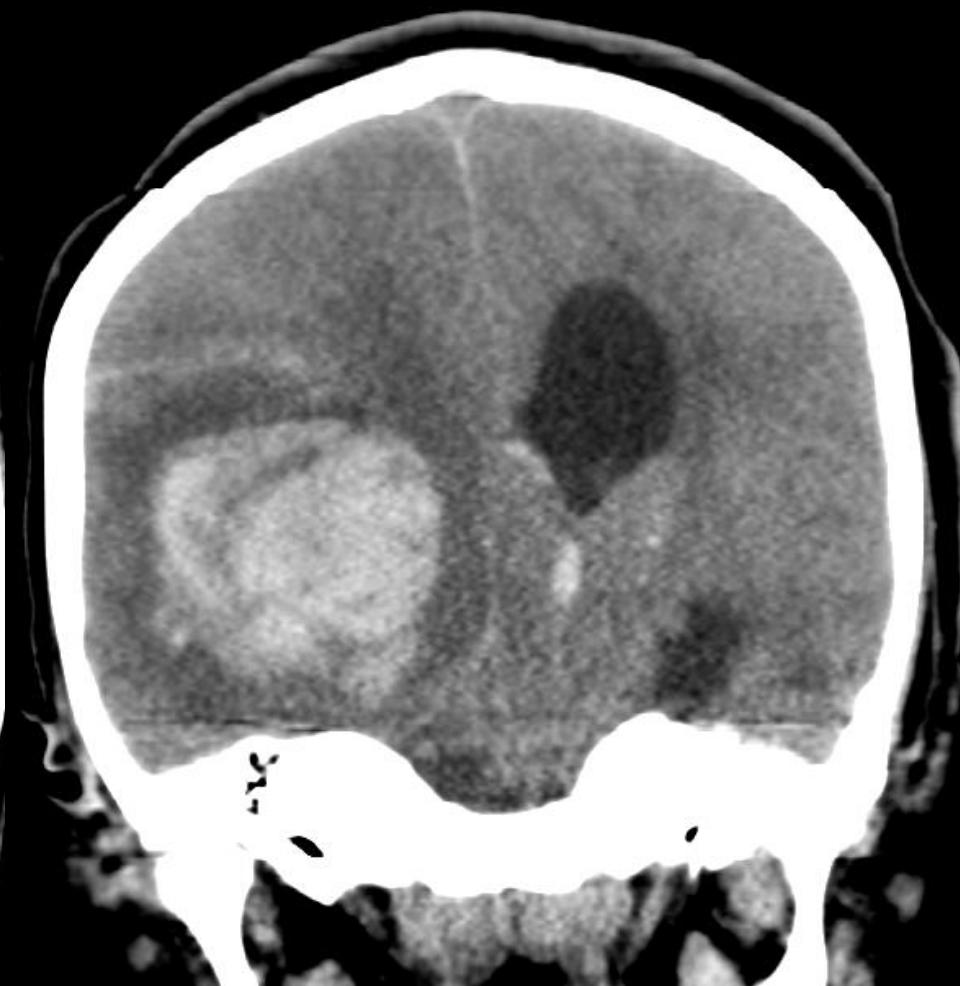
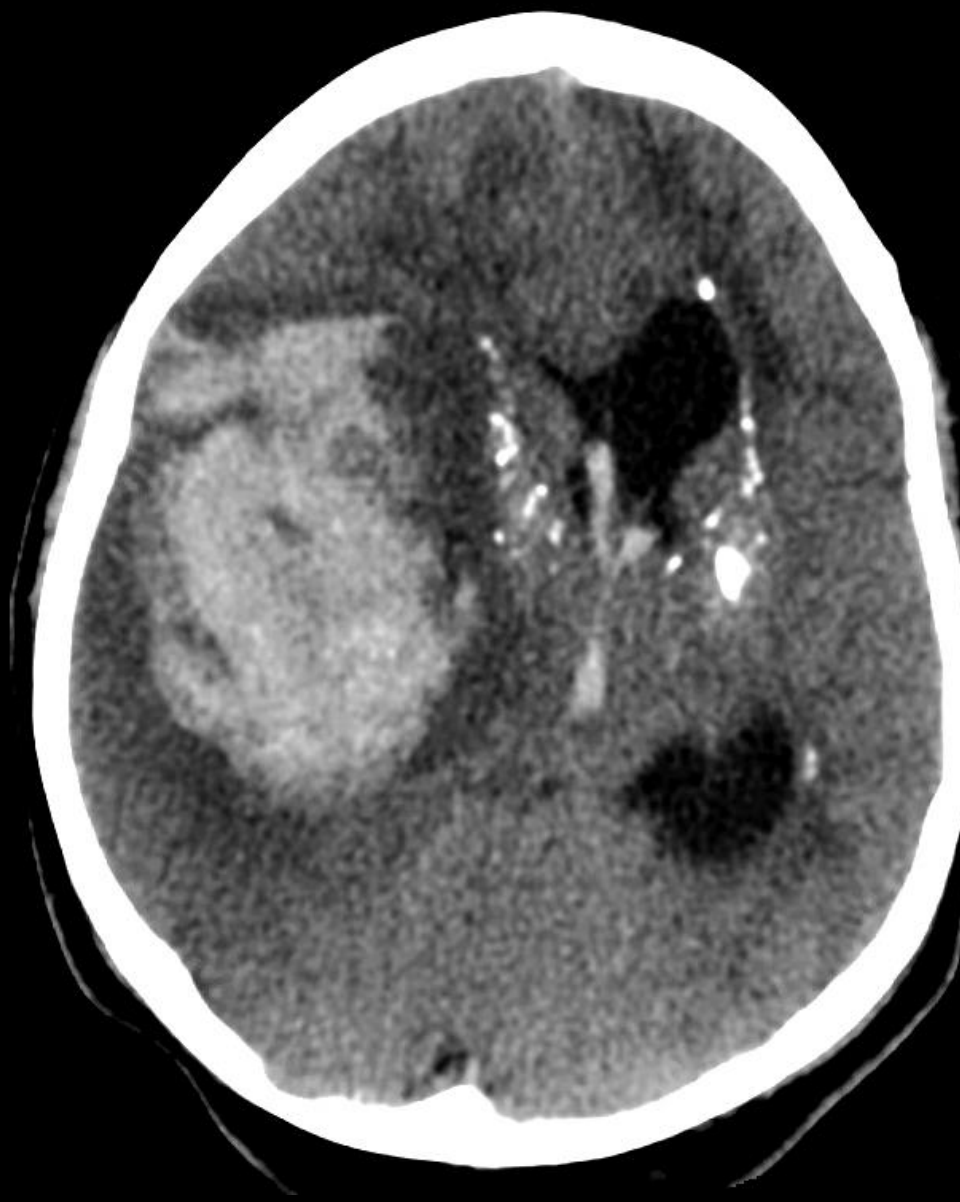


Emerging clinical applications for TCD in pediatric critical care: Ultrasound in vasospasm management

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The Ohio State University College of Medicine

Case Presentation

- 11 yo female with Aicardi-Goutieres Syndrome type 1, spastic CP, and remote hx of seizures presented with unresponsiveness, fixed and dilated R pupil, decreased movement of her right upper extremity, and agonal breathing.



Hunt/Hess: 5
Fisher grade 4



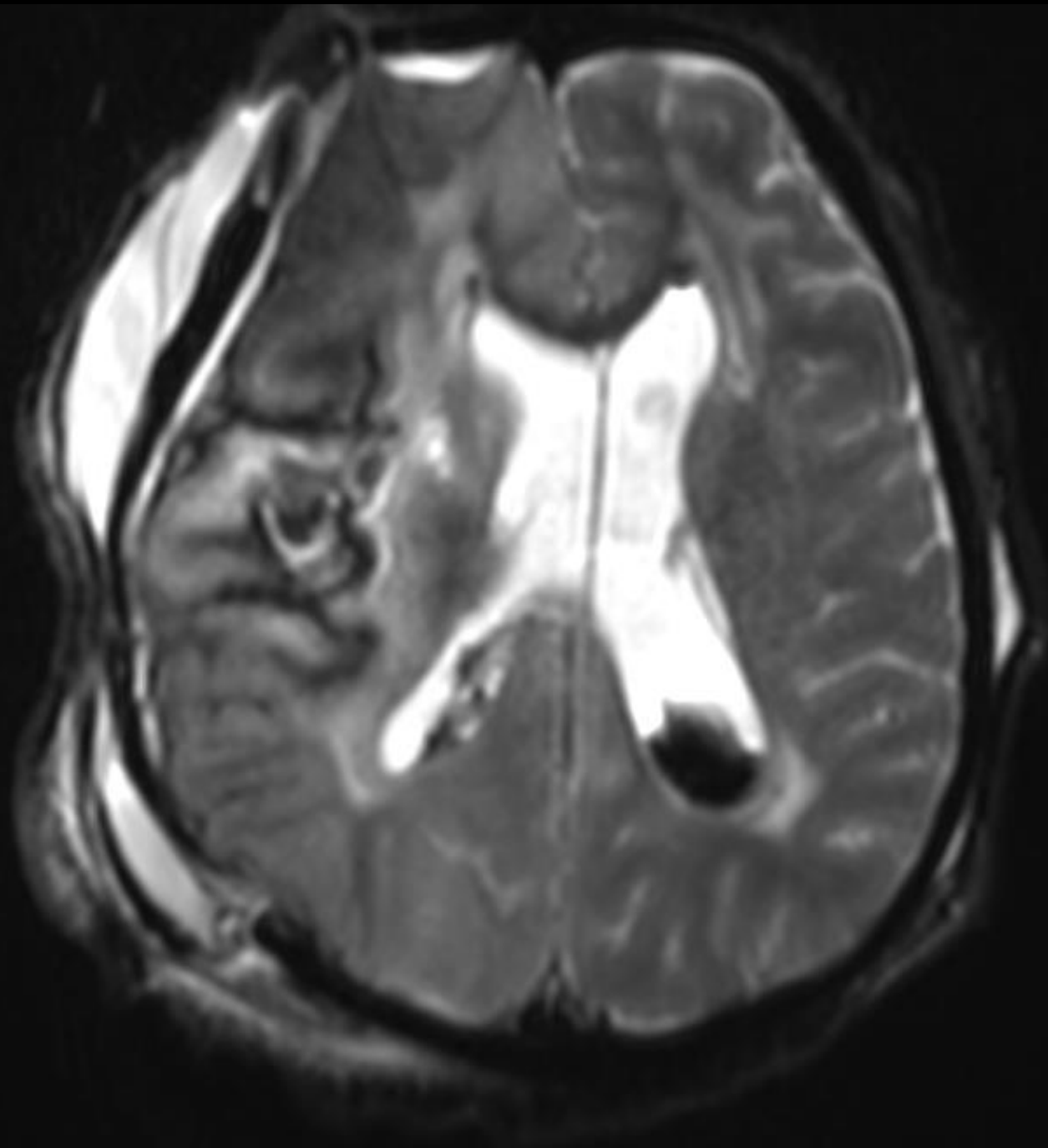
Hospital Course

- HD #1:
 - Underwent R frontotemporal decompressive hemicraniectomy
 - Evacuation of R IPH
 - Clipping of large R M2 MCA bilobed aneurysm
 - EVD placement
 - Started nimodipine

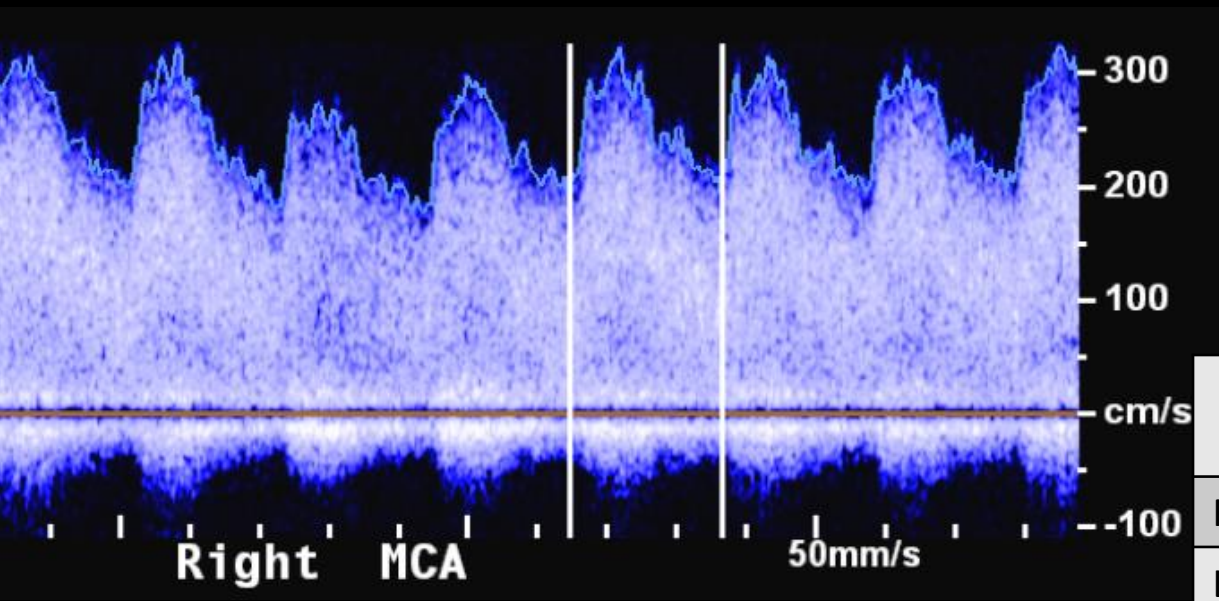
Hospital Course

- HD #2:
 - Initial TCD obtained
 - R MCA (Vs/Vd/Vm (SD), LR): 132/59/83 (0.18 SD), 1.2
 - L MCA (Vs/Vd/Vm (SD), LR): 141/31/68 (1.8 SD), 1.4
- HD #3:
 - DSA: identified 2nd small saccular M1 aneurysm, no large vessel vasospasm; L sided cerebral hypoperfusion

HD #6

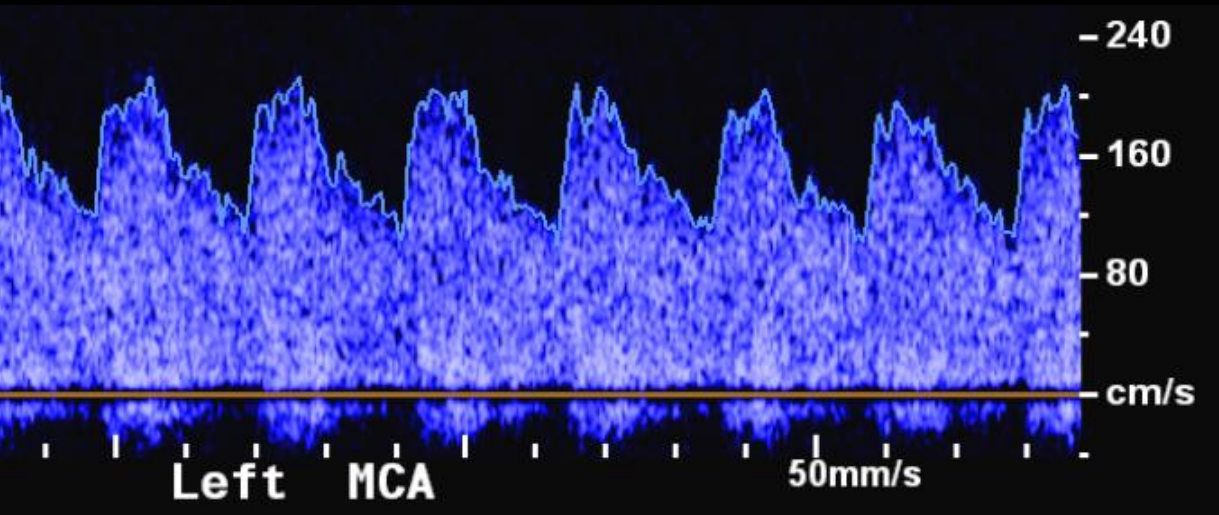


HD #7



+13.5 SD

	Vs (cm/s)	Vd (cm/s)	Vm (cm/s)	LR
Right	325	182	230	3.9
Left	230	129	171	2.6

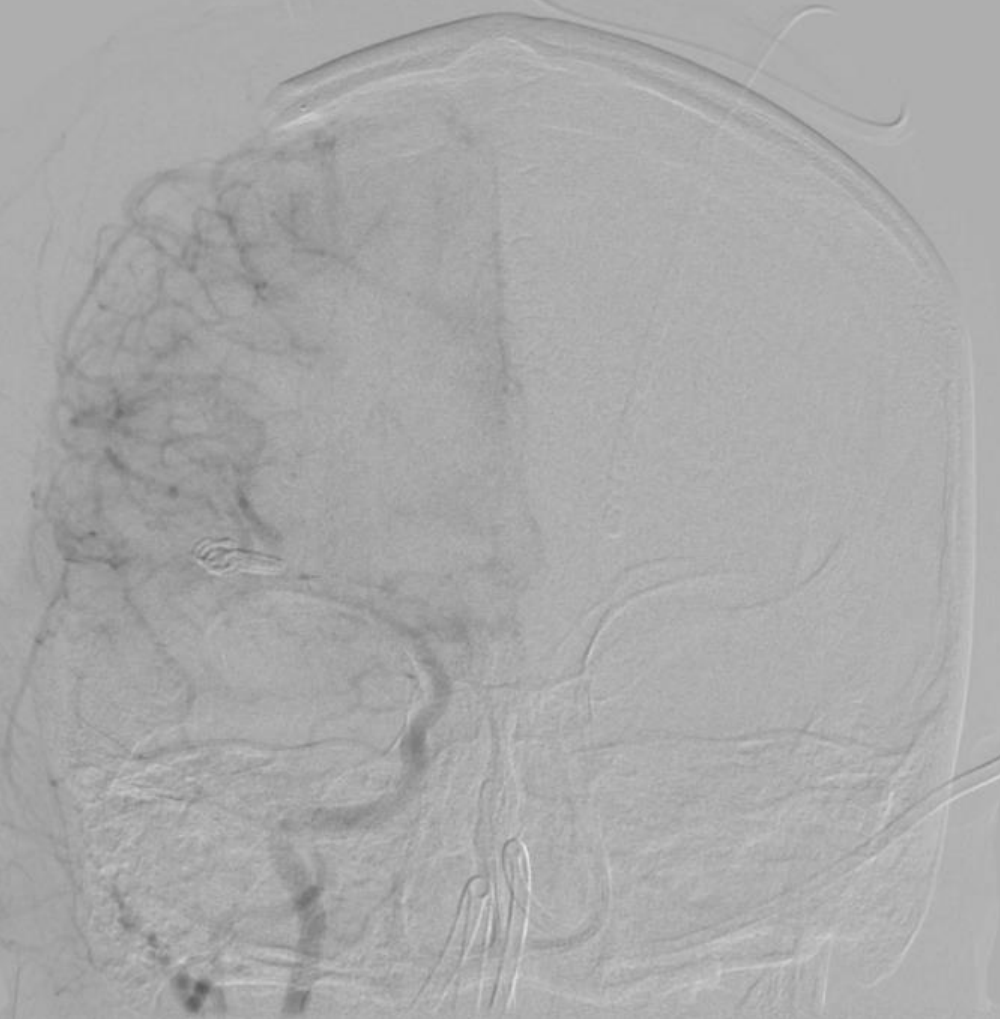


+8.2 SD

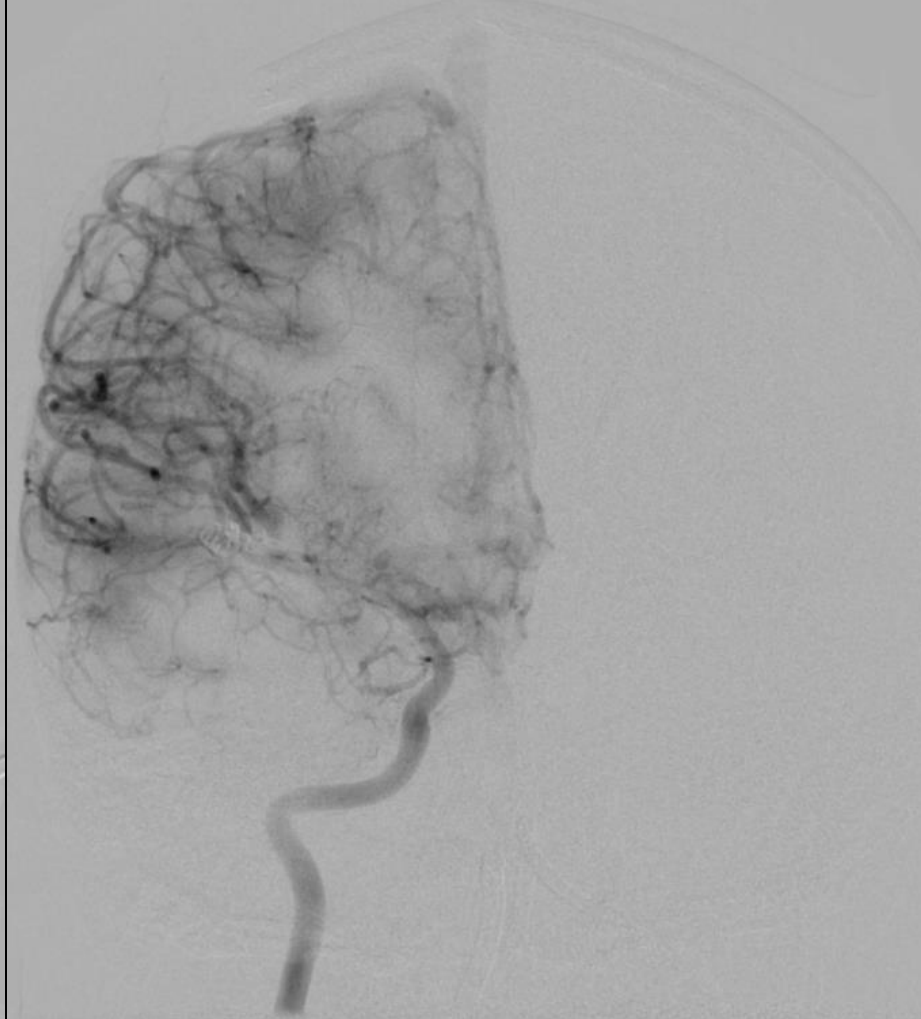
Prompted DSA

HD #8

Pre IA verapamil



Post IA verapamil



HD #8

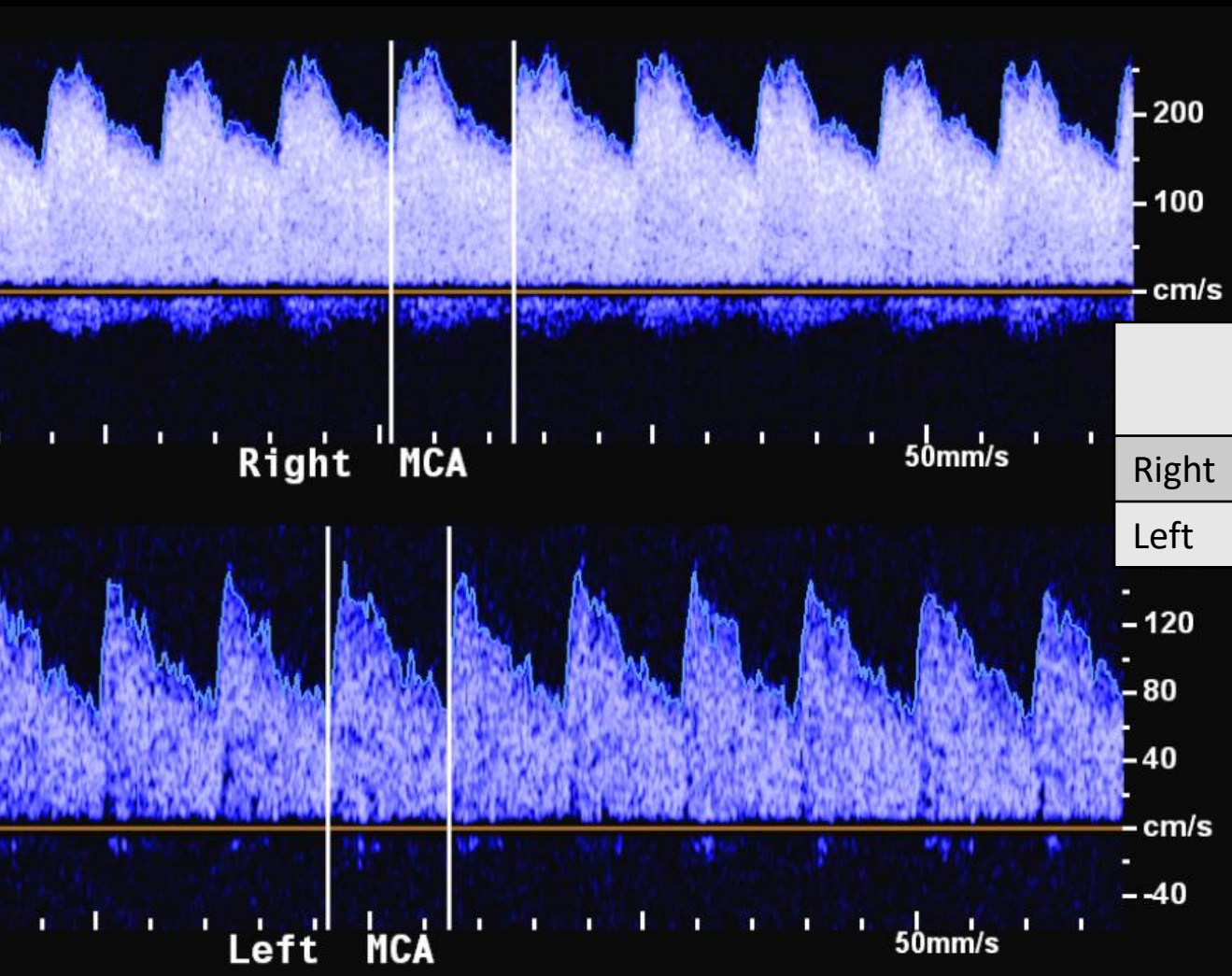
Pre IA verapamil



Post IA verapamil



HD #9

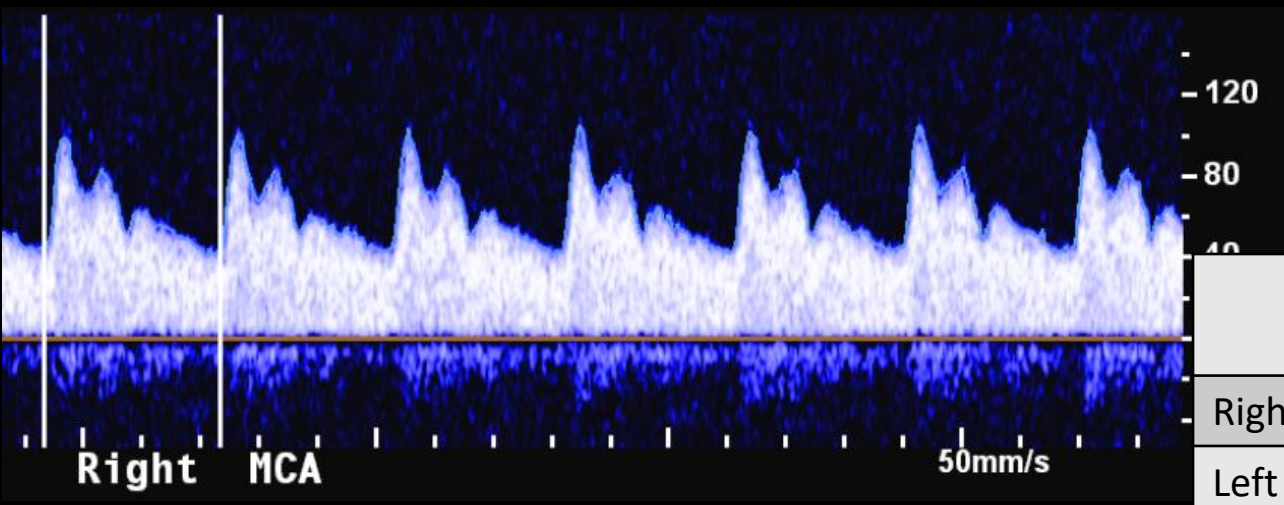


+12.8 SD

	Vs (cm/s)	Vd (cm/s)	Vm (cm/s)	LR
Right	281	162	215	2.9
Left	163	66	99	1.2

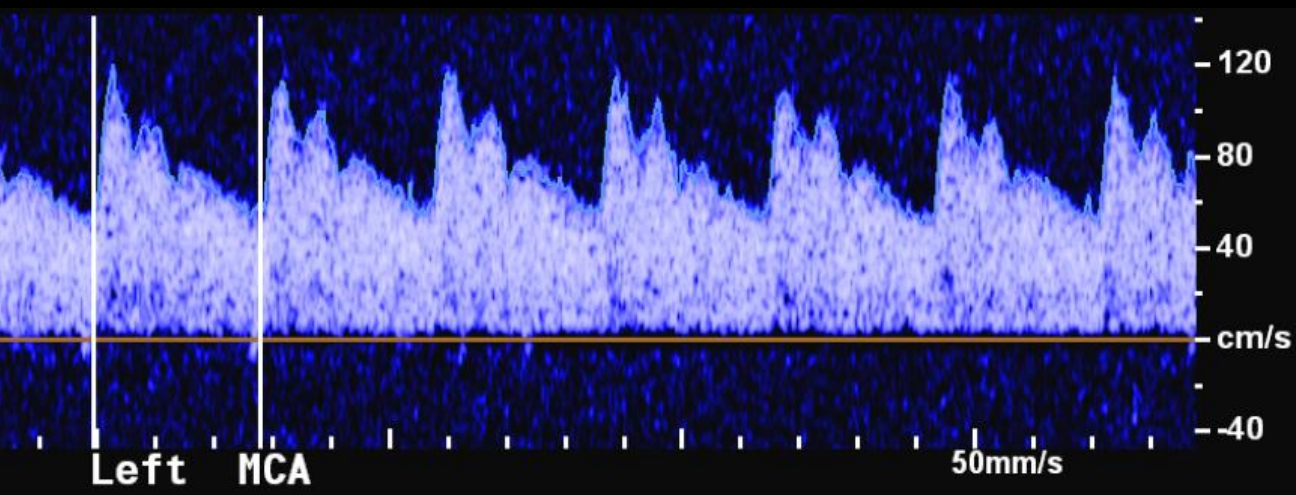
+1.6 SD

HD #14



-1.4 SD

	Vs (cm/s)	Vd (cm/s)	Vm (cm/s)	LR
Right	110	43	66	1.8
Left	124	55	78	2.0



-0.27 SD

Hospital Course

- HD #14: bone flap cranioplasty
- HD #16: extubated
- HD #22: EVD removed
- HD #35: discharged home

Controversies

- ***TCD-based criteria to diagnose vasospasm in children.***
- Concordance with additional imaging modalities.
- Management of vasospasm in children.

Adult definition

MCA Vasospasm	Mean flow velocity (cm/s)	Lindegaard Ratio
Mild	120-149	3-6
Moderate	150-199	3-6
Severe	>200	>6

Samagh (2019)

Should we apply these definitions to children?

- What are “normal” flow velocities in children?
- Would the application of adult definitions give an over-estimate or under-estimate of cerebral vasospasm?

Table 3 Mean (SD) flow velocities in basal cerebral arteries (in cm/second) in a cross sectional study of healthy children (n=112)

Age	n	Middle cerebral artery	Internal carotid artery	Anterior cerebral artery	Posterior cerebral artery		Basilar artery
					PI*	P2†	
Systolic peak flow velocity:							
0-10 days	18	46 (10)	47 (9)	35 (8)	—	—	—
11-90 days	14	75 (15)	77 (19)	58 (15)	—	—	—
3-11.9 months	13	114 (20)	104 (12)	77 (15)	—	—	—
1-2.9 years	9	124 (10)	118 (24)	81 (19)	67 (18)	69 (9)	71 (6)
3-5.9 years	18	147 (17)	144 (19)	104 (22)	84 (20)	81 (16)	88 (9)
6-9.9 years	20	143 (13)	140 (14)	100 (20)	82 (11)	75 (10)	85 (17)
10-18 years	20	129 (17)	125 (18)	92 (19)	75 (16)	66 (10)	68 (11)
Mean flow velocity‡:							
0-10 days	18	24 (7)	25 (6)	19 (6)	—	—	—
11-90 days	14	42 (10)	43 (12)	33 (11)	—	—	—
3-11.9 months	13	74 (14)	67 (10)	50 (11)	—	—	—
1-2.9 years	9	85 (10)	81 (8)	55 (13)	50 (17)	50 (12)	51 (6)
3-5.9 years	18	94 (10)	93 (9)	71 (15)	56 (13)	48 (11)	58 (6)
6-9.9 years	20	97 (9)	93 (9)	65 (13)	57 (9)	51 (9)	58 (9)
10-18 years	20	81 (11)	79 (12)	56 (14)	50 (10)	45 (9)	46 (8)
End diastolic peak flow velocity:							
0-10 days	18	12 (7)	12 (6)	10 (6)	—	—	—
11-90 days	14	24 (8)	24 (8)	19 (9)	—	—	—
3-11.9 months	13	46 (9)	40 (8)	33 (7)	—	—	—
1-2.9 years	9	65 (11)	58 (5)	40 (11)	36 (13)	35 (7)	35 (6)
3-5.9 years	18	65 (9)	66 (8)	48 (9)	40 (12)	35 (9)	41 (5)
6-9.9 years	20	72 (9)	68 (10)	51 (10)	42 (7)	38 (7)	44 (8)
10-18 years	20	60 (8)	59 (9)	46 (11)	39 (8)	33 (7)	36 (7)

*Precommunicating part of posterior cerebral artery.

†Postcommunicating part of posterior cerebral artery.

‡Mean flow velocity=time-mean of the maximal velocity envelope curve.

Bode and Wais (1988)

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

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User Guide

ost recent  Display options 

Disease Process	# of studies
SAH	5 (3 case reports)
Malaria	1
TBI	5
Concussion	1
CNS Infections	2
Medulloblastoma	1 (case report)
Migraine	1
Rabies	1 (case report)

Definition	Studies
MFV ≥ 2 SD above norms AND LR ≥ 3	Reuter-Rice et al (TBI, 2018) O'Brien et al (TBI, 2018) O'Brien et al (TBI, 2015)
MFV > 2 SD above normative values AND LR > 3 AND dicrotic notch present on MCA waveform analysis	O'Brien et al (Malaria, 2018)
MFV > 120 cm/s	Snelling et al (SAH, case report, 2017)
MFV > 120 cm/s AND LR ≥ 3 OR MFV > 200 cm/s	Ducharme-Crevier et al (CNS infections, 2016)
MFV 160-199 cm/s (mild), > 200 cm/s (moderate-severe)	Heffren (SAH, 2015)
MFV > 120 cm/s AND LR ≥ 3	Moftakhar (aneurysmal/traumatic SAH, 2014) Van Toorn (TB meningitis, 2014)
MFV > 120 cm/s OR MFV > 120 cm/s AND LR ≥ 3	O'Brien et al (TBI, 2010)
MFV > 100 cm/s AND LR ≥ 3	Mandera et al (TBI, 2002)
LR > 3	Boasso et al (migraines, 2004)

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

Nicole Fortier O'Brien¹ Karin Reuter-Rice² Mark S. Wainwright³ Summer L. Kaplan⁴
Brian Appavu⁵ Jennifer C. Erklauer⁶ Suman Ghosh⁷ Matthew Kirschen⁸ Brandi Kozak⁹
Karen Lidsky¹⁰ Marlina Elizabeth Lovett¹¹ Amy R. Mehollin-Ray¹² Darryl K. Miles¹³
Craig A. Press¹⁴ Dennis W. Simon¹⁵ Robert C. Tasker¹⁶ Kerri Lynn LaRovere¹⁷

To diagnose abnormal flow, mean flow velocities \leq or \geq 2 SD from age and gender normal value can be used. No Lindegaard ratio (LR) 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. However, following LR values over time may have clinical utility to determine trends in cerebral blood flow.

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. However, following Sviri/Soustiel values over time may have clinical utility to determine trends in cerebral blood flow.

Radiographic validation (with CT, MRI, etc.) of abnormal TCD findings should be strongly considered depending on the clinical indication for TCD examination.

Study	Population	% with TCD vasospasm	Confirmed	Treatment	Outcome
O'Brien (2018, 2015)	TBI	23 (19/83)	MRA (6 kids)	No	sTBI: 18% good outcome modTBI: 76% good
Heffren (2015)	SAH	88 (8/9)	Angio (6/8)	Nimodipine	See next slide
Moftakaar (2015)	SAH	81 (13/16)	Angio (55% of vessels +TCD/-angio)	IA verapamil papaverine angioplasty	68% good outcome

3 studies mentioned confirmation of vasospasm on additional modality
2 studies reported treating vasospasm

Concordance

- Heffren et al:
 - Definition: MFV > 160-199 cm/s (mild), > 200 cm/s (moderate to severe)
 - 77% concordance
- Moftakhar et al:
 - Definition: MFV > 120 cm/s AND LR \geq 3
 - MCA: TCD 85% sensitive, 40% specific in diagnosing vasospasm in comparison to DSA

Study	Population	% with TCD vasospasm	Confirmed?	Treatment	Outcome
O'Brien (2018)	Malaria	13 (21/160)	N	N	37% nl outcome, 45% w/ neuro sequelae, 18% died
Reuter-Rice (2018)	TBI	43 (26/60)	N	N	56% good, 28% moderate disability, 16% severe disability
O'Brien (2018, 2015)	Total: 104/475				8% good ne BI: 76% good
Ducharme-Crevier (2016)					ported
Heffren (2015)	SAH	88 (8/9)	Angio (6/8)	Nimodipine	See next slide
Moftakaar (2015)	SAH	81 (13/16)	Angio (55% of the vessels +TCD/-angio)	IA verapamil or papaverine or angioplasty	TCD 95% sensitive, 59% specific 68% good outcome
Van Toorn (2014)	TB Meningitis	5 (1/20)	N	N	Normal
O'Brien (2010)	TBI	45.5 (10/22)	N	N	Not reported
Mandera (2002)	TBI	0 (0/23)	N	N	n/a
Boasso (2004)	Migraine	6 (4/62)	N	N	Not reported

Thoughts

- Helpful to trend.
- May prompt additional imaging.
- Need to acknowledge the limited and heterogenous literature.

Controversies

- TCD-based criteria to diagnose vasospasm in children.
- Concordance with additional imaging modalities.
- Management of vasospasm in children.

Need more literature!