

# Assessing middle cerebral artery blood flow velocities and outcomes in pediatric severe traumatic brain injury using transcranial doppler ultrasound

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## Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability in children, with over 475,000 children annually visiting emergency departments in the United States, 35,000 hospitalizations, and 26,000 deaths. Neurovascular events such as cerebral vasospasm (CVS) are thought to reduce CBF below critical thresholds leading to cerebral ischemia and have been seen in adult patients with aneurysmal (aSAH) and traumatic subarachnoid hemorrhage. Low flow states are gaining attention as a potential neurovascular complication with acute and chronic implications. The ability to measure this post-traumatic event has the potential for early identification of ischemia and hemodynamic perturbations in this age population but remains relatively under studied.

## Research Question

We sought to assess the cerebrovascular flow velocities of pediatric TBI patients using TCD and to assess for acute and long-term clinical correlations. Specifically, in this patient population, we aimed to characterize the relationships between clinical characteristics, TCD velocities and functional outcome using the GOS-E Peds score.

## Materials and Methods

This is a retrospective study of pediatric patients who suffered a severe TBI defined as Glasgow Coma Scale  $\leq 8$ . A total of 47 patients were treated between January 2014 and August 2018 and all patients received TCD assessments for cerebral blood flow velocity for a total of 210 measurements. MCA velocities were identified as high flow or low flow states using age-adjusted standardized velocities. Persistent low flow states were defined as  $>50\%$  of TCD recordings per patient displaying the specified flow state without resolution to a flow state within 2 standard deviations of age-sex defined normal. The primary outcome measure was 3- month Pediatric Glasgow Outcome Scale-Extended (GOS-E Peds). Secondary outcomes included mortality and the global function using Pediatric Glasgow Outcome Scale-Extended (GOS-E Peds) at 6 and 12 months and the association of the TCD findings to other physiologic variables at the time of scanning. This study was reviewed and approved by Phoenix Children's hospital Institutional Review Board (IRB#17-142)

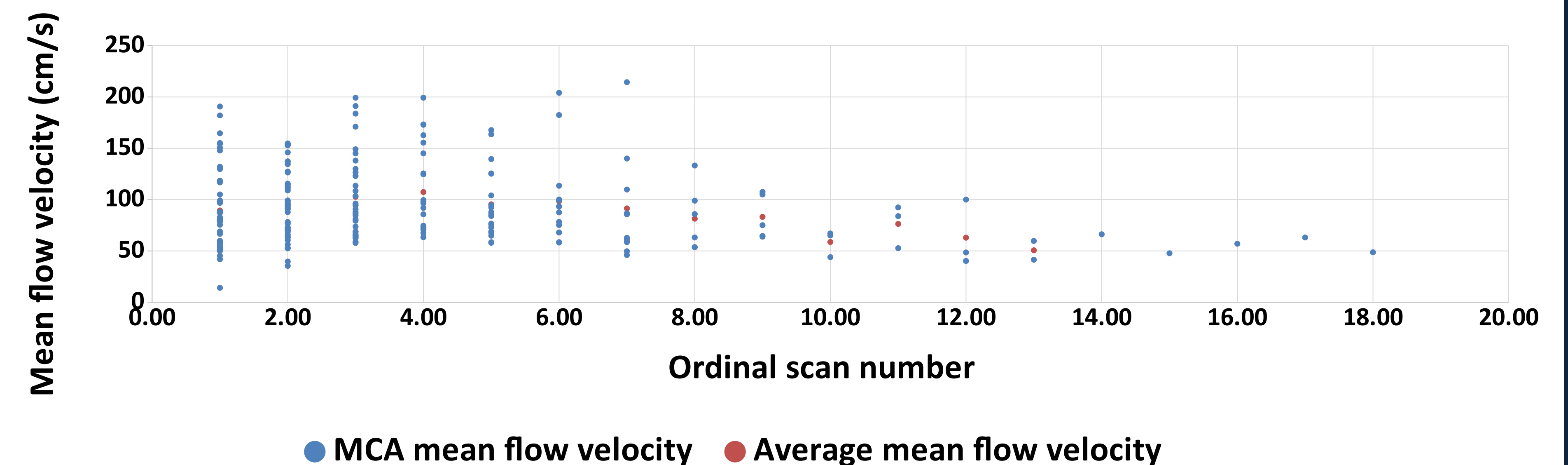
## Results

Of the 47 patients identified, there were 33 (70%) males, 24 (51%) Hispanic patients, with a mean age was 8.24 years ( $\pm 5.82$ ). The most common mechanism of injury was motor vehicle related collision (51%) and most injuries were closed TBIs (89%). There were 3 deaths (6.4%), occurring in the acute setting secondary to their injuries.

Patient age proved to be the only demographic factor independently statistically associated with flow velocity. We found no differences in GOS-E Peds scores based on single incidences of low and high flow velocity but did note all 3 deaths occurred in patients with  $\geq 1$  low flow velocity. There were significant associations with decreased hemoglobin (mean 10.35 g/dL in normal flow state compared to 9.6 g/dL in high flow state). Flow states were not otherwise associated with concurrent measures such as PaO<sub>2</sub>, PaCO<sub>2</sub>, HR, SBP, ICP or temperature. Additional assessment of the trends for patients with low flow states found that following detection of low flow velocity 8 (40%) patients later recovered to normal flow velocities. Following detection of high flow velocity 4 (40%) patients later recovered to a normal flow velocities.

**Table 1: Demographics and associations in patients with  $\geq 1$  abnormal flow velocity TCD**

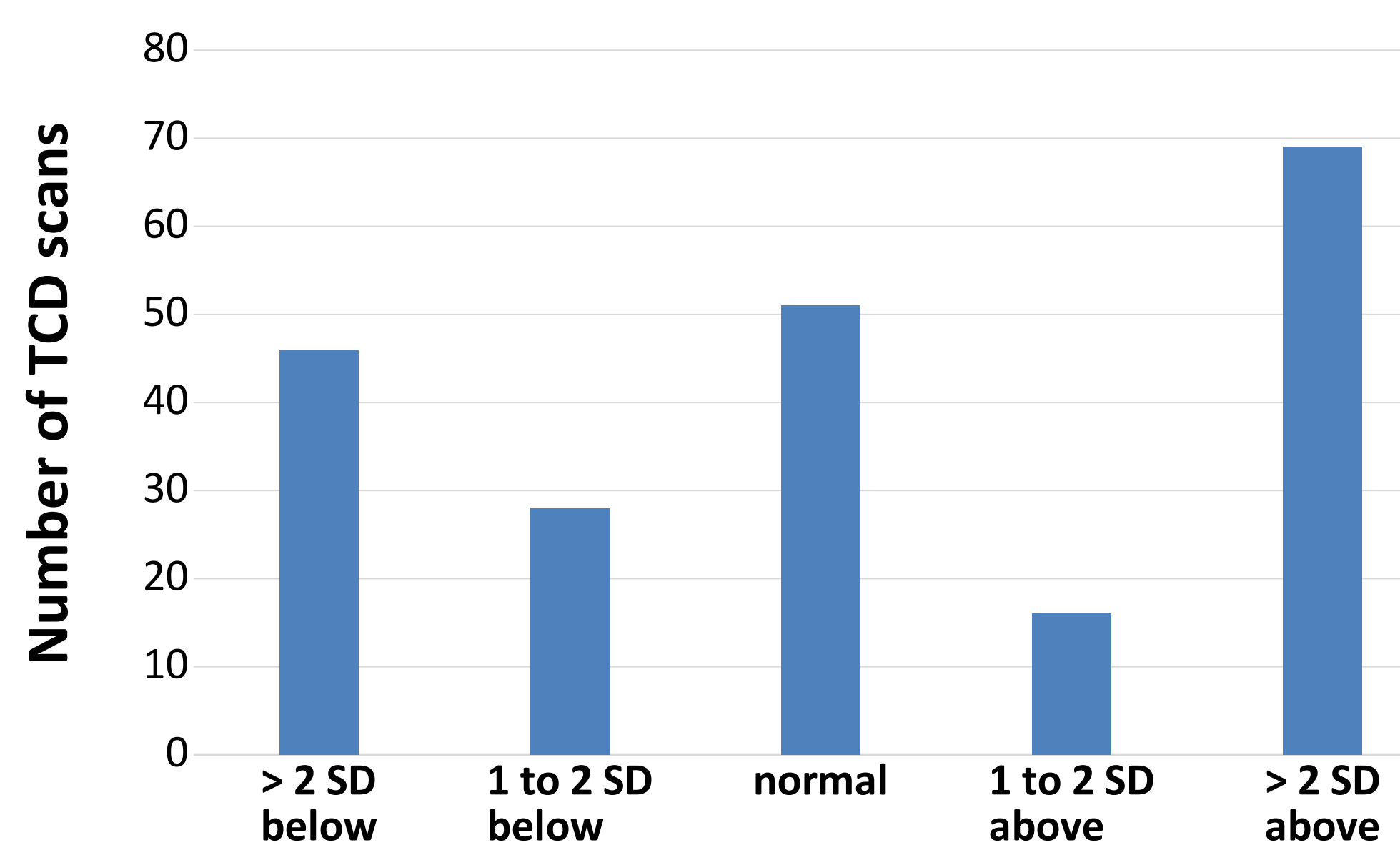
Demographics	Total (n=47)	Normal (n=18)	Low flow <sup>1</sup> (n=20)	High flow <sup>1</sup> (n=10)	P-value
<b>Age</b>					
0 to 1	7 (15%)	5 (28%)	1 (5%)	1 (10%)	0.12
1.1 to 5	11 (23%)	2 (11%)	6 (20%)	4 (40%)	0.19
5.1 to 10	7 (17%)	1 (6%)	6 (30%)	0 (0%)	0.068
10.1 to 15	12 (27%)	4 (22%)	4 (20%)	4 (40%)	0.52
>15	10 (17%)	6 (33%)	3 (15%)	1 (10%)	0.34
<b>Sex</b>					0.89
Male	33 (70%)	13 (72%)	13 (65%)	7 (70%)	
Female	14 (30%)	5 (28%)	7 (35%)	3 (30%)	
<b>Race</b>					
White	16 (34%)	4 (22%)	11 (55%)	2 (20%)	0.056
Black	1 (2%)	1 (6%)	0 (0%)	0 (0%)	0.58
Hispanic	24 (51%)	11 (61%)	6 (30%)	7 (70%)	0.058
Native American	6 (11%)	2 (11%)	3 (15%)	1 (10%)	0.90
<b>Mechanism of Injury</b>					0.63
Motor vehicle accident	25 (51%)	12 (67%)	8 (40%)	5 (50%)	
Accidental fall	9 (19%)	3 (17%)	5 (25%)	1 (10%)	
Suicide/self-harm	2 (4%)	0 (0%)	1 (5%)	1 (10%)	
Homicide/intentional	6 (13%)	1 (6%)	3 (15%)	2 (20%)	
Other	5 (11%)	2 (11%)	3 (15%)	1 (10%)	
<b>Outcomes</b>					
<b>GOS-E Peds 3 month</b>					0.69
<5	23 (49%)	10 (55%)	9 (45%)	4 (40%)	
$\geq 5$	24 (51%)	8 (45%)	11 (55%)	6 (60%)	
<b>GOS-E Peds 6 month<sup>2</sup></b>					0.48
<5	21 (46%)	11 (65%)	9 (45%)	5 (50%)	
$\geq 5$	25 (54%)	6 (35%)	11 (55%)	5 (50%)	
<b>GOS-E Peds 12 month<sup>3</sup></b>					0.86
<5	15	6 (35%)	6 (33%)	3 (38%)	
$\geq 5$	24	8 (57%)	12 (67%)	5 (62%)	
<b>Death</b>	3	0 (0%)	3 (16%)	0 (0%)	0.22



**Figure 1: Distribution of MCA velocities by TCD scan number per patient. Trend displays longer TCD usage for patients showing lower mean flow velocities on previous scans**

**Table 2: Associations with persistently low flow velocities**

Demographics	Persistent low (n=12)	All others <sup>1</sup> (n=35)	P-value
<b>Age</b>			
0 to 1	1 (8%)	6 (17%)	0.66
1.1 to 5	3 (25%)	8 (23%)	0.30
5.1 to 10	5 (42%)	3 (9%)	<b>0.008</b>
10.1 to 15	2 (17%)	11 (31%)	0.41
>15	1 (8%)	7 (20%)	0.20
<b>Sex</b>			0.08
Male	6 (50%)	27 (77%)	
Female	6 (50%)	8 (23%)	
<b>Race</b>			
White	7 (58%)	9 (26%)	0.081
Black	0 (0%)	1 (3%)	0.73
Hispanic	3 (25%)	21 (60%)	<b>0.035</b>
Native American	2 (17%)	4 (11%)	0.94
<b>Mechanism of Injury</b>			
Motor vehicle related incident	4 (33%)	20 (57%)	0.34
Accidental fall	1 (8%)	8 (23%)	0.73
Suicide/self-harm	0 (0%)	2 (6%)	1
Homicide/purposeful	2 (17%)	4 (11%)	0.48
Other	5 (42%)	0 (0%)	0.11
<b>GOS-E Peds 3 month</b>			0.21
<5	4 (33%)	19 (54%)	
$\geq 5$	8 (67%)	16 (46%)	
<b>GOS-E Peds 6 month</b>			0.09
<5	4 (33%)	21 (62%)	
$\geq 5$	8 (67%)	13 (38%)	
<b>GOS-E Peds 12 month</b>			0.48
<5	3 (27%)	12 (43%)	
$\geq 5$	8 (73%)	16 (57%)	
<b>Death</b>	3 (25%)	0 (0%)	<b>0.014</b>



**Figure 2: Distribution of TCD detected flow velocities measured as standard deviations from normalized values. Displays high volume of very high and low flow velocities when controlling for age-sex normalized values.**

## Limitations

There were limitations to this study. The first is the small sample size which likely hindered the study's ability to capture the long-term impacts of single flow recordings. To further examine the role of race, a larger sample of patients and longitudinal prospective data is required. Also, due to the retrospective nature of the study, the TCD examinations were not performed following a time standardized protocol, but rather as a daily screen for changes in velocity and potential for CVS as a potential contributor of ischemia.

## Conclusion

This study adds to expanding literature describing the diverse cerebrovascular dynamics of pediatric TBI patients with unique findings related to low flow velocities and implications of patient race. Further studies are needed to evaluate the complex cerebrovascular physiology of pediatric TBI assessed by TCD and correlate findings with other measures of cerebral autoregulation and anatomical neuroimaging.

## Summary

- TCDs used in routine care for pediatric patients with severe TBI may be useful in detecting secondary neurovascular changes.
- Acutely detected low flow velocities may be particularly indicative of poor long-term prognosis.
- More investigations are needed into correlations with anatomic studies and more specific neurologic assessments such as EEG

## Acknowledgements

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