

# Emboli Detection During Pediatric Mechanical Circulatory Support

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**ASN 42<sup>ND</sup> ANNUAL MEETING  
JANUARY 24-26, 2019**



**PUERTO RICO** 

# DISCLOSURES

**Kerri L LaRovere** has no conflicts of interest or financial disclosures to make

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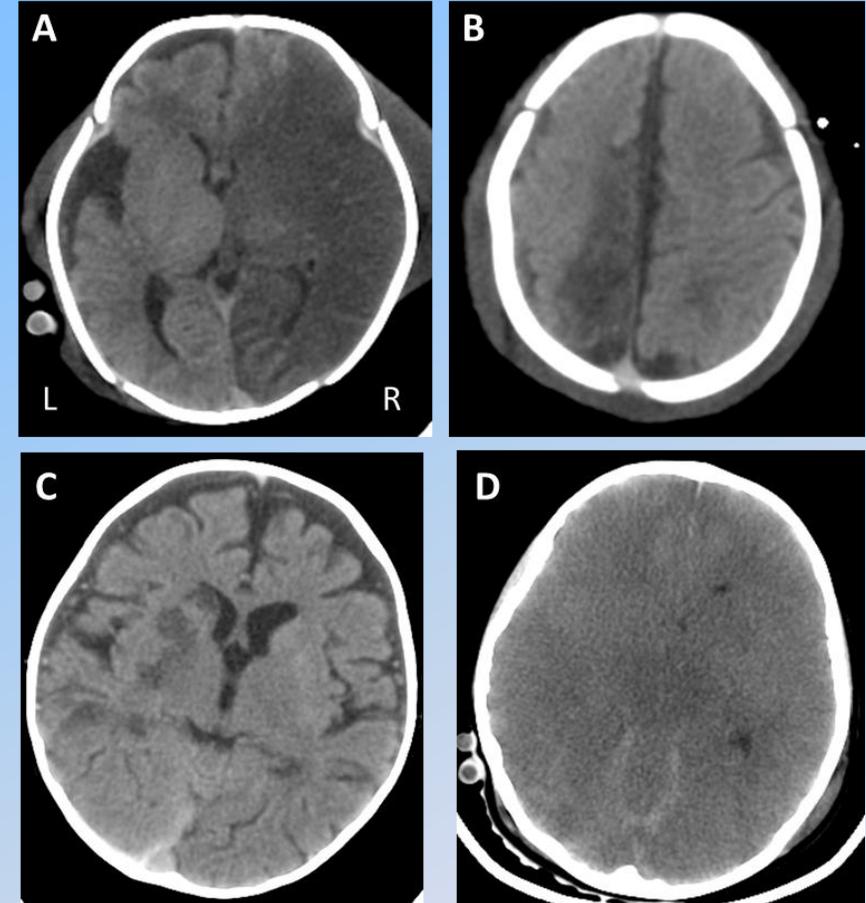
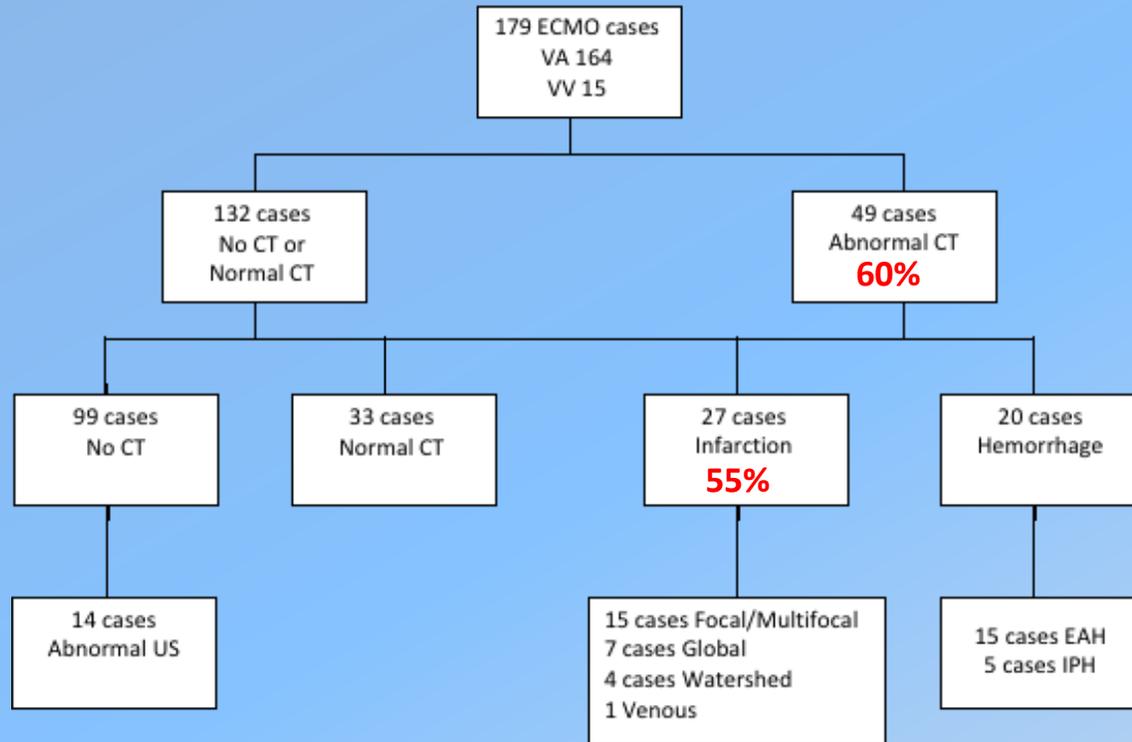
# Objectives

- Review epidemiology of acute neurologic injury (ANI) during pediatric mechanical circulatory support (MCS)
- Discuss our study of emboli detection in children undergoing cardiac catheterization or on MCS with extracorporeal membrane oxygenation (ECMO) or ventricular assist device (VAD) therapy

# Epidemiology of ANI

- 60,000 children treated with ECMO (2009 – 2015)
- Survival rates for ECMO: 50 – 65% overall
- Acute neurologic injury (ANI) in ECMO patients
  - Intracranial hemorrhage 5 – 25%
  - Cerebral ischemia 5 – 30%
  - Seizures 8 – 30%
  - Brain death 10% (ECPR group)
- After ANI, survival is reduced: 20 – 35%

# Stroke During Pediatric ECMO



- **Reduced survival** for infarction (OR, 0.22; 95% CI, 0.09 – 0.54) and hemorrhage (OR, 0.31; 95% CI, 0.13 – 0.72)
- **Increased cognitive disability** (moderate or worse; p=0.01) with abnormal CT

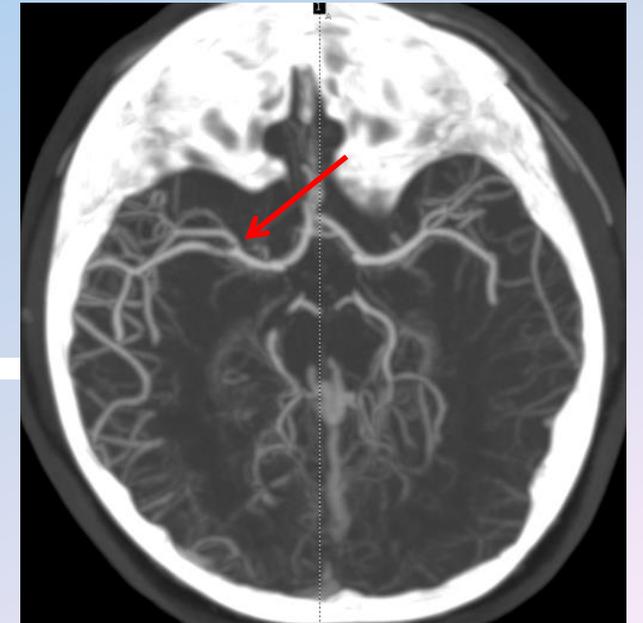
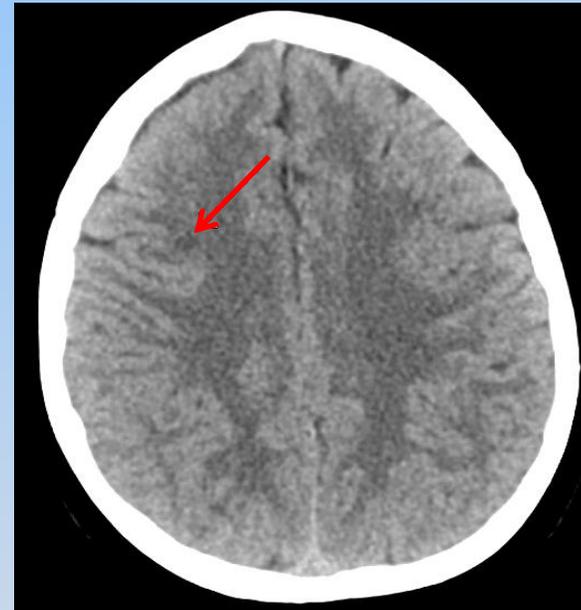
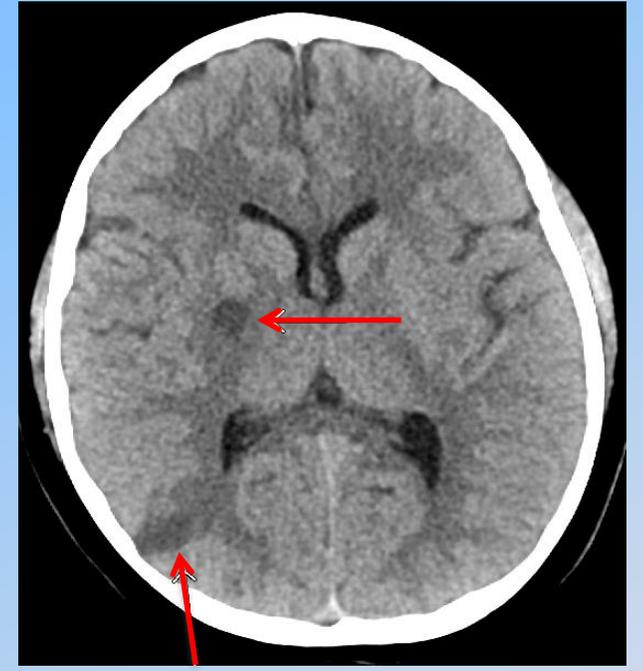
- A: Multifocal AIS (10 cases)
- B: Focal arterial ischemic stroke (5 cases)
- C: Watershed infarction (4 cases)
- D: Global infarction (7 cases)

# Embolic Stroke During VAD therapy

8 year old with dilated  
cardiomyopathy,  
biventricular  
thrombi

Acute left HP (arm/leg)

**Pediatric NIHSS Total  
Score: 30**



# Risk factors for ANI

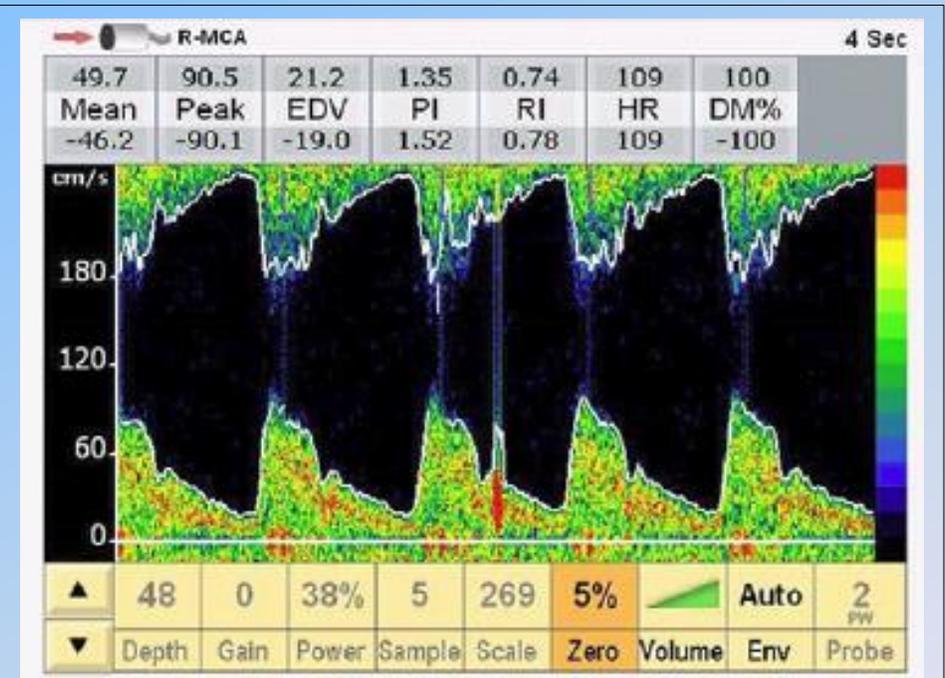
- **On pump**
  - Alterations of CBF (cerebral venous hypertension, non-pulsatile blood flow)
  - Mode of ECMO (VA vs. VV)
  - Change to anticoagulation
  - Drug neurotoxicity
  - Embolic phenomena (air, solid)
- **Perinatal** (prematurity, hypoxia-ischemia)
- **Pre-existing** (genetic, chronic cyanosis)
- **Peri-cannulation** (hypoxia, hypotension, CPR, acidosis)
- **Modifiers** (developmental stage, indication, disease severity, other)

# Cerebral Emboli

- Potential target cause or marker of risk of ANI during MCS
- TCD can detect emboli, representing air or solid
- Detected as high intensity transient signals (HITS) within Doppler spectrum
- Knowledge about prevalence and circumstances of HITS in children undergoing MCS is lacking

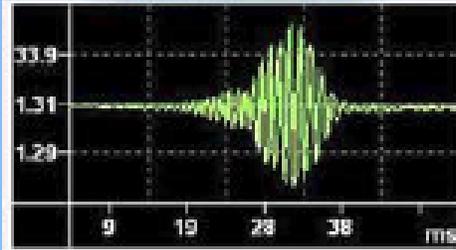
# Stroke 1995 Emboli Criteria by TCD

- Increased energy level above background
- Unidirectional within the Doppler spectrum
- Audible component (snap, chirp, moan)



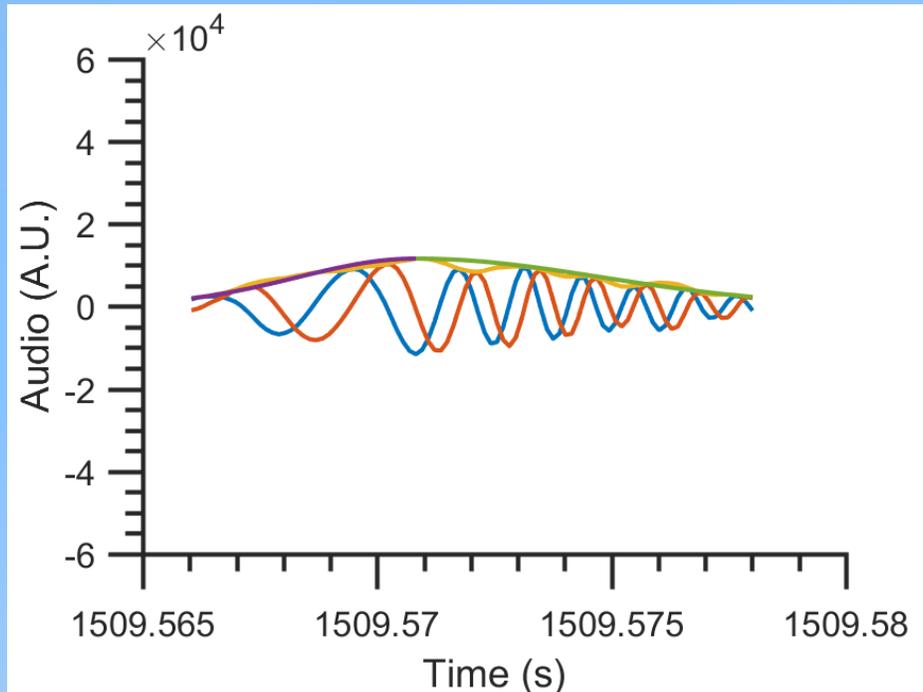
# Amplitude Modulation

Audio (A.U.)

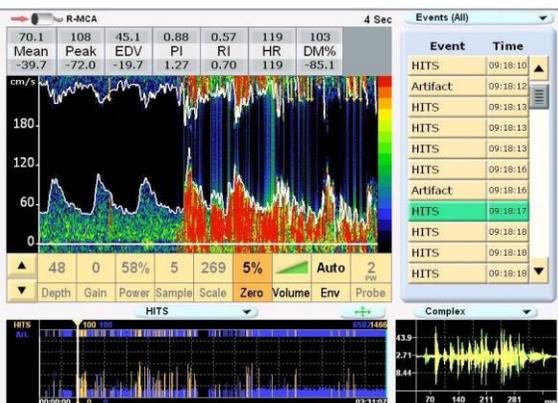
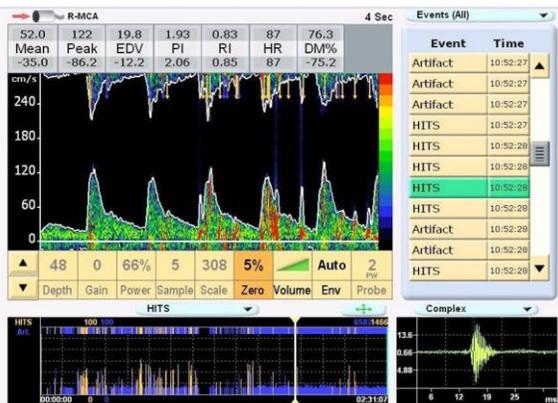
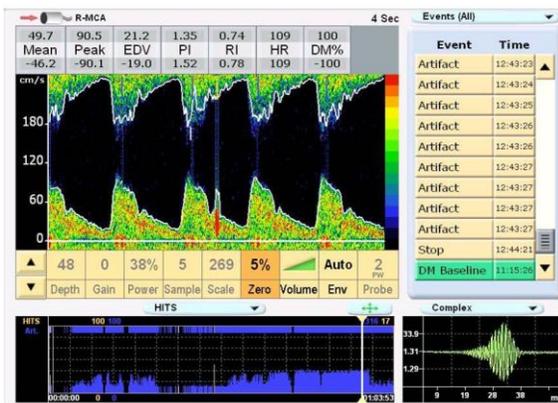


Time

**Time domain signal:** amplitude and/or frequency modulation over time



**Emboli: sinusoidal envelope**



# Cerebral High-Intensity Transient Signals during Pediatric Cardiac Catheterization: A Pilot Study Using Transcranial Doppler Ultrasonography

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## ABSTRACT

**BACKGROUND AND PURPOSE:** Cerebral emboli are one potential cause of acute brain injury in children with congenital heart disease (CHD) undergoing cardiac catheterization. In this pilot study using transcranial Doppler (TCD) ultrasonography, we sought to evaluate the incidence, burden, and circumstances of cerebral high-intensity transient signals (HITS), presumably representing emboli, during pediatric cardiac catheterization.

**METHODS:** Emboli monitoring of the right middle cerebral artery was performed in five children. HITS, counted offline, were defined as unidirectional signals associated with audible "chirp" and sinusoidal correlation. HITS were grouped as single, > 10 HITS ("cluster"), or HITS "with curtain effect" per 3–5 cardiac cycles. Cerebral blood flow velocity (CBFV) and pulsatility index (PI) were recorded after anesthetic induction (baseline).

**RESULTS:** Total HITS in the cohort was 1,697 (790 single HITS, 606 HITS within clusters, and 301 HITS within curtains). HITS in clusters and curtains comprised 53% (907/1,697) of total HITS, and occurred in 44 clusters/curtains. Events associated with clusters/curtains included left ventricular angiography (39%; 17/44), right ventricular angiography (16%; 7/44), device placement (16%; 7/44), heparin bolus (9%; 4/44), pulmonary artery angiography (9%; 4/44), venous access (5%; 2/44), right atrial angiography (2%; 1/44), arterial access (2%; 1/44), and hemodynamic measurements (2%; 1/44). No patient had clinically detectable neurologic injury.

**CONCLUSIONS:** HITS are common during pediatric cardiac catheterization, and associated with procedural factors. Whether curtains/clusters are worse than single, repetitive HITS is unknown. Larger studies are needed to determine whether HITS are a marker of risk of neurologic injury from emboli during pediatric cardiac catheterization.

Not always easy  
to count and identify events

# Current project

To develop a novel algorithm to improve discrimination of emboli vs artifact from analysis of TCD signals

## Collaborators

### **Thomas Heldt, PhD**

Associate Professor of Electrical and Biomedical Engineering, Massachusetts Institute of Technology (MIT)

### **Syed Muhammad Imaduddin, MIT PhD candidate**

### **Barry D. Kussman, MD, MBBCh, FFA(SA)**

Associate Professor, Department of Anesthesiology, Perioperative and Pain Medicine, Boston Children's Hospital

# Current project

- Prospective observational study with informed consent
- Inclusion – children undergoing cardiac catheterization, ECMO, VAD
- Exclusion – unable to get window
- Emboli monitoring (DWL Doppler-Box™X) of MCA (bilateral if possible) for up to 2 hours
- Prototype fixation device made by 3D printing



# Current project

Year 1

- Developed a data visualization and annotation tool
- Developed a three-stage emboli detection scheme using coarse segmentation (with embolus-to-blood ratio), fine segmentation of HITS, and artifact rejection using simple features

Year 2

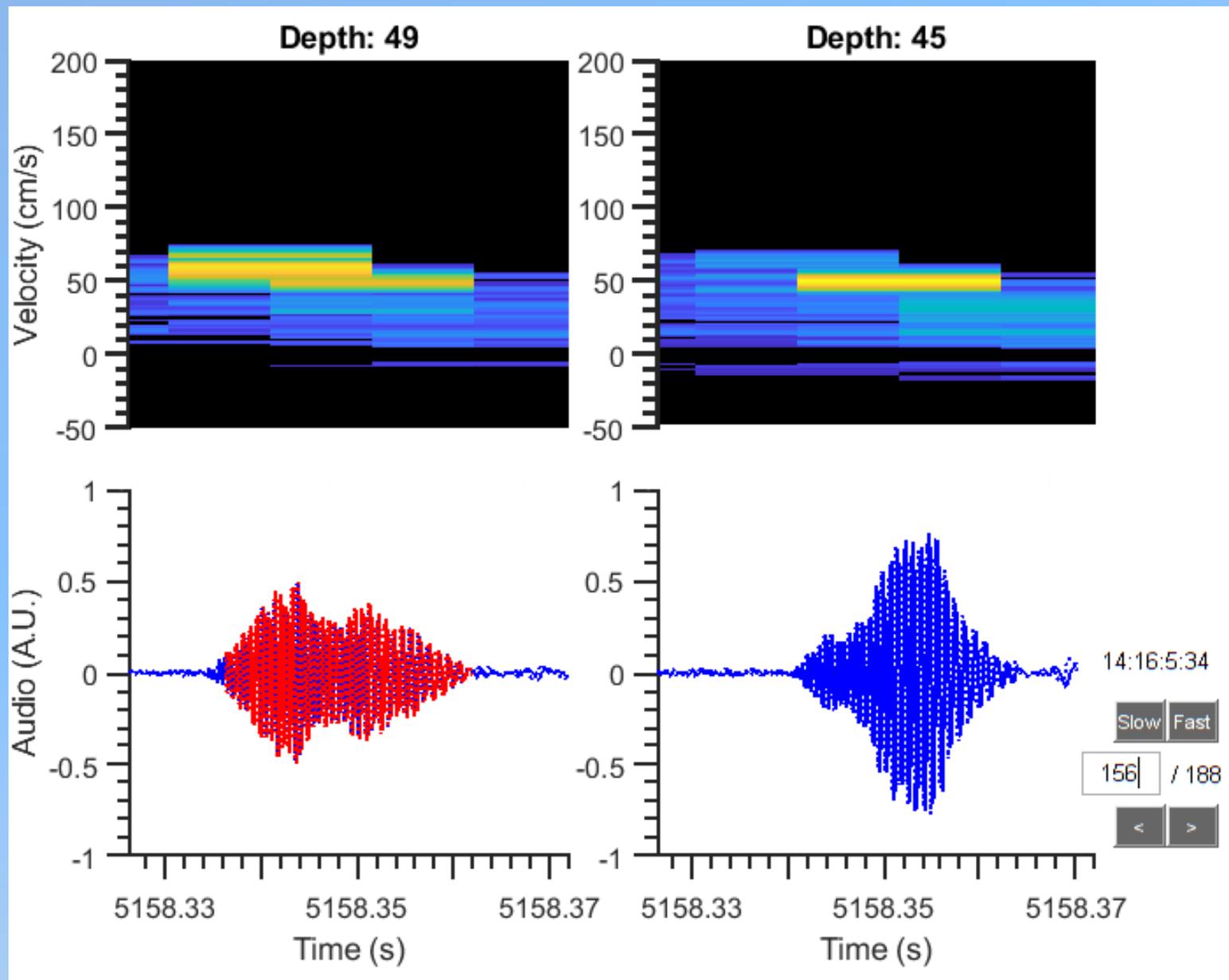
- Annotation of HITS manually to verify artifact rejection strategy
- Build classification model to distinguish between artifacts and emboli

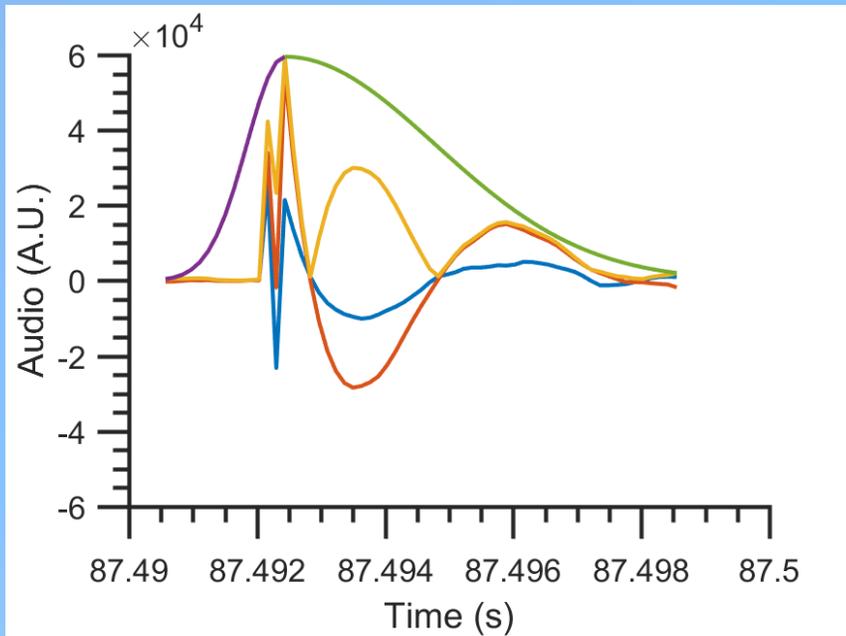
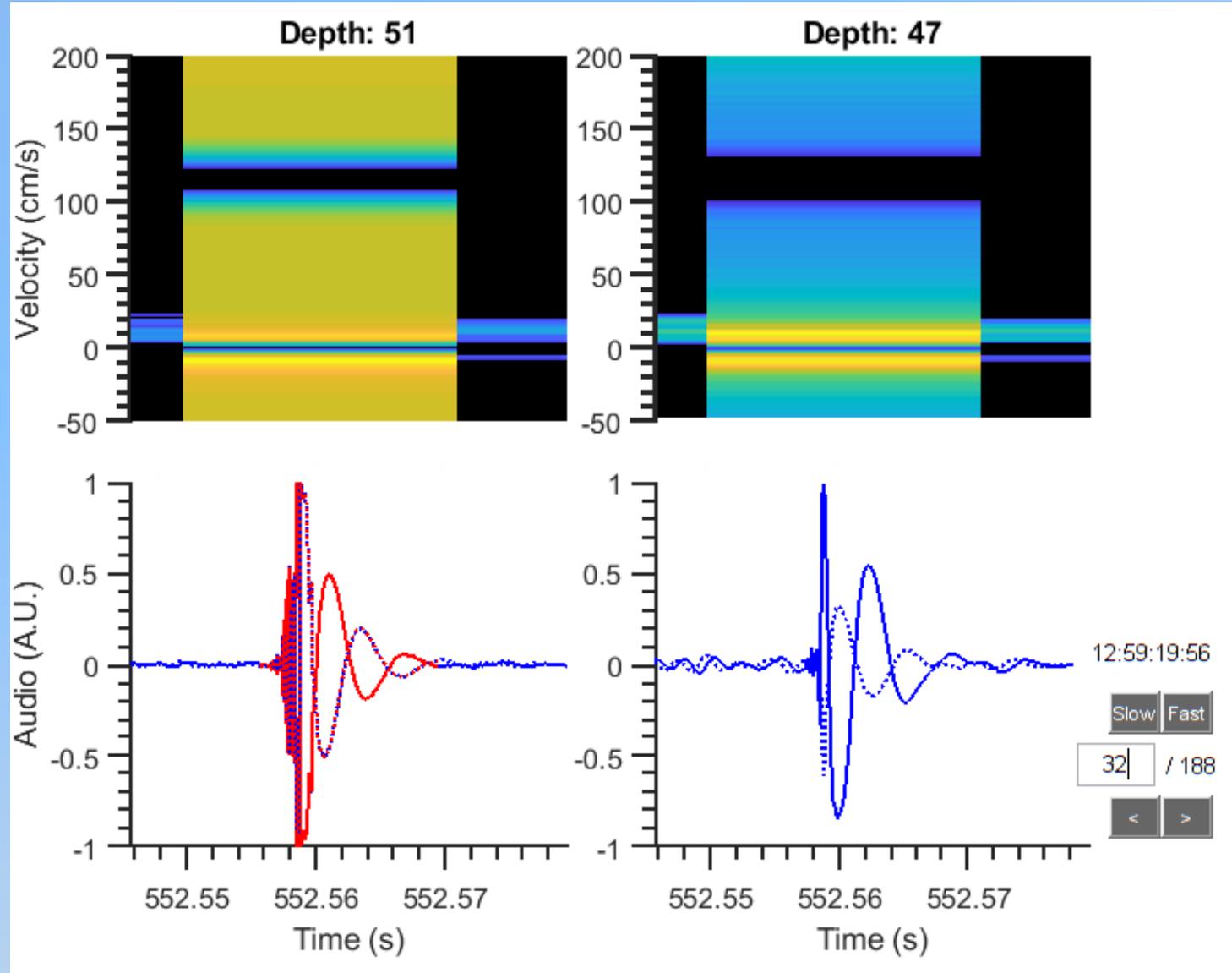
Year 3+

- Correlation of HITS with neurologic outcomes
- Identify specific modifiable factors causing HITS, and determine which HITS may be clinically actionable
- Study targeted strategies to reduce emboli and ANI

# Challenges

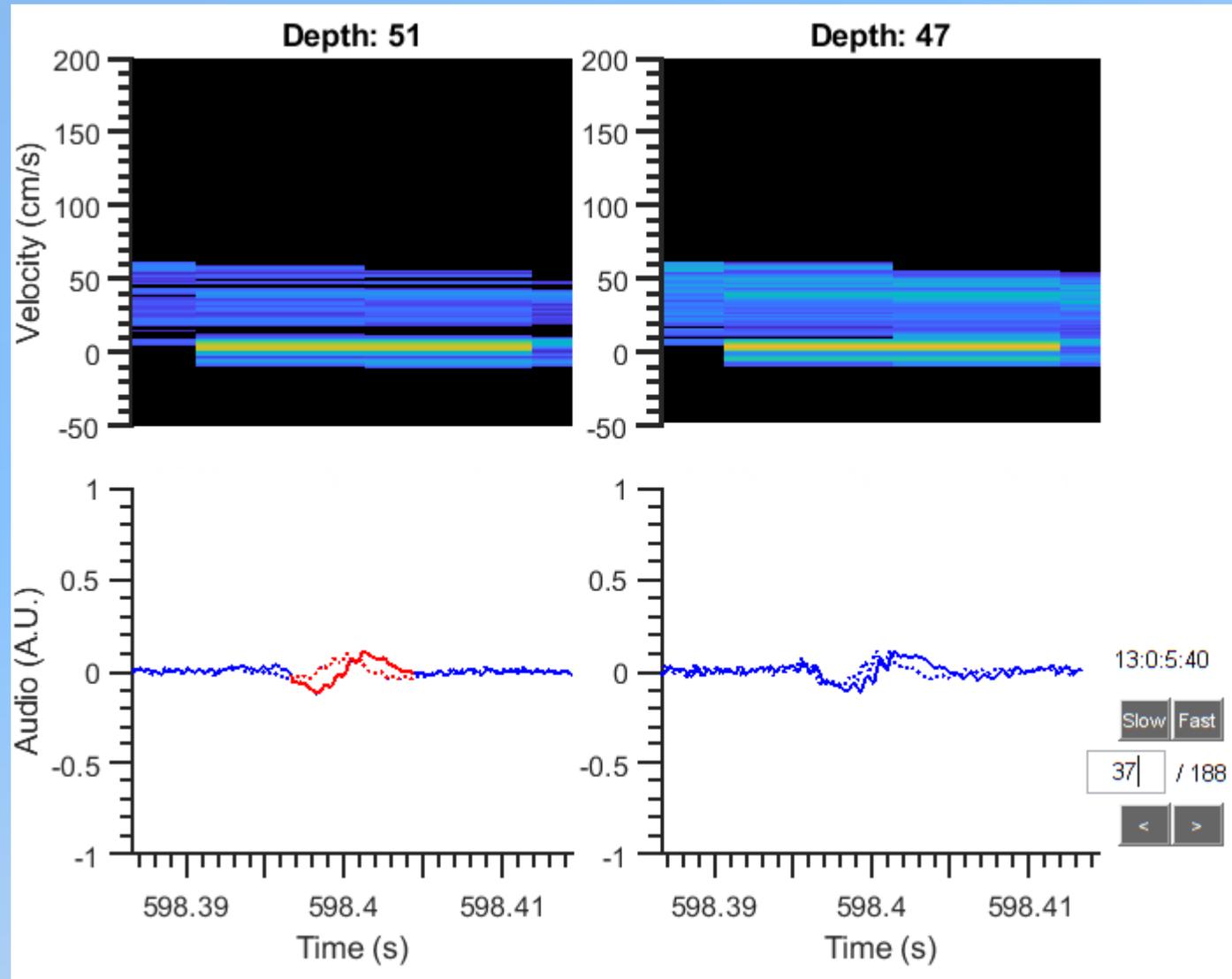
- Technical (windows, probe fixation)
- Time spent performing manual annotations (days to weeks)
- Consistency annotating events with artifact or embolic “features”
- Event separation



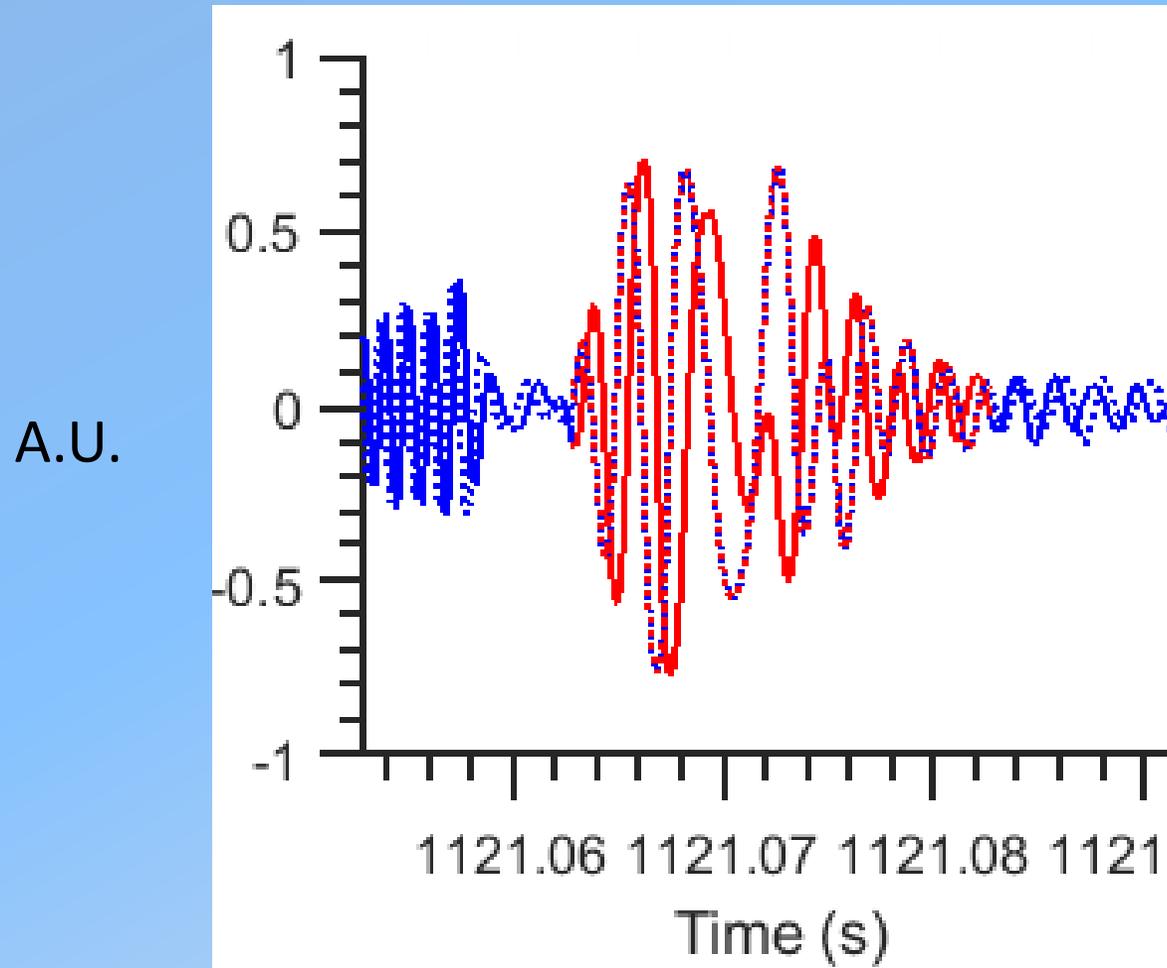


**Artifacts: skewed signal envelope**

# What about this segment?



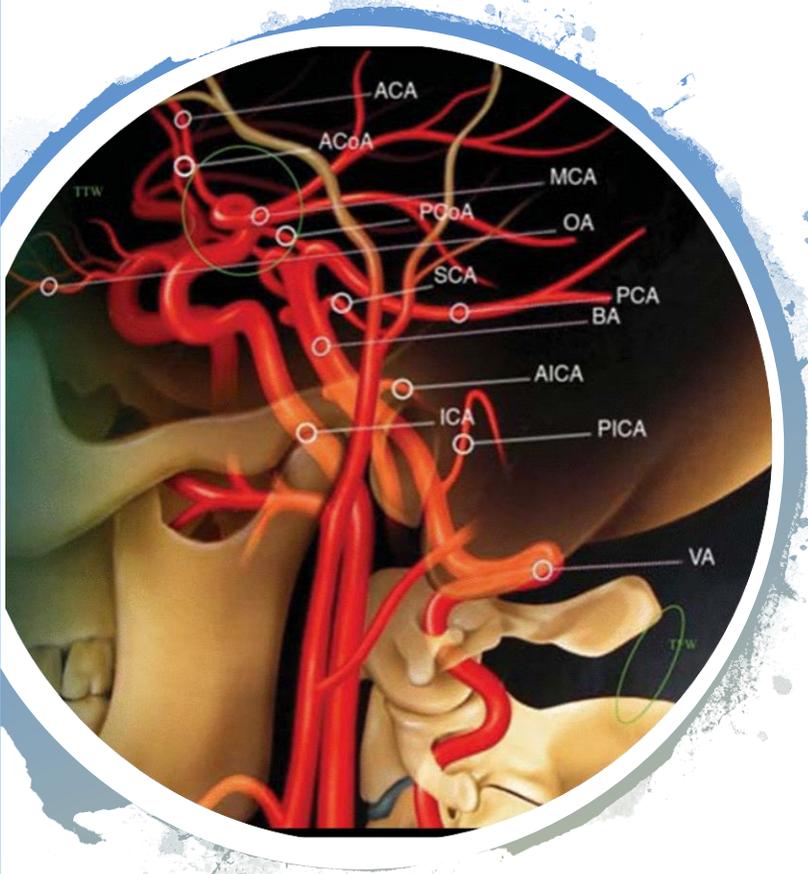
# What about this segment?



2 events at the same time with different velocities?

# Summary

- ANI remains a prevalent clinical problem during MCS in children
- Emboli are one potential target cause or marker of ANI and can be detected by TCD
- Further refinement and consensus about specific criteria for embolus and artifact are needed



**Thank you for your  
attention!**

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