Pediatric Neurosonology Part 1

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January 27, 2020

Boston Children's Hospital

Until every child is well℠

HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

Disclosures

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

The content of this presentation does not contain reference to, nor advocates use of, unlicensed medicines or devices

Objectives

- Who to monitor (besides sickle cell disease)
- Review practice recommendations for TCD in the PICU (expert opinion)

WHO TO MONITOR?

VS

Who to monitor?

There is no answer. It's just done.

Who to monitor?

Depends on the intervention that is going to occur.

Traumatic Brain Injury

- Is there "raised ICP“?
- Is autoregulation intact or not?
- Is traumatic vasospasm present?
- Is there unappreciated vascular injury?
- Is this patient in a poor prognostic category?

Reference. Author (Year)	Design Country (n)	Period	Disease	Device	Period (Months)	Indication
Vavilala et al. (2006)	Prospective USA (28)	May 2003 – March 2005	TBI, GCS<9	Multidop X	36	Autoregulation
Vavilala et al. (2007)	Prospective USA (10)	May 2003 – February 2006	TBI, GCS<9	Multidop X	36	Autoregulation
Tontisirin et al. (2007)	Prospective USA (9)	June 2004 – August 2006	TBI, GCS<8	Multidop X	27	Autoregulation
Vavilala et al. (2008)	Prospective USA (42)	June 2004 – August 2006	TBI, GCS≤12	Multidop X	27	Autoregulation
Freeman et al. (2008)	Prospective USA (37)	May 2002 – June 2007	TBI, GCS<13	Multidop X	60	Autoregulation
Chaiwat et al. (2009)	Prospective USA (36)	May 2002 – October 2007	TBI, GCS<9	Multidop X	60	Autoregulation
Philip et al. (2009)	Prospective USA (42)	NR	TBI, GCS<9	Multidop X	NR	Autoregulation
Visocchi et al. (2007)	Prospective Italy (6)	NR	TBI, GCS<8	NIC Vue	NR	Intracranial hypertension
Figaji et al. (2009a)	Prospective SA (34)	June 2006 – May 2008	TBI, GCS≤8	Smart-lite	24	Intracranial hypertension
Figaji et al. (2009b)	Prospective SA (24)	June 2006 – May 2008	TBI, GCS≤8	Smart-lite	24	Autoregulation
Figaji et al. (2010)	Prospective SA (28)	NR	TBI, GCS≤8	Smart-lite	NR	Response to normobaric hyperoxia
O’Brien et al. (2010)	Prospective USA (22)	May 2007 – March 2009	TBI, GCS≤12	Companion III	10	Vasospasm
O’Brien et al. (2014)	Prospective USA (69)	NR	TBI, GCS≤12	Sonara	NR	Vasospasm
Obrien et al. (2015)	Prospective USA (36)	NR	TBI, GCS≤8	Sonara	NR	Intracranial hypertension
Scavarda et al. (2010)	Prospective France (36)	1991 – 2000	TBI, GCS 3 – 15	NR	120	Prognosis
Moftakhar et al. (2015)	Retrospective USA (37)	1990 – 2013	Aneursym and TBI, GCS≤12	Neuroguard	276	Vasospasm

LaRovere et al. J Neurotrauma 2016

Other Clinical Applications in Children

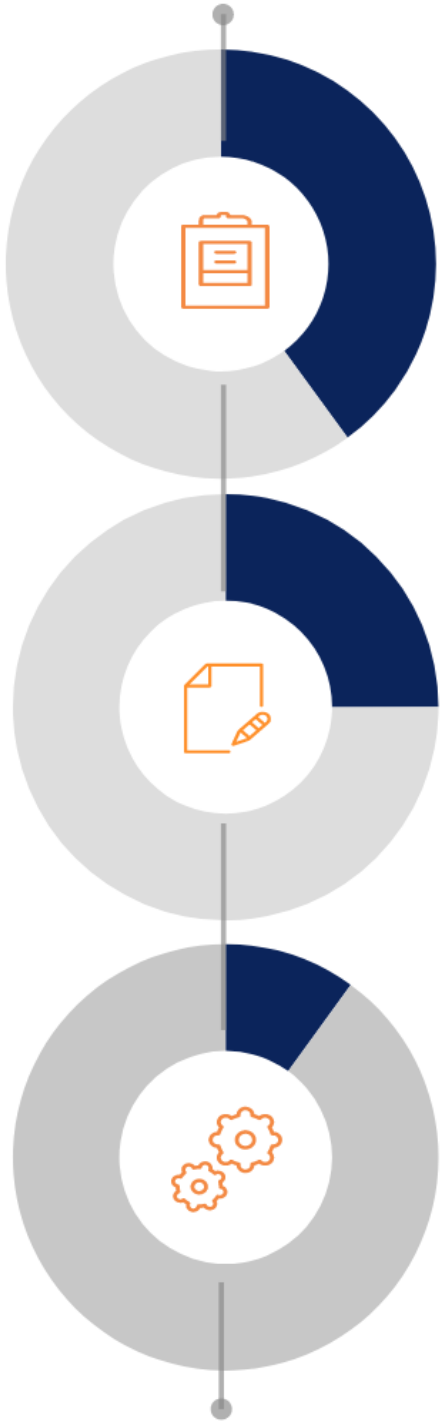
- CNS infections
- Vasospasm (TBI, SAH)
- Brain Death
- Hydrocephalus
- Postoperative Monitoring
- Shock/Severe Sepsis

Clinical Application	TCD Finding	References
CNS Infection and Malaria	**Diagnostic**: Elevated CBFV **Prognostic**: Impaired autoregulation, low CBFV, elevated PI	O'Brien et al. (Malaria, 2018, N=160,) van Toorn et al (TBM, 2014, N=20) Ducharme-Crevier et al (CNS infections, N=20, 2016)

Clinical Application	TCD Finding	References
Brain Death	**Diagnostic**: Sensitivity 95%, specificity 99% in adults	Monteiro et al 2006 (meta-analysis, N=270 in 2 high quality studies) Riggs et al 2017 (N=13 had TCD and ophthalmic ultrasound)

Clinical Application	TCD Finding	References
Shock/Severe Sepsis	TCD and NIRS data being collected	NCT03731104 (Shock) NCT03055455 (Severe Sepsis)

Many research opportunities



ANALYZE

- Establish need
- Literature review of scope of practice
- Explore by survey and early collaboration

TEST

- Rigorous, prospective clinical trials with validated clinical outcomes needed

EVALUATE

- Validate and compare results
- Redesign interventions
- Refine theoretical understanding

TCD PRACTICE RECOMMENDATIONS

Experience Matters – Survey Results

- 43 centers with PNCC services surveyed
- 29 (67%) responses
- 27 hospitals use TCD in clinical practice and research in PICU

LaRovere et al. 2020

Experience Matters – Survey Results

- Wide range in clinical use and research interests
  - Most common clinical applications: **stroke, TBI, and cardiac arrest**
- TCD directed care in three-fourths of PICUs

Hospital	Obtain imaging	ΔCPP	ICP treat	Surgery	ΔMV	Inform counsel	ΔantiC	ΔHOB
7	■	■			■	■		■
6	■	■		■	■	■		
18	■	■		■		■		
8	■	■	■					
10	■	■	■		■			
11	■		■		■			
20	■	■		■				
21	■	■			■			
3	■			■		■		
25	■	■					■	
1	■	■						
2, 4, 14, 17	■							
13, 15, 23	■	■						
22		■		■				
19				■				
5, 9,12,16, 24, 26, 27								

30% (8/27 hospitals) had written protocol

LaRovere et al. 2019

More Questions

- Are the waveforms high quality?
- What data is being collected?
- How is the data being reported?
- What criteria are used for interpretation?
- Appropriate integration into clinical practice?

Practice Recommendations for Transcranial Doppler Ultrasonography in Critically Ill Children in the Pediatric Intensive Care Unit: A Multidisciplinary Expert Consensus Statement

Nicole Fortier O'Brien[1] Karin Reuter-Rice[2] Mark S. Wainwright[3] Summer L. Kaplan[4]
Brian Appavu[5] Jennifer C. Erklauer[6] Suman Ghosh[7] Matthew Kirschen[8] Brandi Kozak[9]
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Journal of Pediatric Intensive Care 2020

Aim

- To develop expert consensus guidelines on the performance, interpretation, and documentation standards for the clinical use of TCD in the PICU

- Findings intended to standardize practice of TCD for both clinical care and research in critically ill children, allowing for the comparison of results across centers and studies as well as generation of meaningful and reproducible results

Study Design and Population

- **Study Design:** Three round modified Delphi process using an electronic survey system.

- **Study population:** Panel of multidisciplinary clinicians with expertise in the use of TCD in the pediatric critical care setting.

Methods

- Questions that scored ≥9 by ≥80% of respondents were considered to have met our *a priori* definition of "near perfect or near unanimous agreement" and were deemed to have met consensus.
- Surveys for each of the three rounds of the Delphi process were sent electronically (SurveyMonkey Inc, San Mateo, CA) from August 2019-October 2019

Methods

- Panelists were provided with a summary of the aims of the consensus project before each round
- An in-person meeting was held in Vancouver, British Columbia during the annual Neurocritical Care Society Meeting in October 2019

Participating Panelists

Description	Value
Medicine (number,%)	
Pediatric Critical Care	5 (31%)
Pediatric Neurology	5 (31%)
Both Pediatric Critical Care and Neurology	2 (13%)
Pediatric Radiology	2 (13%)
Nursing (number,%)	1 (6%)
Ultrasound Technician (number,%)	1 (6%)
Years in Clinical Practice (mean, SD)	12 (±2)
Years using TCD in the PICU (mean, SD)	7.5 (±3)

Consensus reached on

34 statements in 4 domains

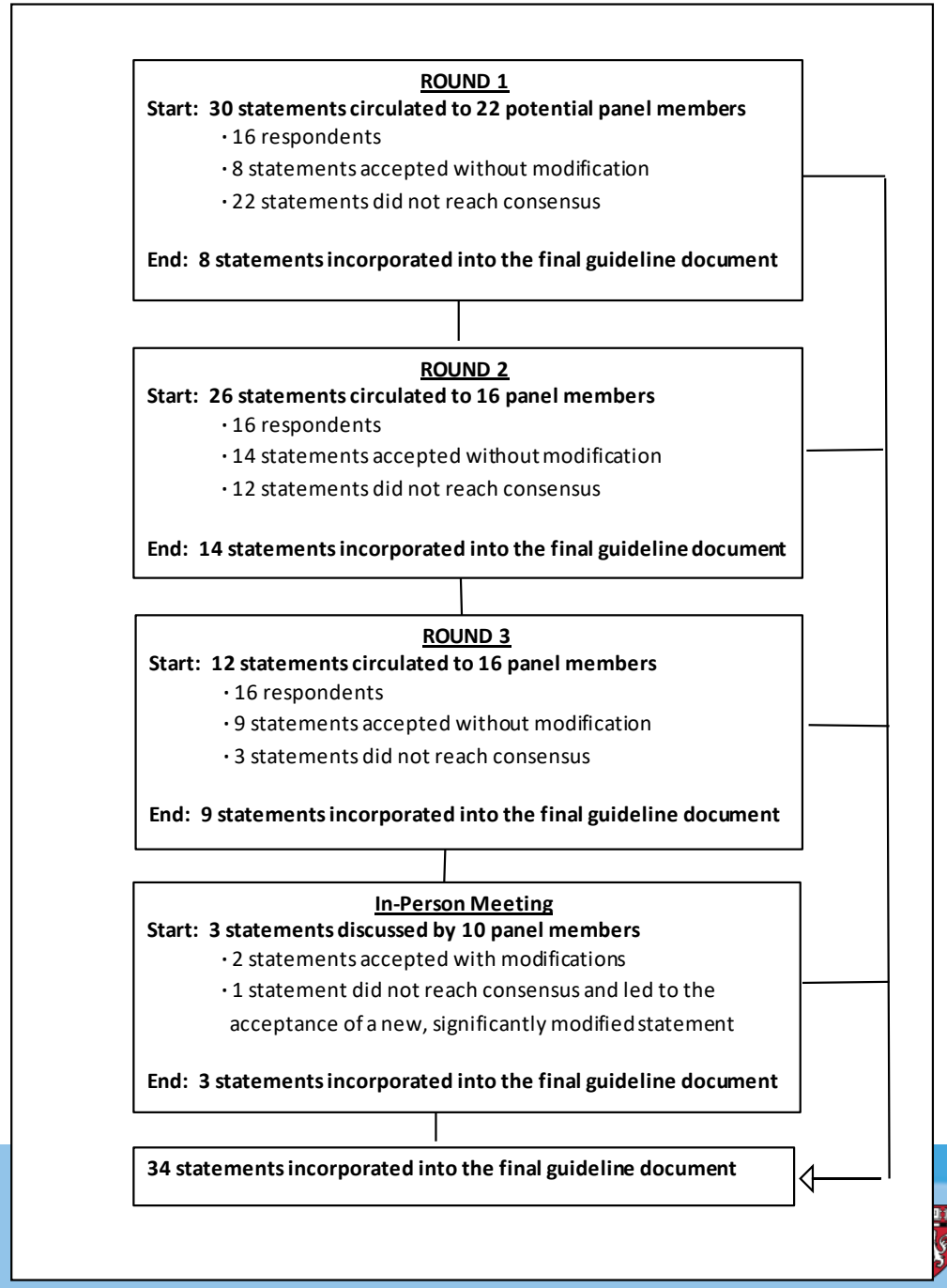

Figure 1.

Alternative Statement

- No agreement could be reached on “It is necessary that the individual performing and interpreting the TCD in the PICU for clinical examinations should have received formal training and passed a written exam by a governing body”
- Agreement with alternative statement reached – “Individuals performing and interpreting TCD in the PICU should be accredited by their institution to do so”

Indication and Request for Examination Standards

Domain	Consensus Statement
Indication and Request for Examination Standards	• Any patient in the PICU with concern for pathophysiological changes to cerebral hemodynamics is a candidate to undergo TCD examination • The written or electronic request must provide sufficient information to interpret the examination and should include relevant history (known or suspected acute or chronic diagnoses), signs or symptoms, and specific questions of the treating team.

Technical Performance Standards

Domain	Consensus Statement
Technical Performance Standards	• For positioning of a patient for a TCD in the PICU, 30-45 degree head of bed positioning is ideal but the exam can be performed in any position based on the patient's clinical requirements. • The vessel being insonated should always, at least in part, be identified by direction of flow, flow velocities, and depth of insonation. • A complete TCD examination includes evaluation of MCAs, ACAs, PCAs, VAs, BA, ICAs, and Ex-ICAs (bilaterally for all except BA). • A limited TCD examination can include any one or more of the vessels in the complete examination depending on the clinical indication for the examination. • The transtemporal window should be used to evaluate the MCA, ACA, PCA, and ICA

Technical Performance Standards

Domain	Consensus Statement
Technical Performance Standards	• The transorbital window should be used to evaluate the OA. • The submandibular window should be used to evaluate the Ex-ICA and distal ICA. • The transforamenal window should be used to evaluate the bilateral VA and the BA. • Through the transtemporal window it is acceptable to locate the MCA/ACA bifurcation songraphically as an anatomic landmark to determine which vessels are being insonated when the probe angle is altered or the depth is advanced or reduced. • The appropriate depth to insonate the MCA in adolescents and young adults is 65-35 mm. In pediatric patients, it may be less deep due to smaller head size.

Technical Performance Standards

Domain	Consensus Statement
Technical Performance Standards	• The appropriate depth to insonate the ophthalmic artery in adolescents and young adults is 40-50 mm. In pediatric patients, it may be less deep due to smaller head size. • The appropriate depth to insonate the ex-ICA and distal ICA in adolescents and young adults is 40-60 mm. In pediatric patients, it may be less deep. • The appropriate depth to insonate the BA in adolescents and young adults is 65-80 mm. In pediatric patients, it may be less deep due to smaller head size. • Measurements should be recorded every 2mm.

Data Interpretation Standards

Domain	Consensus Statement
Data Interpretation Standards	• Temperature, mean arterial pressure, partial pressure of carbon dioxide, hemoglobin or hematocrit, the use of invasive or non-invasive mechanical ventilation, and the use and type of sedatives or anxiolytics at the time of TCD examination are necessary to record and consider when interpreting TCD examinations. • Intracranial pressure and cerebral perfusion pressure should also be included when available. • When interpreting a TCD examination of a non-intubated child < 18 years of age in the PICU, normative values from Bode et al. should be used. • In order to diagnose abnormal flow, mean flow velocities ≤ or ≥ 2SD from age and gender normal value can be used. • No Lindegaard ratio has been validated in children to differentiate between hyperemia and vasospasm in the MCA and thus using specific cut-offs for diagnosing, grading, or determining the clinical significance of vasospasm in the MCAs cannot be recommended.

Data Interpretation Standards

Domain	Consensus Statement
Data Interpretation Standards	• No Sviri or Soustiel ratio has been validated in children to differentiate between hyperemia and vasospasm in the BA and thus using specific cut-offs for diagnosing, grading, or determining the clinical significance of vasospasm in the BA cannot be recommended. • Radiographic validation (with CT, MRI, etc.) of abnormal TCD findings should be strongly considered depending on the clinical indication for TCD examination. • Individuals performing and interpreting TCD in the PICU should be accredited by their institution to do so.

Data Reporting Standards

Domain	Consensus Statement
Data Reporting Standards	• The initials of the operator should be included on the report. • The type of TCD machine (imaging vs non-imaging), window used for insonation, and side of examination (right vs left vs bilateral) are mandatory to report. • Sample volume size, gain, and power settings may be considered to include in the report. • The name, age, and gender of the child are mandatory to report. • It is necessary to report if the study was technically adequate to allow interpretation.

Data Reporting Standards

Domain	Consensus Statement
Data Reporting Standards	• Depths of measurement (in mm) for Vs, Vd, Vm, and PI in each vessel are mandatory to report. • Abnormalities to the waveform characteristics such as delayed upstroke, reversal of flow, and embolic signals (if present) should be reported. • If serial examinations are performed, reporting trends in measured velocities and/or Lindegaard/Sviri/Soustiel ratio is encouraged. • Reporting the number of standard deviations from selected reference values for the measured flow velocities is encouraged. • The neurocritical care team (intensivist, neurosurgeon, and/or neurologist) should be involved in the process of interpretation based on the patient's underlying pathophysiology.

Impact and Future Directions

- To ensure that high quality TCD images are captured, interpreted, and reported using standard nomenclature
- To aid in ensuring reproducible and meaningful study results between TCD practitioners and across PICUs

Potential Pitfalls and Alternate Strategies

- Who is a TCD expert in the PICU setting?
  - Future collaboration with all stakeholders, including radiology
- Evidence in support of recommendations is weak, and largely derived from adults
- Limitations of Delphi method

Summary

- Who to monitor?
  - Data driven or experience driven approach
- Wide range of clinical use and research interest in critically ill children
- Practice recommendations are “stepping stone” towards meaningful and reproducible results in clinical practice and research

Thank you for your attention!

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