Clinical Applications for Emboli Monitoring in the Perioperative and ICU setting in Children

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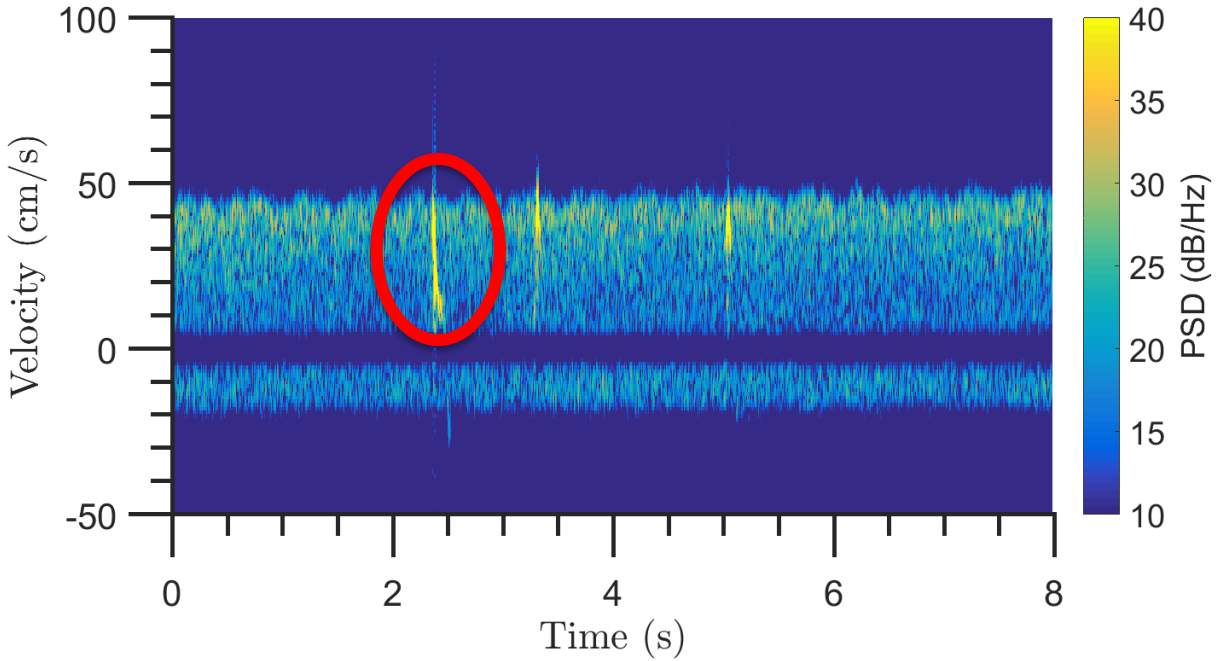
Objectives

- Basic principles of emboli monitoring
- Clinical applications in the perioperative and ICU settings in children

BASIC PRINCIPLES

Emboli Detection

- Different acoustic impedance of emboli compared to surrounding blood
- Relative intensity signal increase are referred to as high intensity transient signals (HITS)
- HITS may represent emboli composed of gas or solid matter, or reflect artifact



HITS criteria: brief, unidirectional, high intensity, accompanied by audible chirp, pop (Ringelstein 1995)

Technical Performance and Interpretation

- Requires prolonged monitoring to allow adequate time to detect possible emboli
- Probe fixation/dislodgement and signal loss are a challenge in perioperative and ICU setting
- Gold standard is human observer

Technical Performance and Interpretation

- No ground truth – composition and size
- Automatic embolus detection software of current commercial TCD systems still lacks sensitivity and specificity necessary for clinical use

Leunissen et al. 2017; LaRovere et al. 2017

Counting Emboli

- Depends on
  - System settings
  - Signal processing algorithms
  - Embolus speed
  - Direction of embolus movement
  - Position in the cardiac cycle
  - Timing and duration of monitoring study, may require > 30 minutes in some clinical scenarios

CLINICAL APPLICATIONS

Cardiac Surgery

Study (Sample Size)	Median HIT Number	Outcome
O'Brien et al 1997 (N=25)	122 (range, 2-2664),42% within 3 minutes of release of aortic cross clamp	No association with gross neurologic deficits
Naik et al. 2014 (N=24)	17 (range, 0-55)	No correlation with neuropsychological tests
Rodriquez et al. (N=128)	60 (range, 14-189), detected in 97% of patients	Correlated with de-airing

Cardiac Catheterization

Study (Sample Size)	Median HIT Number	Outcome
Rodriguez et al 1998 (N=32)	44 (95% CI, 27-74), detected in all patients	More frequent with with septal defects or systemic arterial manipulations
Wallace et al. 2015 (N=24)	67 (range, 9-242)	99% temporally associated with catheter manipulation or device placement and release
LaRovere et al. 2017 (N=5, pilot)	1,697 HITS (total number)	Highest burden during LV angiography (39%), RV angiography (16%), and device placement (16%)

Mechanical Circulatory Support

- HITS occur spontaneously and in association with bedside interventions (e.g. oxygenator change)
- May be related to increased ECMO flow rates leading to turbulence and thromboses in aortic root, within heart, and at ECMO cannula tips
- Depending on degree of cardiac ejection, flows from arterial cannula and ventricle can intersect in aortic arch, leading to propagation of solid emboli

Imaduddin et al. 2019; Janák et al. 2017

Future Directions

- Overcome existing challenges with novel algorithms
  - Inability to separate multiple emboli
  - Excessive false positive events
  - Computations over large signal blocks
  - Inability to determine emboli composition
- Electronically steered systems

Guepie et al. 2019; Lipperts et al. 2009.

Summary

- TCD monitoring allows detection of cerebral emboli
- HITS are common during cardiac surgical procedures and MCS.
- Pathologic combination of embolic load (number of HITS), size, and composition is unknown
- Future autonomous continuous emboli monitoring for patients at risk of embolic events may prevent or reduce embolic related brain injury

Thank you for your attention!

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