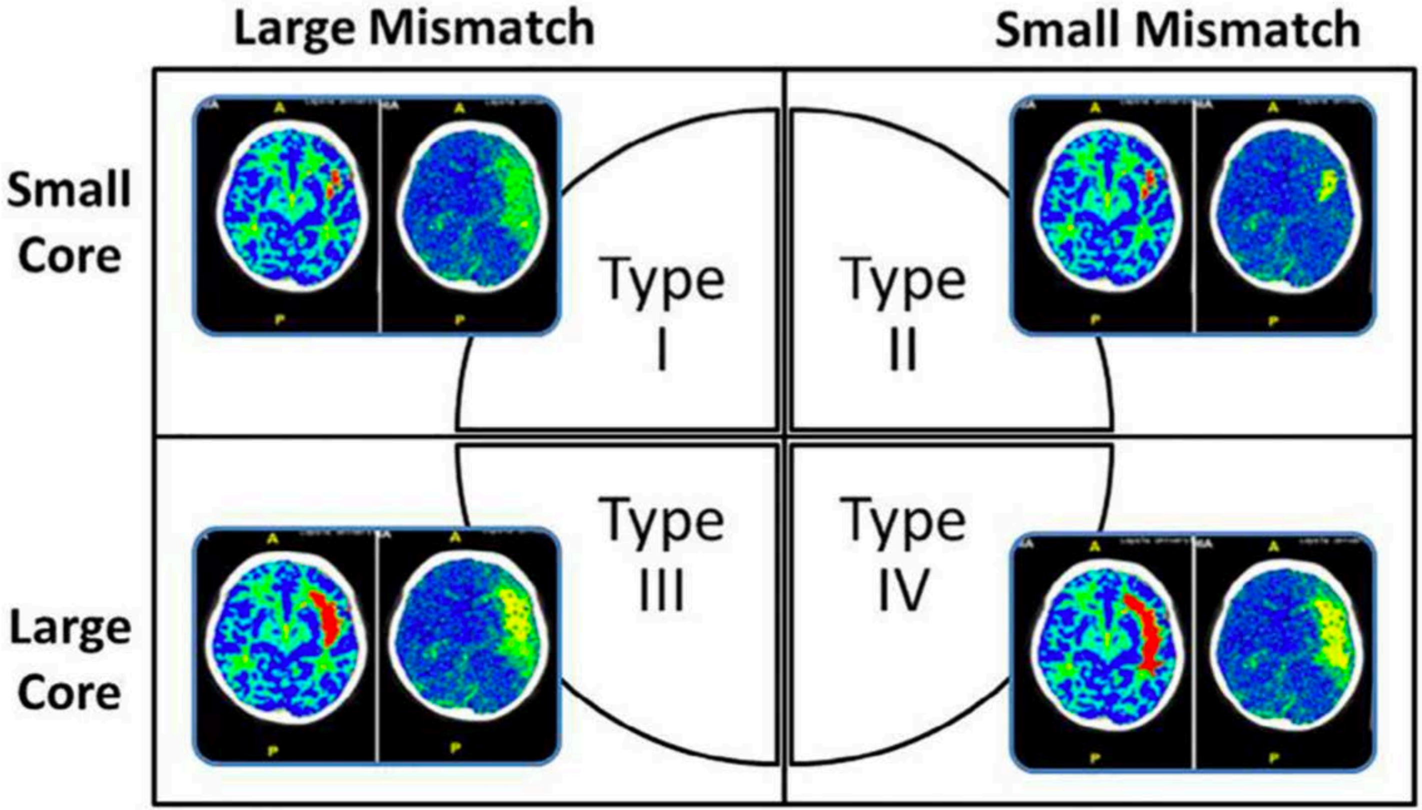
Camilo R. Gomez, MD, MBA*,†

"…it is no longer reasonable to believe that the effect of time on the ischemic process represents an absolute paradigm. It is increasingly evident that the volume of injured tissue within a given interval after the ETO shows considerable variability, in large part due to the beneficial effect of a robust collateral circulation."

Gomez. *J Stroke Cerebrovasc Disease.* 2018.




Gomez. *J Stroke Cerebrovasc Disease.* 2018.




Gomez. *J Stroke Cerebrovasc Disease.* 2018.

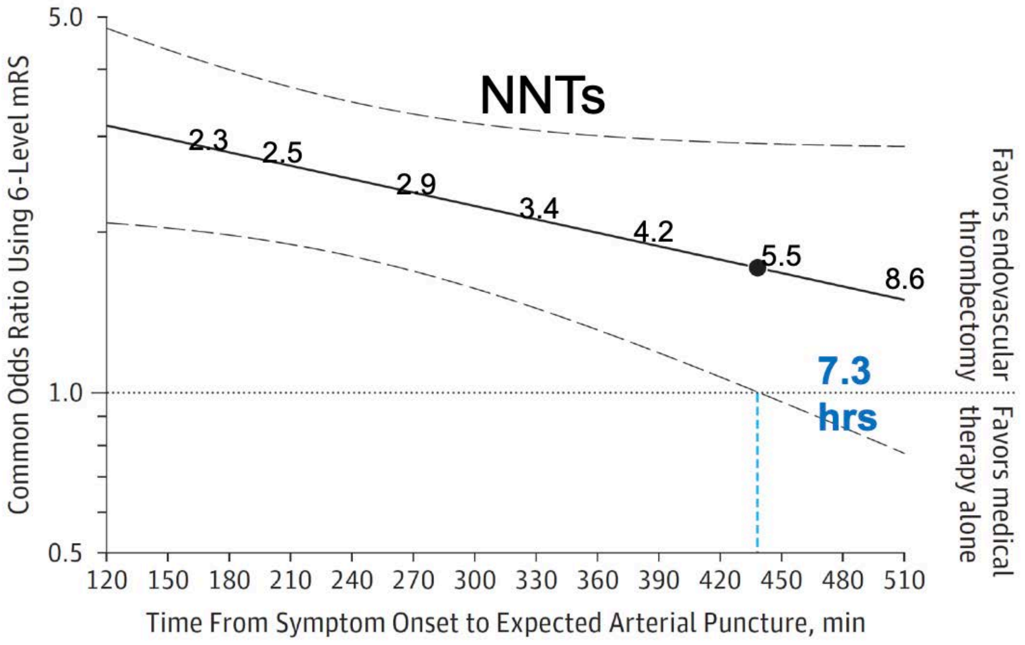
# NEED to Reduce Time to Treatment

## *HERMES: Outcome Correlates with Time to Treatment*

**For each 1000 patients treated 15 min faster:**

39 patients with less disability

25 more patients with functional independence

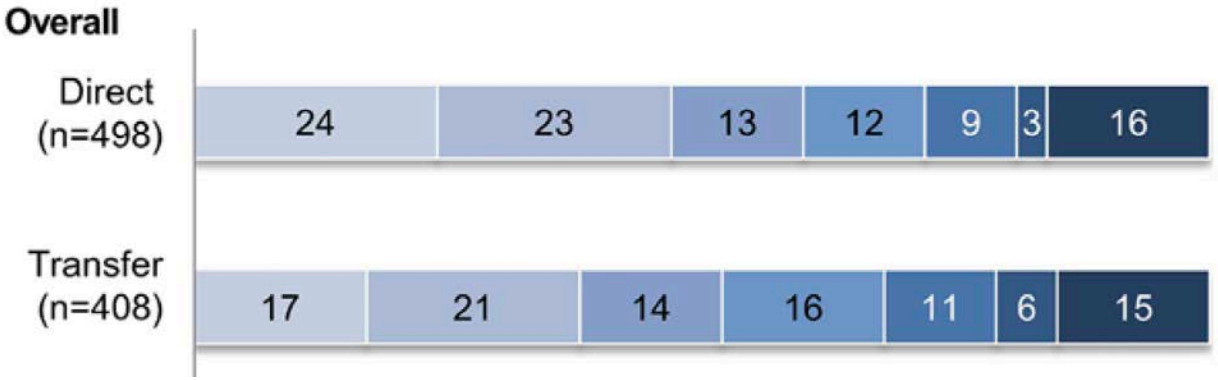



Saver at al. *JAMA*. 2016.

# STRATIS: Inter-hospital Transfers Associated with Treatment Delays and Worse Outcomes

➢ **In 984 patients, <u>Direct</u> vs. Inter-Hospital Transfer:**

- ➢ Saved 110 minutes on average
- ➢ Increased odds of functional independence (mRS 0-2 at 90d) by 1.38
- ➢ Increased odds of excellent outcome (mRS 01 at 90d) by 1.46




Froehler et al. *Circulation.* 2017.

# Current Triage Methods for LVO

## *Low Sensitivity, Low Reproducibility*

| | AUC* | CP | Sensitivity | Specificity |
|---|---|---|---|---|
| 3ISS (95% CI) | 0.74 | ≥3 | 0.50 (0.47–0.53) | 0.92 (0.91–0.93) |
| LAMS (95% CI) | 0.74 | ≥4 | 0.57 (0.54–0.60) | 0.84 (0.82–0.85) |
| RACE (95% CI) | 0.78 | ≥5 | 0.59 (0.56–0.62) | 0.86 (0.84–0.87) |
| CPSSS (95% CI) | 0.76 | ≥2 | 0.59 (0.56–0.62) | 0.86 (0.84–0.87) |
| PASS (95% CI) | 0.75 | ≥2 | 0.64 (0.61–0.67) | 0.83 (0.81–0.85) |

Hastrup S, et al. *Stroke.* 2016.

# AHA/ASA:
# LVO Prediction Scales are Not Accurate

**AHA/ASA Systematic Review**

## Accuracy of Prediction Instruments for Diagnosing Large Vessel Occlusion in Individuals With Suspected Stroke

### A Systematic Review for the 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke

*Reviewed for evidence-based integrity and endorsed by the American Association of Neurological Surgeons and Congress of Neurological Surgeons*

*Endorsed by the Society for Academic Emergency Medicine*

# AHA/ASA:
# LVO Prediction Scales are Not Accurate

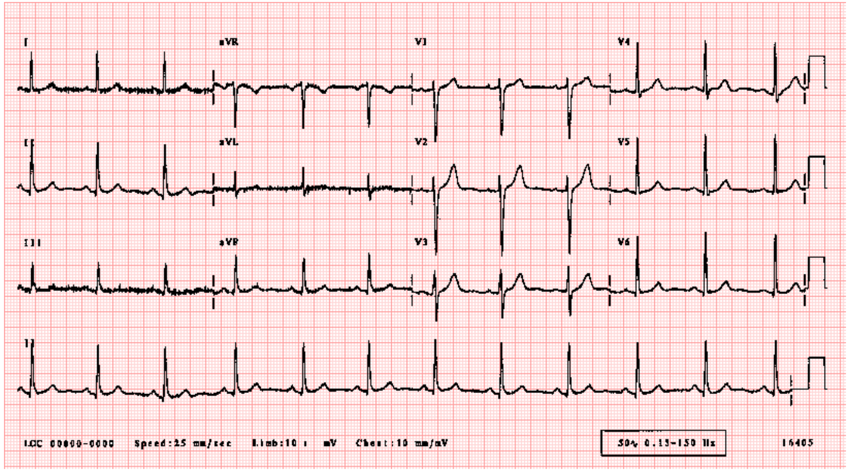
**Most frequently validated LVO prediction instruments reviewed**

- NIHSS, CPSSS, LAMS and RACE
- NO scale predicted LVO with both high sensitivity and high specificity
- No convincing evidence for superiority of any one prediction instrument
- Systems that use LVO prediction instruments for triage will miss some patients with LVO

# The Brain EKG

Portable
Easy to use
Inexpensive
Fast
Accurate

# The Brain EKG




STEMI on 12 lead EKG

Sensitivity - 68.6%
Specificity - 81.2%

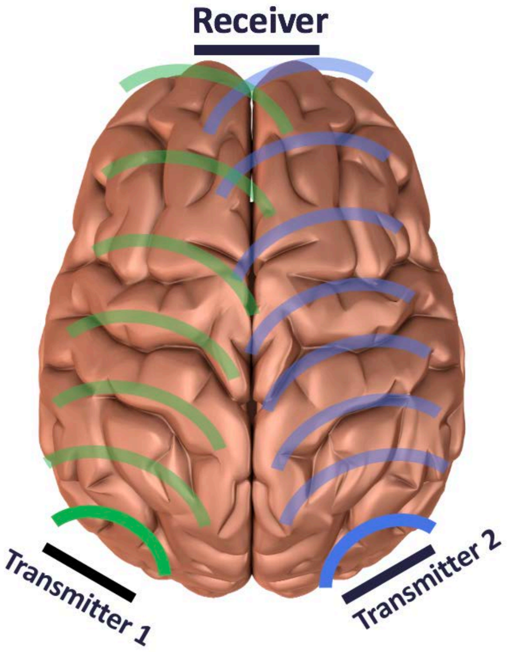
Menown et al. Optimizing the initial 12-lead electrocardiographic diagnosis of acute myocardial infarction. *Eur. Heart J.* 2000; 21:275–283.

# Prehospital Stroke Detection Devices

1) Cerebrotech Visor
2) Neural Analytics
3) AlphaStroke
4) BrainPulse
5) BrainScope
6) Infrascanner
7) Sense
8) StrokeFinder

# Bioimpedance Asymmetry for the Detection of Severe Stroke

## *Volumetric Impedance Phase-Shift Spectroscopy*




Low-energy radio waves pass through the brain at multiple frequencies

The device measures brain tissue *bioimpedance* in both hemispheres of the brain across a wide range of frequencies

Detects fluid asymmetries

Aids in neurological assessment

# Bioimpedance Asymmetry for the Detection of Severe Stroke


## NEXT Generation Visor System
## Designed for acute triage

Easy to use

Results within 30 seconds

Objective result

Does not require specialized training

Proprietary machine learning platform

New Devices

# The VITAL study and overall pooled analysis with the VIPS non-invasive stroke detection device

Christopher P Kellner,[1] Eric Sauvageau,[2] Kenneth V Snyder,[3] Kyle M Fargen,[4] Adam S Arthur,[5] Raymond D Turner,[6] Andrei V Alexandrov[7]

## Derivation Study of an Early Version of the Technology

Identified severe ischemic and hemorrhagic strokes across

the entire cohort of all analyzed subjects with:

93% sensitivity and 87% specificity

Kellner et al. *JNIS.* 2018.

# The VITAL Study
# And Overall Pooled Analysis With
# VIPS Non-Invasive Stroke Detection

Pilot cohort: 41 Acute stroke codes at MUSC
Healthy normal cohort: 79 normal healthy controls
VITAL cohort: 128 wide ranging brain pathology subjects
Multicenter: University at Buffalo, Mount Sinai Health System, MUSC, Baptist Hospital at Jacksonville Florida, University of Tennessee

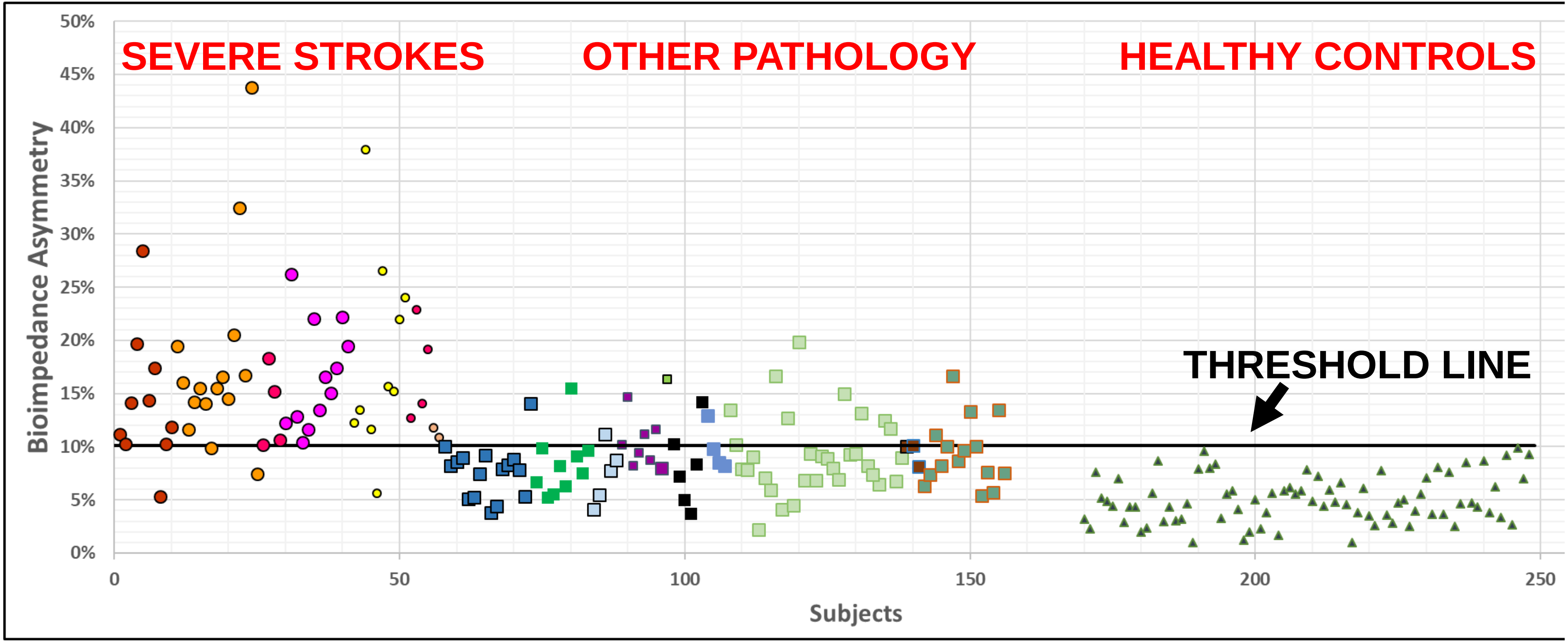
Excluded: Subjects with prior craniotomy or intracranial implant (5%)

Kellner et al. *JNIS.* 2018.

# Need for Severe Stroke Triage

| Yes | No |
| --- | --- |
| LVO: ICA/M1 | Acute Small Strokes |
| LVO: Prox M2 | ICH < 60cc |
| LVO: Distal M2 | Tumors |
| Severe stenosis with NIHSS ≥ 6 | Old Non-Territorial Strokes |
| ICH ≥ 60cc | Stroke Mimics |
| Established Territorial Strokes | Seizure |
| | SDH |
| | SAH |
| | Other |
| | Healthy Subjects |

# Results - Overall Pooled Data - 235 Subjects



# Results

**Table 2** Mean bioimpedance asymmetry in subjects with severe stroke, small strokes, and healthy adults

| | No of patients | Mean bioimpedance asymmetry |
|---|---|---|
| Stroke | | |
| Severe stroke | 57 | 16.5% (95% CI 14.6 to 18.4) |
| Small stroke | 26 | 8.0% (95% CI 6.9 to 9.0) |
| Healthy adults | 79 | 5.0% (95% CI 4.5 to 5.5) |

# Results

**Table 3** Diagnostic accuracy of the volumetric impedance phase shift spectroscopy device

| | Sensitivity | Specificity | AUC |
|---|---|---|---|
| Severe strokes among all strokes | 93% (95% CI 83 to 98) | 92% (95% CI 75 to 99) | 0.93 (95% CI 0.85 to 0.97) |
| Severe strokes among all evaluated subjects | 93% (95% CI 83 to 98) | 87% (95% CI 81 to 92) | 0.93 (95% CI 0.89 to 0.96) |

# Next Steps: Clinical Trial Validation
# *Demonstrate Effectiveness as Severe Stroke Triage Tool*

VUE – Visor User Experience – Multicenter, international effort

VIGOR Study: Volumetric Impedance Guiding Stroke Response

Validate a refined algorithm to detect Severe Stroke in the hospital

FIELD Study: Field Cerebral Impedance Evaluation for Large Stroke Detection

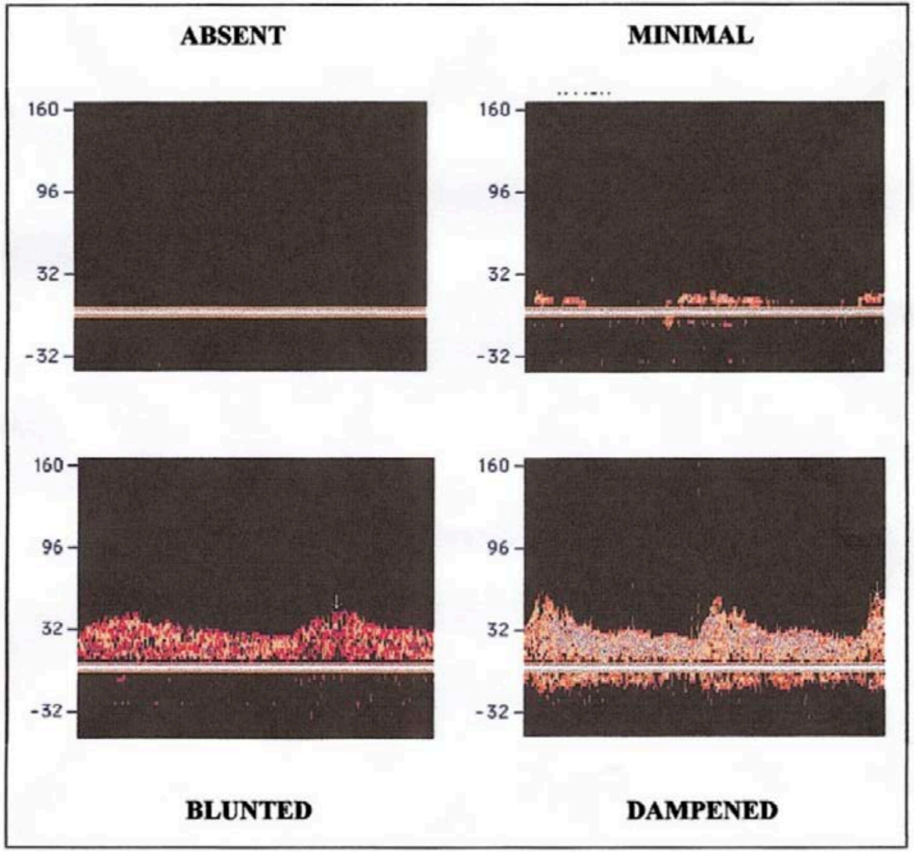
Expand validation to EMS use in the ambulance

# Specific Transcranial Doppler Flow Findings Related to the Presence and Site of Arterial Occlusion

Andrew M. Demchuk, MD, FRCPC; Ioannis Christou, MD; Theodore H. Wein, MD, FRCPC; Robert A. Felberg, MD; Marc Malkoff, MD; James C. Grotta, MD; Andrei V. Alexandrov, MD, RVT

190 patients studied from 1997 to 1999.
Angiography demonstrated occlusion in 48 patients

Sensitivity of 83% and specificity of 94%
Optimal sensitivity in the proximal ICA (94%) and MCA (93%)




*Abnormal ICA, MCA, or ACA Waveforms*

1. *Dampened signal:* Pulsatile flow with normal flow acceleration and decreased MFV (≥30% difference between hemispheres); any PI values.
2. *Blunted signal:* Delayed flow acceleration with stepwise maximum velocity arrival during mid to late systole compared with contralateral side and focal decreased MFV and positive end-diastolic flow (low PI≤1.1).
3. *Minimal signal:* Presence of a flow signal with no end diastolic flow; PI≥1.2.
4. *Absent signal:* No detectable flow at 40- to 65-mm depths (toward the probe) via transtemporal window (double-checked with insonation from contralateral window across midline at depths of 80 to 100 mm).

Demchuk et al. *Stroke.* 2000.

# Specific Transcranial Doppler Flow Findings Related to the Presence and Site of Arterial Occlusion

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Additional Signs of Arterial Occlusion

Reversed ophthalmic artery flow
Anterior cross-filling via acomm
Anterior cross-filling via pcomm
Contralateral compensatory velocity increase

Demchuk et al. *Stroke.* 2000.

**TABLE 2. Flow Diversion, Velocity Increase, and Collaterals in the Anterior Circulation Occlusion**

| Occlusion Site | Flow Diversion, % | | | Velocity Increase, % | | Collaterals, % | | |
|---|---|---|---|---|---|---|---|---|
| | ACA | PCA | Perforators | Contralateral | Posterior | OA | ACoA | PCoA |
| MCA | 46.7* | 33 | 73.3† | 62.5 | 46.2 | 23.5† | 31.3† | 23.1† |
| dICA | 12.5 | 42.9 | 22.2 | 70 | 88.9 | 16.7‡ | 50 | 60 |
| pICA | 8.3 | 9.1 | 16.7 | 84.6 | 62.5 | 70.6 | 78.6 | 71.4 |
| None | 2.8 | 6.7 | 1.8 | 17.9 | 13.1 | 5.6 | 8.2 | 8.5 |
| $P$ ($\chi^2$) | $<$0.001 | 0.003 | $<$0.001 | $<$0.001 | $<$0.001 | $<$0.001 | $<$0.001 | $<$0.001 |

d indicates distal; p, proximal; t, terminal; OA, ophthalmic artery; and $P$ ($\chi^2$), 2-tailed $P$ value, $\chi^2$ analysis.
*$\chi^2$ $P<0.1$ proximal ICA vs MCA; †$\chi^2$ $P<0.05$ proximal ICA vs MCA; ‡$\chi^2$ $P<0.05$ distal ICA vs proximal ICA.

Demchuk et al. *Stroke.* 2000.

# Robotic Transcranial Doppler

The Lucid™ Robotic System by Neural Analytics is an FDA/ CE cleared advanced ultrasound robotic TCD system that automates the collection of neurological brain blood flow data.

The system is indicated to measure and monitor cerebrovascular blood flow and count embolic particulate

FDA cleared – May of 2018

CE Marked – May of 2018

# Robotic Transcranial Doppler

**The Lucid M1 Transcranial Doppler Ultrasound System™ and Neuralbot™ Accessory (Lucid Robotic System) is a robotically assisted, transcranial doppler medical grade ultrasound system.**

- It combines an all-in-one neurovascular ultrasound device, designed to non-invasively measure and display brain blood flow information with a medical robot to collect data under the guidance of a healthcare professional

**The Lucid Robotic System measures and discerns blood flow patterns in a patient's brain by combining ultrasound with robotics and machine learning to identify physiological changes associated with neurological disorders in real-time.**

- **94% accuracy** in detection of acute ischemic stroke with Lucid System vs. an invasive CT test
- The Lucid System collects **data equivalent to an expert Ultrasound Technologist**

# Robotic Transcranial Doppler

Analysis is non-invasive and can be performed in settings inside and outside the hospital enabling physicians and first responders to diagnose brain disorders, prior to the need for additional, more invasive testing.

It can also be used to monitor particulate in the blood during and after surgery and for the detection of PFOs (holes in the heart).

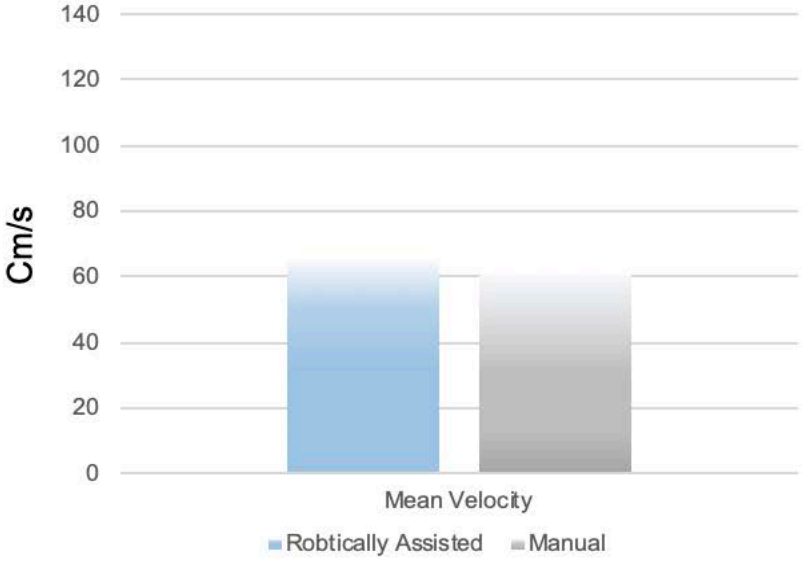
# Robotic Transcranial Doppler

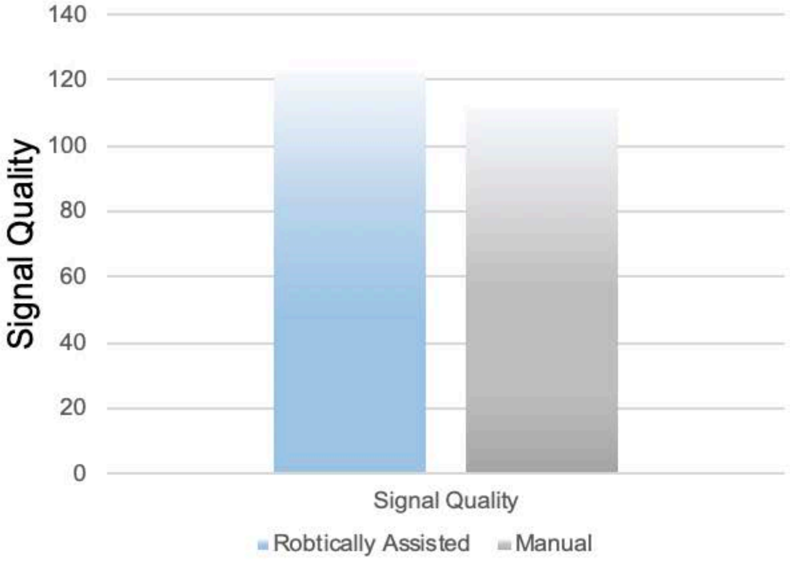
## Robotically Assisted

A robotically assisted medical ultrasound system capable of searching, finding and displaying cerebrovascular blood flow velocity and embolic data under the guidance of a medical professional.

# Robotic Transcranial Doppler

Spectrogram signal quality and measurements are equivalent to expert manual acquisition




*O'Brien, et.al. Fully Automated Transcranial Doppler Ultrasound Insonation of the MCA Using a Five Degree of Freedom. Presented. ESNCH 2018

# AlphaStroke

EEG based technology

Takes approximately 1 minute to provide a reading

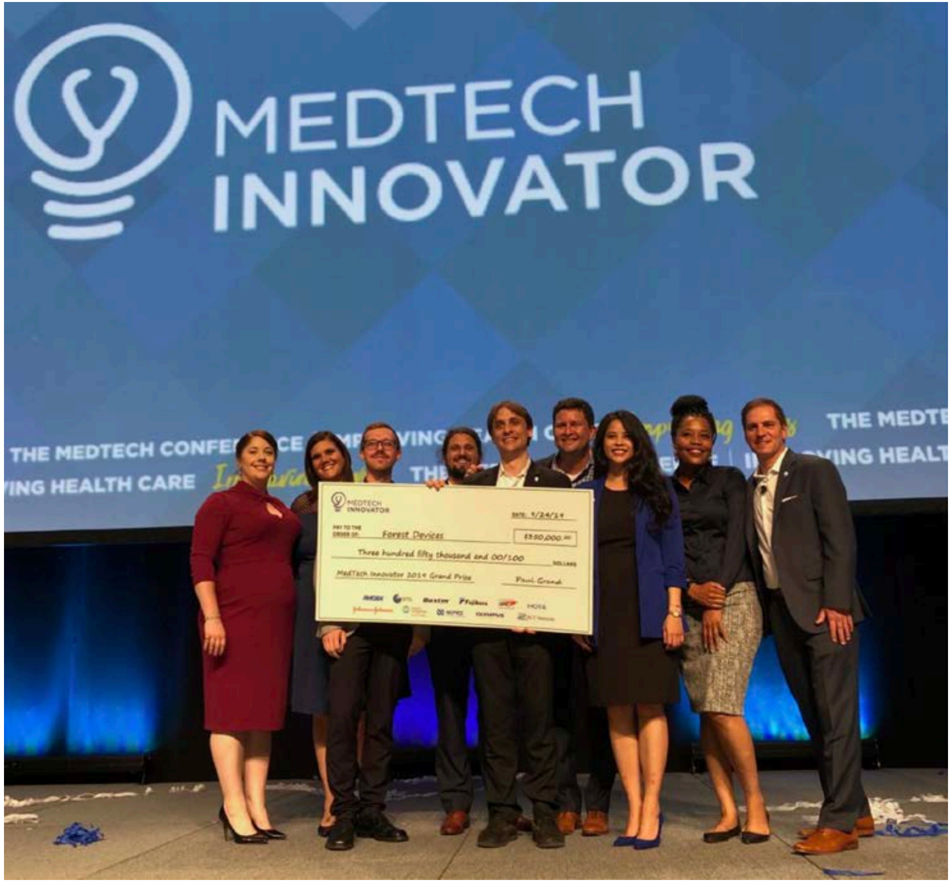
Handheld (smartphone size) connected wirelessly to the EEG leads attached to the head.

# AlphaStroke

Forest Devices

Founded in 2015 in Pittsburgh

“The first device designed to detect stroke in any environment. The mission of Forest Devices is to reduce the disability of stroke victims by getting these patients needed treatments faster.”


MEDTECH
INNOVATOR
Forest Devices
Three hundred fifty thousand and 00/100
MedTech Innovator 2019 Grand Prize

# BrainPulse

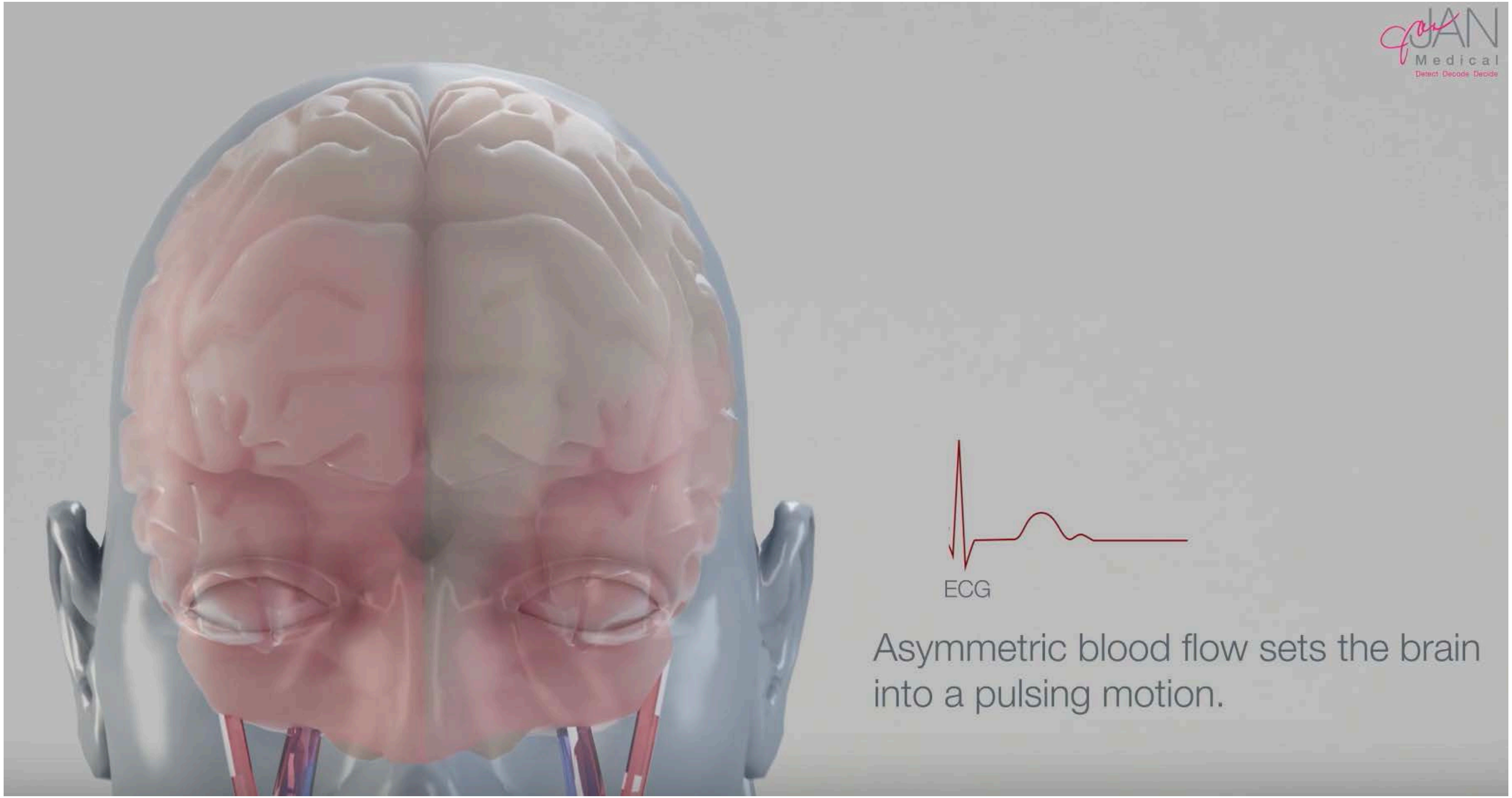
Developed by Jan Medical, Inc., in Mountain View, CA

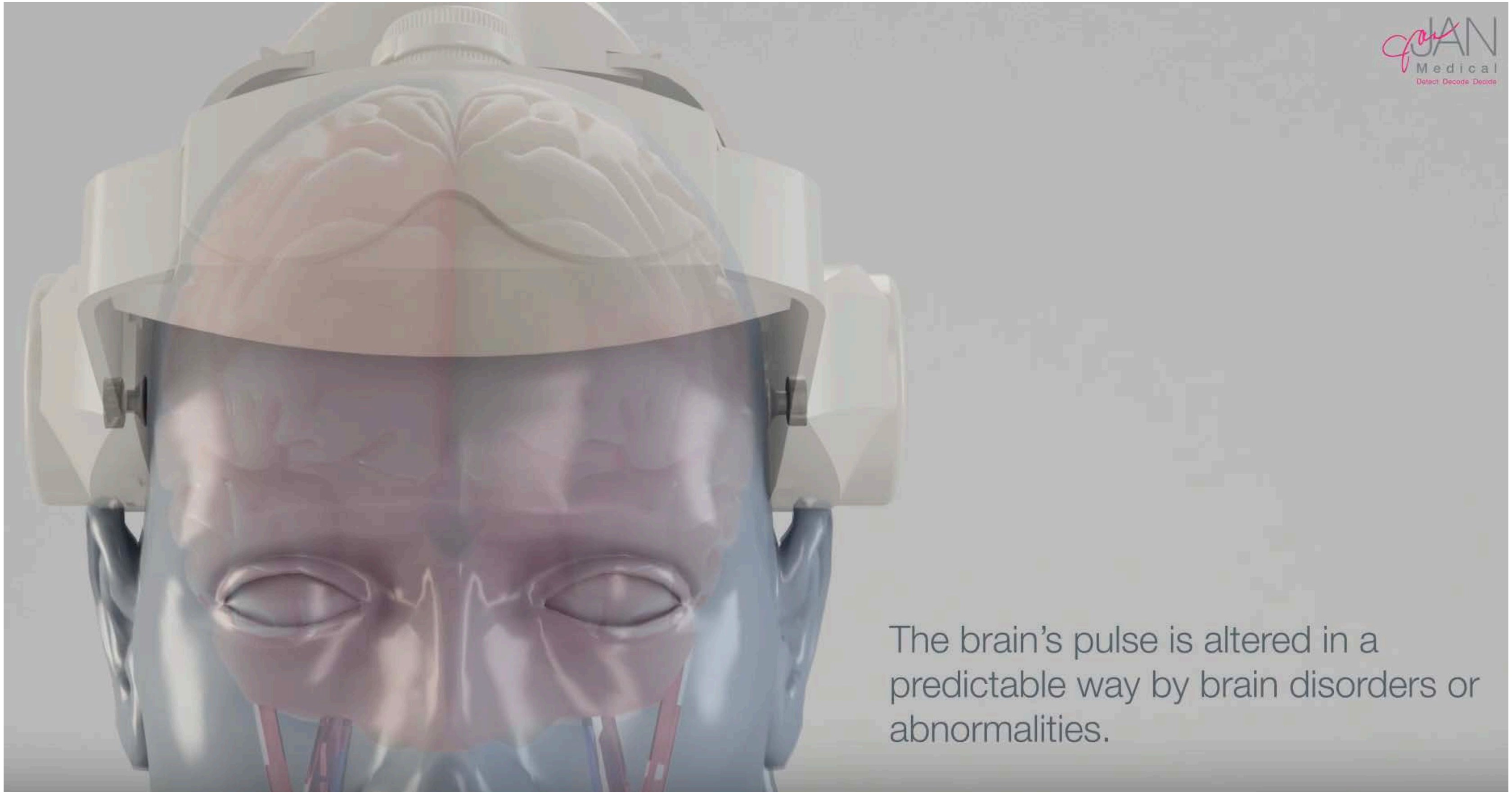
Technology utilizes accelerometers

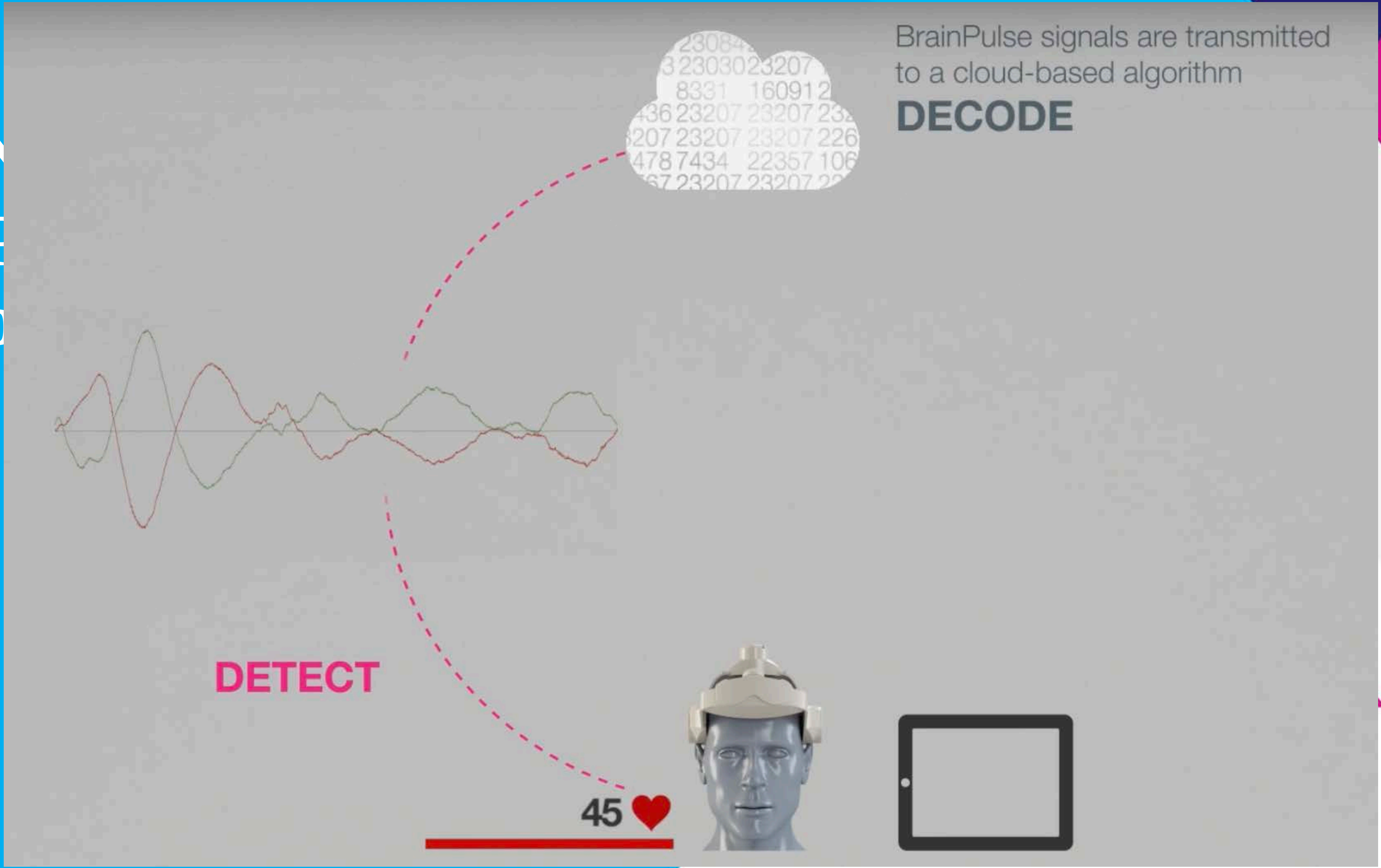
Potentially Applicable to acute stroke, concussion, vasospasm, and  other brain pathology

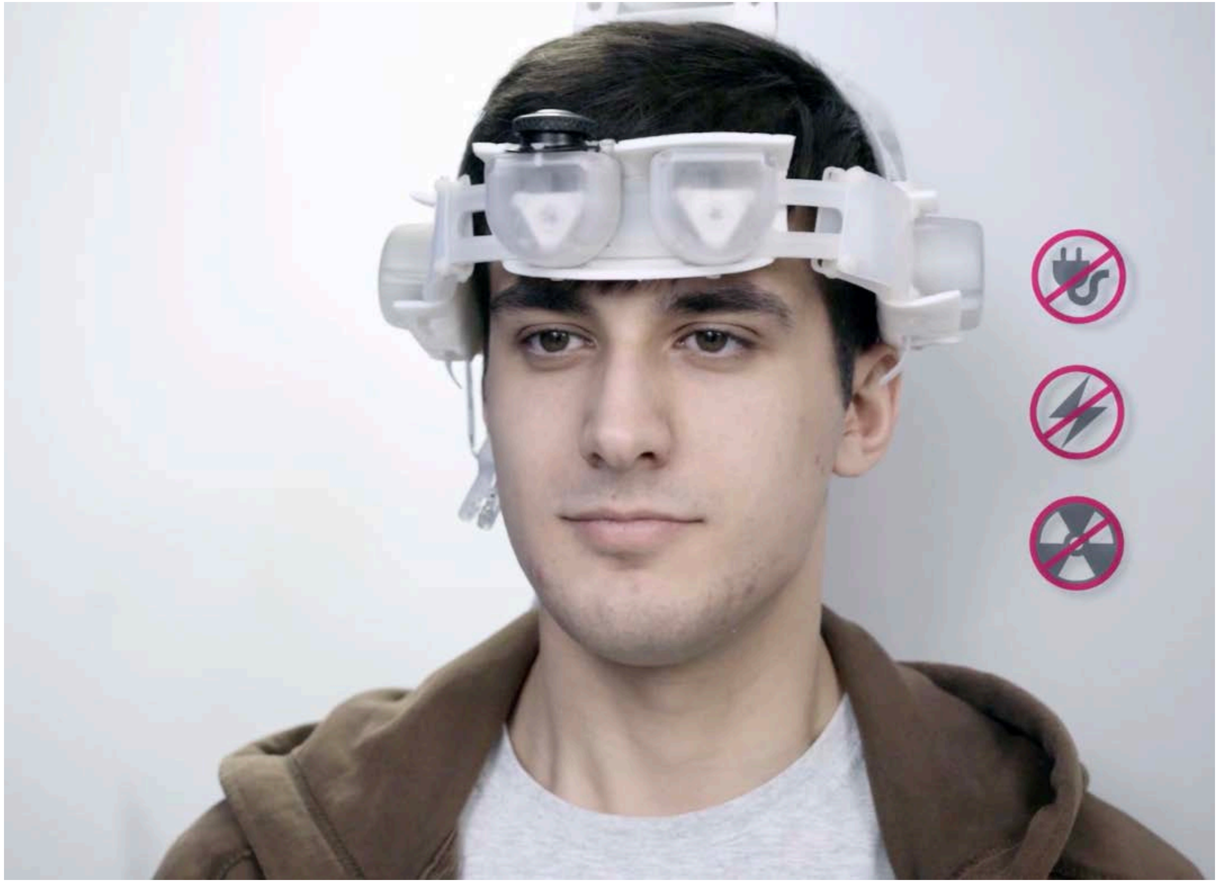
Takes 45 seconds to get a reading

Collaborating with the US Army


ECG
Asymmetric blood flow sets the brain
into a pulsing motion.
Medical
Detect Decode Decide


JAN
Medical
Detect Decode Decide
The brain's pulse is altered in a predictable way by brain disorders or abnormalities.


BrainPulse signals are transmitted
to a cloud-based algorithm
DECODE
DETECT
45



# Pilot Study of Acute Stroke Using the Brainpulse™

## Study Design

Go to

| | |
|---|---|
| Study Type : | Observational |
| Estimated Enrollment : | 75 participants |
| Observational Model: | Cohort |
| Time Perspective: | Prospective |
| Official Title: | Non-Blinded Data Collection Pilot Study of Acute Stroke Using the Brainpulse™ |
| Actual Study Start Date : | September 10, 2017 |
| Estimated Primary Completion Date : | June 1, 2020 |
| Estimated Study Completion Date : | June 1, 2020 |

Neurocritical Care
December 2015, Volume 23, Issue 3, pp 364–369 | Cite as

# Cranial Accelerometry Can Detect Cerebral Vasospasm Caused by Subarachnoid Hemorrhage

Authors | Authors and affiliations

Wade S. Smith [1]
Email author

Janet L. Browne [1]

Nerissa U. Ko [1]

1. Department of Neurology, University of California, San Francisco, San Francisco, USA

# Brainscope

Developed by Brainscope Company, Inc in Bethesda, MD

Utilizes EEG

Takes minutes to get a reading


BrainScope
Electrode Headset
RoHS Compliant
C1
Hairline
C2
Innovated and Created in the USA
R1
Keep Tab Above Eyebrow
L1
Keep Tab Above Eyebrow
R2
L2
Avoid Artery
Align Nasion First
BrainScope® One Information Hub
PATIENT INFORMATION
John Williams
ID: 123123 DOB: Nov/23/1990
Date of Injury: Jun 3, 2017 GCS: 15
Time of Injury: 5:34 PM Injury Type: Fall
STRUCTURAL INJURY ASSESSMENT
TEST RESULT / SCORE
EEG
Structural Injury Classifier (SIC)
Negative
Likely no head injury visible on head CT
FUNCTIONAL INJURY ASSESSMENTS
TEST RESULT / SCORE
EEG
Brain Function Index (BFI)
9th Percentile Below Average B
NEURO COG
Complex Reaction Time
Clearly Below Average C
Match to Sample
Below Average B

P

Academic Emergency Medicine / Volume 22, Issue 1

Original Contribution | Free Access

# Identification of Acute Stroke Using Quantified Brain Electrical Activity

Edward A. Michelson MD, Daniel Hanley MD, Robert Chabot PhD, Leslie S. Prichep PhD

First published: 06 January 2015
https://doi.org/10.1111/acem.12561


Forty-eight stroke patients (31 ischemic and 17 hemorrhagic) and 135 stroke mimic controls were included. Within the ischemic population, approximately half were CT– but later confirmed for stroke with MRI (CT–/MRI+). Sensitivity to stroke was 91.7%, specificity 50.4% (to stroke mimic), NPV 94.4%, and PPV 39.6%.

# Published Evidence

11 peer reviewed publications for use in traumatic brain injury

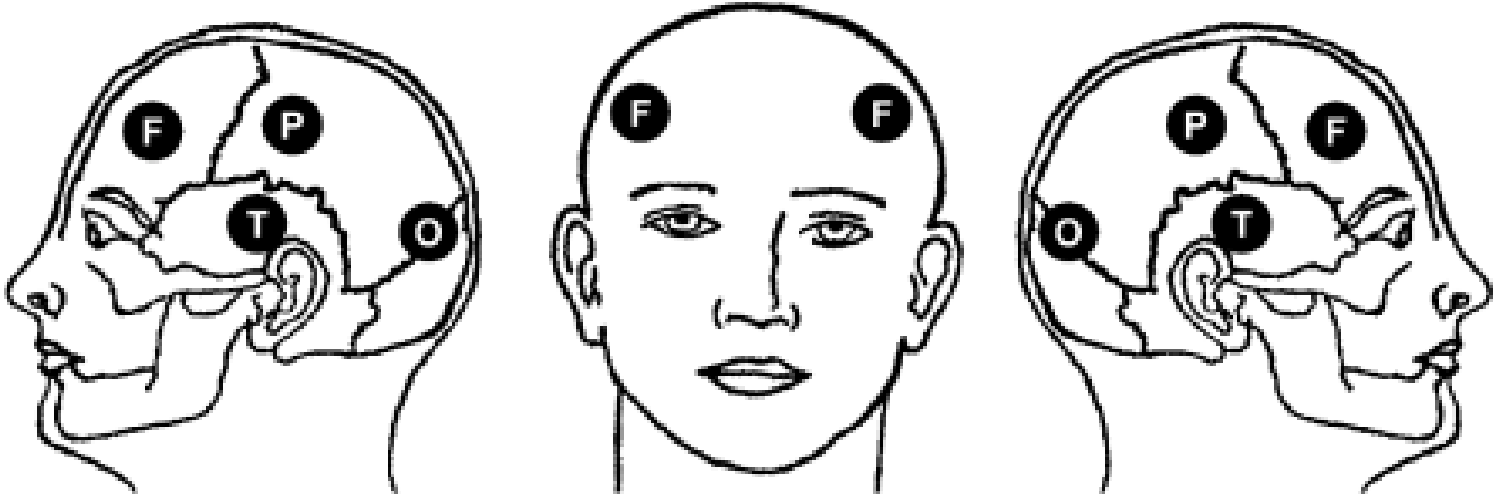
Collaborating with the Department of Defense

# Infrascanner

Developed by Infrascan, Inc. from Philadelphia

Utilizes near-infrared (NIR) to detect differential light absorption between injured and noninjured parts of the brain


FRASCANNER®
Locate




| | |
|---|---|
| **F**rontal | Left/Right forehead, above the frontal sinus |
| **T**emporal | In the Left/Right temporal fossa |
| **P**arietal | Above the Left/Right ear, midway between the ear and the midline of the skull |
| **O**ccipital | Behind the Left/Right ear, midway between the ear and the occipital protuberance |

# Publications

18 peer-reviewed publications

Focusing on traumatic brain injury and intracerebral hemorrhage

4 February 2019

# Early diagnosis of traumatic intracranial hematomas

Hasan Ayaz; Meltem Izzetoglu; Kurtulus Izzetoglu; Banu Onaral; Baruch Ben Dor

The evaluation of Infrascanner measurements in comparison to CT scans is based on a total of 431 patient data, where 122 of them were hematoma cases of various sizes, depths, and locations. Study results address the hematomas that clinicians may expect the Infrascanner to detect in the clinical practice setting. Consistent with preclinical testing, the Infrascanner demonstrated high sensitivity (88%) in detecting hematomas >3.5>3.5 cc in volume and <2.5cm<2.5 cm from the surface of the brain. Specificity in the per protocol population was 91%.

# Sense

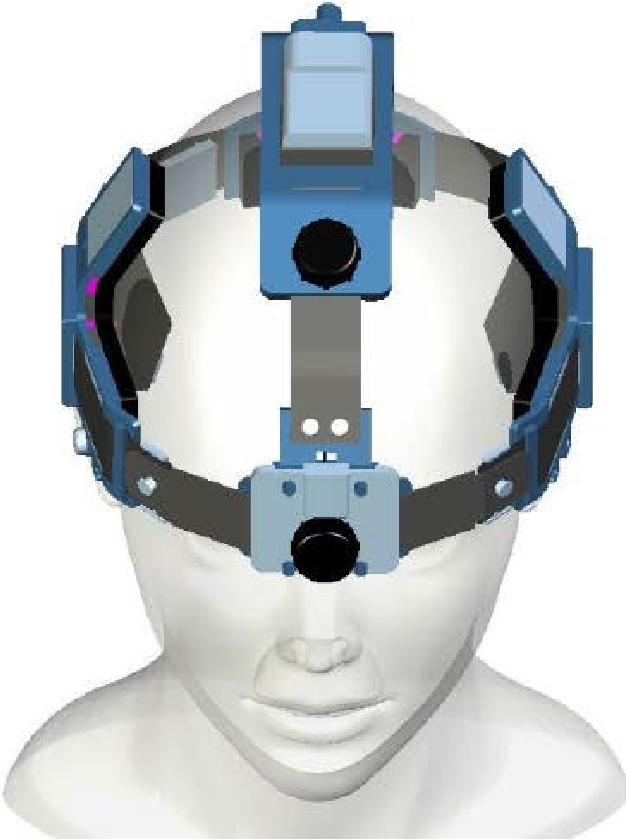
Developed by Sense Diagnostics from Cincinnati, OH

Utilizes low powered electro-magnetic pulse in the radiofrequency range

Detects changes in the signal that may indicate hemorrhage, swelling, or seizure sense

Diagnostics, Inc

Non-invasive, low-power
radar for the brain



# A Study to Test the SENSE Device in Patients With Intracranial Hemorrhage

| | |
|---|---|
| Study Type ℹ : | Interventional (Clinical Trial) |
| Actual Enrollment ℹ : | 10 participants |
| Intervention Model: | Single Group Assignment |
| Masking: | None (Open Label) |
| Primary Purpose: | Other |
| Official Title: | An Early Feasibility Study to Evaluate the User Interfaces and Sensitivity of the SENSE Device in Patients With Intracranial Hemorrhage |
| Actual Study Start Date ℹ : | February 23, 2017 |
| Actual Primary Completion Date ℹ : | December 31, 2017 |
| Actual Study Completion Date ℹ : | December 31, 2017 |

## Strokefinder

Developed by Medfield Diagnostics from Goteborg, Sweden

Utilizes microwave technology

Proposed for stroke and traumatic brain injury

# Evidence

8 peer reviewed publications

# Microwave-Based Stroke Diagnosis Making Global Prehospital Thrombolytic Treatment Possible

**Publisher: IEEE**

**8 Author(s)** Mikael Persson ; Andreas Fhager ; Hana Dobšíček Trefná ; Yinan Yu ; Tomas Mc... **View All Authors**

2014

10 ICH and 15 ischemic stroke, 65 healthy vounteers

- Differentiating ICH from ischemic stroke
- AUC 0.85
- Differentiating ICH from healthy
- AUC 0.87

# Conclusions

Time is critical for some patients.

We need new technology to triage these patients.

We have some good options that require further investigation.

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# Thank you.
# Questions?

Mount Sinai