

# Cerebral Blood Flow Changes in Severe Paediatric Head Trauma Using Transcranial Doppler Ultrasonography



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## Abstract

Head injury is an important factor in children's morbidity and mortality. Following severe head injury, derangements of the cerebral vasculature and cerebral blood flow often occur rendering the brain at risk of secondary ischemia. The non-invasiveness and the ease in the use of the transcranial Doppler ultrasound technique make it an important tool for assessment of changes in cerebral circulation not only for the purpose of diagnosis but also for follow up. This study was conducted to: Monitor blood flow changes of the middle cerebral artery and the extracranial part of internal carotid artery by transcranial Doppler ultrasonography in severe pediatric head injury. Assess the ischemic factors detected by TCD that may potentially affect the outcome after severe head injury in children and to estimate the effects of calcium channel blockers in the management of cerebral vasospasm in children after severe head trauma. A prospective cohort study was conducted on 80 severe head injured children admitted to the Neurosurgery Department at Mansoura Emergency Hospital from April 2003 to May 2006. Patients were eligible for inclusion if they were children below 12 years of age had severe closed head injury with GCS scores of 8 or less on admission and who arrived within 24 hours after trauma.

Transcranial Doppler was traced for all and children for measuring the blood flow velocities for both middle cerebral and extracranial internal carotid arteries on both sides on admission and during the monitoring period on day 3, day 7 and also at discharge. The Mean blood flow velocity was considered abnormally elevated if exceeded 90cm/sec in the middle cerebral artery and 44cm/sec in the extracranial internal carotid artery and vasospasm was diagnosed if the Lindegaard ratio was more than three. Children with severe head trauma had mean age of 7.4 ±3.2 years, boys constituted the majority of cases. Motor vehicle accidents were the commonest cause of pediatric head trauma. Measuring the blood flow velocity by transcranial Doppler ultrasonography in severe pediatric head trauma showed a pattern of increase in the mean blood flow velocity on admission, day 3 reaching the peak on day 7 and thereafter, the flow velocity decreased on discharge in both middle cerebral and extracranial internal carotid artery. Children with post-traumatic vasospasm who were given nimotop showed a lower mean blood flow velocity in middle cerebral arteries compared to the children with post-traumatic vasospasm who were not given the drug. However, the beneficial effect of nimotop on the outcome was not statistically significant.

## Introduction

Head injury is an important factor in children's morbidity and mortality. Arterial vasospasm and probably resulting from this, delayed ischemic deficit are important sequels of head trauma with detrimental effects on outcome Mander et al. [1] Cerebral ischemia is considered a key factor in the development of secondary damage after brain injury Santbrink et al. [2] and still have a high prevalence in fatally head injured patients. Early detection and treatment of ischemia may improve the outcome after head trauma Chan et al. [3]. Post traumatic vasospasm is a delayed complication that involves the large basal intracranial arteries. It has been demonstrated in the past by angiography and recently by transcranial Doppler ultrasonography Martin et al. [4]. The noninvasiveness and the ease in the use of the transcranial Doppler ultrasound technique make it an important tool for assessment of changes in cerebral circulation not only for the purpose of diagnosis but also for follow up. The use of Doppler ultrasound technique for the estimation of blood flow velocity

within the intracranial circulation allows better understanding on the pathophysiological and haemodynamic mechanisms of post traumatic lesions Mander et al. [1].

## Aim of the Study

This study will be carried out to:

- Monitor blood flow changes of the middle cerebral artery and the extra cranial part of the internal carotid artery by transcranial Doppler sonography in severe pediatric head injury.
- Assess the ischemic factors detected by transcranial Doppler that may potentially affect the outcome after severe head injury in children.
- Estimate the effects of calcium channel blockers in the management of cerebral vasospasm in children after severe head trauma.

### Subjects and Methods

#### Subjects

A prospective cohort study was conducted upon 80 severe head injured children admitted to the Neurosurgery Department at Mansoura Emergency Hospital throughout the period from April 2003 to May 2006. There were 51 boys and 29 girls their age ranged from 1.5 to 12 years with a mean age of  $7.4 \pm 3.2$  years. Patients were eligible for inclusion if they were children below 12 years of age, had severe closed head injury, with Glasgow Coma Scale score (GCSs) of eight points or less on admission and who arrived within 24 hours after trauma.

#### Methods

Following resuscitation, a base line demographic data was collected including age, sex, type of trauma and the mean time from injury until the patients were examined in the emergency hospital and. Then the child underwent a clinical evaluation for the overt signs of head injury on admission. Assessment the level of consciousness using the Glasgow Coma Scales scores, pupillary response and were carried out as a measure of neurological indices of brain injury. After emergency clinical evaluation with stabilization of ventilation and hemodynamics a computed tomography (CT) was performed and initial transcranial Doppler ultrasonography (TCD) was traced for all children in admission. The Glasgow Coma Scale scores and general clinical status were monitored during the whole period of treatment. The duration of the follow up depended on both clinical circumstances and the Transcranial Doppler findings. CT scans were repeated on 5th, day, when clinically indicated and on discharge. TCD, however were performed on day 3, day 7, if any deterioration occurs as regard (GCS) and on discharge. TCD recordings were made using Multi-Dopx2 version DWL 2.55 e made by DWL Elektronische system GmbH Langerach 4 Germany .

The mean blood flow velocity in both of the middle cerebral arteries (MCA) and both of the extracranial internal carotid arteries (EC-ICA) were measured bilaterally using 2MHz and 8 MHz probes. The vessels were insonated through temporal (MCA) and submandibular (EC-ICA) windows. The exact positioning of the ultrasound probe was rather critical in most subjects. A satisfactory signal could only be obtained in a restricted region above the zygomatic arch from 1 to 5 cm in front of the ear. An "ultrasonic window" had to be located in each individual by searching this region to obtain a maximum amplitude of the Doppler signals. In order to record the velocity in the middle cerebral artery the depth was set at the range-gate to 5.0 cm. Then the depth setting was increased stepwise until the MCA signal became evident and clear. The depth is 35-45mm for the age between 1-3 years, 40-45mm between the age 3-6years, and 45-50mm between the age 6-18 years [5]. The velocity in the extracranial internal carotid artery in the neck was measured using the same Doppler instrument and probe used for the transcranial recordings.

The probe was placed slightly below the mandibular angle and aimed cranially. The depth of the range-gate was set in the

range from 3.5 to 4.0 cm to achieve insonation at a sharp angle of less than  $30^\circ$  [6]. The blood flow velocity for MCA is  $62 \pm 12$  cm/sec. However, 90 cm/s is considered to be the upper normal range. The mean flow velocity was considered abnormally elevated if it exceeded 100 cm/sec [3]. The velocity in the extracranial ICA was  $37 \pm 6.5$  cm/s. The ratio between the velocity in the MCA and that in the extracranial ICA was  $1.7 \pm 0.41$  [1]. The relation of the mean flow velocity to age, gender, CT and mode of trauma has been studied. Evidence of vasospasm can be diagnosed when the mean blood flow velocity in the MCA is greater than 120 cm/sec and the Lindegaard ratio which is known also as hemispheric ratio is more than 3 Aaslid et al. 1982 and Lindegaard et al. [6,7]. Hyperemia was considered when the flow velocity of the middle cerebral artery exceeds 100 cm/s without evidence of vasospasm [1].

Vasospasm was classified according to the measurements of the blood flow velocity into the following grades: Aaslid et al. [6] and Sloan et al. [8]. Mild: 120- 160 cm/s Moderate: 160-220cm/s Severe: >220cm/s The onset of vasospasm was considered either early or late if occurred before or after 72 hours respectively from head trauma [9]. Cases with vasospasm were randomly assigned to two groups which were matched for age, sex, mode of injury, time interval from injury to admission, neurological status and CT scan findings. One group was given nimotope (the tested drug) which was initially administered orally through a nasogastric tube in a dose of 30 mg/8h Battistella et al. [10] until normalization of the flow velocity, clinical improvement, discharge or death. The other group was not given the treatment under investigation. The outcome of the cases of the two groups was evaluated using the Glasgow Outcome score on discharge. The short term outcome was based on Glasgow Outcome Scale Score at the time of discharge Steiger et al. [11]. The outcome was also subdivided into favorable which includes good recovery and moderate disability and unfavorable which includes severe disability, vegetative and deaths. The classification of CCT findings was determined according to Hirsch et al. [10].

#### Statistical Analysis

The statistical analysis of data done by using Excell program and SPSS program (Statistical Package for Social Science version 10). The description of the data done in form of mean  $\pm$  SD (standard deviation) for quantitative data and frequency and proportion for qualitative data. P is significant if  $\leq 0.05$  at confidence interval 95%.

**I. Table 1:** The age of children with severe head trauma ranged from 1-12 years with a mean age of  $7.4 \pm 3.2$  years. The highest percentage of traumatized children was found in the age group between 10-12 years. Fourteen children (17.5%) were aged 3 years or less, 25 (31.3%) were between 4-6 years, 10 (12.5%) were between 7-9 years and the highest percentage of children (38.8%) were in the age of 10-12 years. Regarding the gender, boys constituted the majority of cases (63.8%) compared to girls (36.3%) with a ratio of 1.8:1. Concerning the mode of trauma, motor vehicle accidents were the commonest cause of Paediatric head trauma (63.8%) followed by falling from height (28.8%). The

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GCS score in the majority of children (65%) was between 6-8. The computerized tomography scan showed that single lesion was the commonest radiographic finding (73.8%) of which edema constituted 36.3%. Combined lesions came next and accounted

for 20% and no pathology detected in 6.3% of the cases. The therapeutic regimen showed that most of the injured children (82.5%) were managed conservatively and the remaining cases (17.5%) received combined medical and surgical treatments.

**Table 1:** Characteristics of children with severe head trauma.

Variables	Total (n=80)	
	No	(%)
<b>Age in Years</b>		
1-3	14	(17.5)
4-6	25	(31.3)
7-9	10	(12.5)
10-12	31	(38.8)
$\bar{x} \pm SD$	7.4±3.2 yrs	
<b>Gender</b>		
Boys	51	(63.8)
Girls	29	(36.3)
<b>Mode of Trauma</b>		
Motor vehicle accidents	51	(63.8)
Falling from height	23	(28.8)
Falling downstairs	4	(5.0)
Blow to head	2	(2.5)
<b>GCS Score</b>		
3-5	12	(15.0)
6-8	68	(85.0)
<b>CT Scan Findings</b>		
No pathology	5	(6.3)
Single lesion	59	(73.8)
Edema	29	(36.3)
Fracture	3	(3.8)
Hemorrhage		
Epidural	4	(6.0)
Subdural	5	(7.5)
Subarachnoid	1	(1.3)
Intracerebral	3	(3.8)
Contusion	13	(16.3)
Combined	16	(20.0)
<b>Therapeutic Regimen</b>		
Medical care	66	(82.5)
Combined medical and surgical treatment	14	(17.5)

$\bar{x}$ : Mean

SD: Standard Deviation

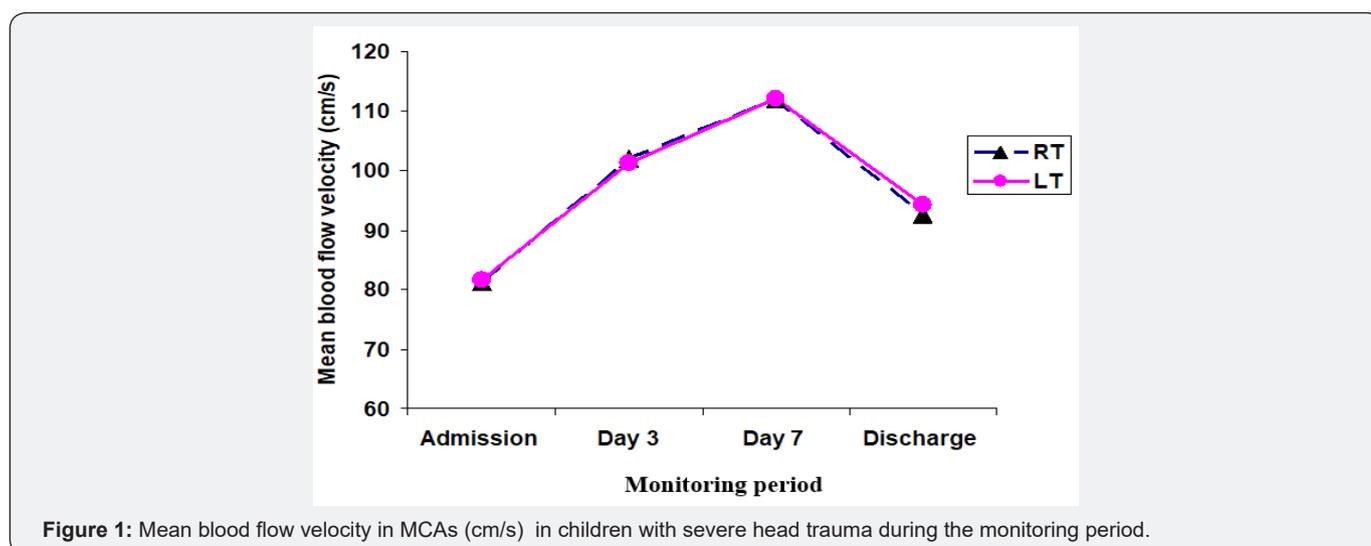
**II. Table 2:** There was no statistically significant difference concerning the gender, mode of trauma, GCS score, CT scan findings and the therapeutic regimen in relation to different age groups ( $P > 0.05$ ).

**Table 2:** Characteristics of children with severe head trauma according to the age.

Characteristics	Age in years								Test of significance	
	1-3 n=14		4-6 n=25		7-9 n= 10		10-12 n=31		Chi- square	P value
	No.	(%)	No.	(%)	No.	(%)	No.	(%)		
<b>Gender</b>										

Boys	10	-71.4	17	-68	7	-70	17	-54.8	1.79	0.61
Girls	4	-28.6	8	-32	3	-30	14	-45.2		
<b>Mode of trauma</b>										
Motor vehicle accidents	9	-64.3	14	-56	7	-70	21	-67.7	5.5	0.78
Falling from height	5	-35.7	9	-36	3	-30	6	-19.4		
Falling downstairs	0	0	1	-4	0	0	3	-9.7		
Blow to head	0	0	1	-4	0	0	1	-3.2		
<b>GCS score</b>										
3-5	0	0	5	-20	2	-20	5	-16.1	3.18	0.36
6-8	14	-100	20	-80	8	-80	26	-83.9		
<b>CT scan findings</b>										
No pathology	0	0	0	0	0	0	5	-16.1	12.4	0.112
Single lesion	12	-85.7	17	-68	6	-60	24	-77.4		
Edema	4	-28.6	10	-40	3	-30	12	-38.7		
Fracture	0	0	1	-4	0	0	2	-6.5		
Hemorrhage	2	-14.3	1	-4	0	0	1	-3.2		
A Epidural										
A Subdural	0	0	1	-4	2	-20	3	-9.7		
A Subarachnoid	0	0	0	0	0	0	1	-3.2		
A Intracerebral	2	-14.3	0	0	0	0	1	-3.2		
A Contusion	4	-28.6	4	-16	1	-10	4	-12.9		
Combined	2	-14.3	8	-32	4	-40	2	-6.5		
<b>Therapeutic regimen</b>										
Medical care	12	-85.7	19	-76	9	-90	26	-83.9		
Combined medical and surgical treatment	2	-14.3	6	-24	1	-10	5	-16.1	1.26	0.73

**III. Figure 1:** Measuring the blood flow velocity in the right and left middle cerebral arteries during the monitoring period showed a statistically significant increase ( $P < 0.05$ ) in the mean blood flow velocity on admission, day 3 reaching the peak on day 7 and thereafter, the flow velocity decreased on discharge.



**Figure 1:** Mean blood flow velocity in MCAs (cm/s) in children with severe head trauma during the monitoring period.

**IV. Figure 2:** Measuring the blood flow velocity in the right and left extracranial internal carotid arteries during the monitoring period revealed a statistically significant increase in the mean blood flow velocity on admission, day 3 and day 7, thereafter there was a decline in the blood flow velocity on discharge.

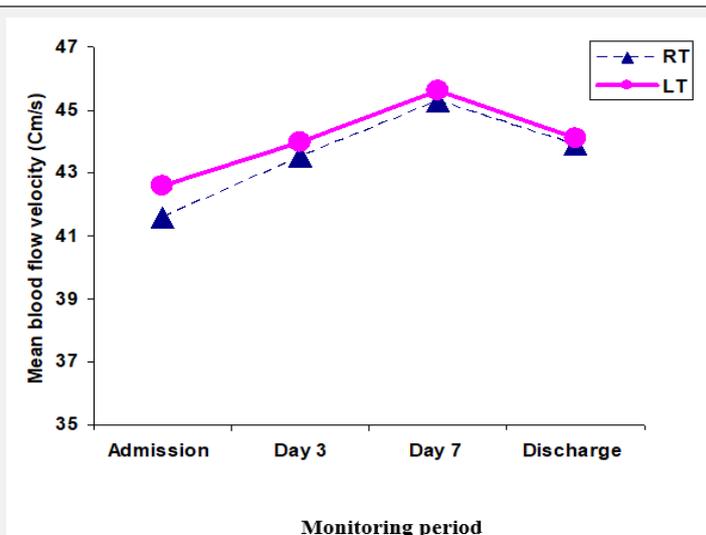


Figure 2: Mean blood flow velocity of EC-ICA in children with severe head trauma during the monitoring period.

V. **Table 3:** Twenty- two out of eighty children with severe head trauma (27.5%) developed post-traumatic vasospasm and the highest percentage of them (40.9%) was in the age group between 1-3 years. The difference in age distribution between children with and without post-traumatic vasospasm was statistically highly significant. Gender, mode of trauma, GCS score, CT scan findings

and the types of management, showed no statistically significant difference between children with vasospasm and those without spasm. However, the mean hospital stay was significantly longer in children with vasospasm (15.9±8.9 days) compared to spasm free children (10.8± 6.2 days).

Table 3: Characteristics of children with severe head trauma in relation to the presence or absence of post-traumatic vasospasm.

Variables	No. of Patients= 80	Post-Traumatic Vasospasm		Test of Sig.		P Value
		Present N=22(27.5%)		Absent N=58 (72.5)		
		No	(%)	No.	(%)	
<b>Age in Years</b>						
1 - 3	14	9	(40.9)	5	(8.6)	X <sup>2</sup> =12.2 0.007**
4 - 6	25	4	(18.2)	21	(36.2)	
7 - 9	10	3	(13.6)	7	(12.1)	
10-12	31	6	(27.3)	25	(43.1)	
X ± SD		8.0±2.94		7.12±3.3		T=1.076 0.25
<b>Gender</b>						
Boys	51	15	(68.2)	36	(62.1)	X <sup>2</sup> =0.258 0.612
Girls	29	7	(31.8)	22	(37.9)	
<b>Mode of Trauma</b>						
Motor Vehicle- Accident	51	13	(59.1)	38	(65.5)	X <sup>2</sup> =1.977 0.577
Falling From Height	23	7	(31.8)	16	(27.6)	
Falling Downstairs	4	2	(9.1)	2	(3.4)	
Blow To Head	2	0	(0)	2	(3.4)	
<b>GCS Score</b>						
3-5	12	2	(9.1)	10	(17.2)	X <sup>2</sup> =0.831 0.362
6-8	68	20	(90.9)	48	(82.8)	
<b>CT Scan Findings</b>						

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No Pathology	5	2	(9.1)	3	(5.2)	X <sup>2</sup> =3.622	0.890
Single Lesion	59	14	(63.6)	45	(77.6)		
Oedema	29	6	(27.3)	23	(39.7)		
Fracture	3	0	(0)	3	(5.2)		
Epidural	6	2	(9.1)	4	(6.9)		
Subdural	4	1	(4.5)	3	(5.2)		
Subarachnoid	1	0	(0)	1	(1.7)		
Intracerebral	3	1	(4.5)	2	(3.4)		
Contusion	13	4	(18.2)	9	(15.9)		
Combined	16	6	(27.3)	10	(17.2)		
<b>Management</b>							
Medical	66	21	(95.5)	45	(77.6)	X <sup>2</sup> =3.52	0.060
Combined Medical And Surgical Treatment	14	1	(4.5)	13	(22.4)		
<b>Hospital Stay</b>							
<b>X ± SD (Days)</b>		15.9±8.9		10.8±6.2		T=2.877	0.005*

$\bar{x}$ : Mean

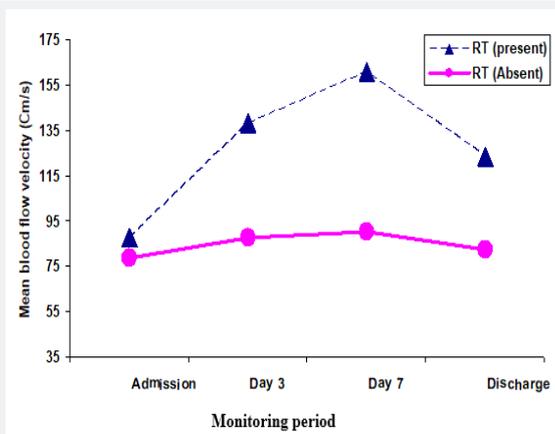
SD: Standard deviation

\*Significance.

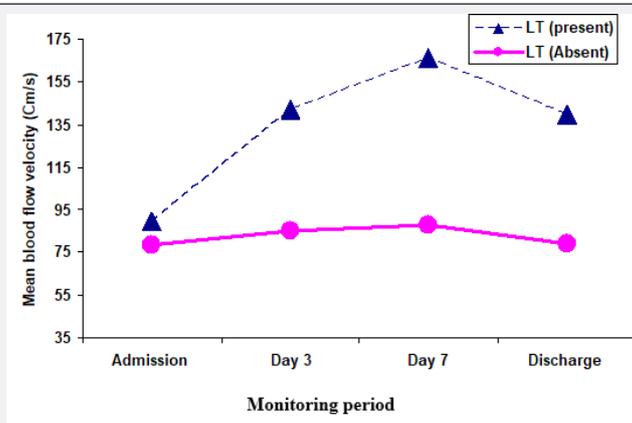
\*\*Highly significance

**VI. Figure 3:** The Mean blood flow velocity in the middle cerebral arteries was higher in children with post-traumatic vasospasm than those without spasm throughout the monitoring period. The difference in blood flow velocity between children

with and without vasospasm was not statistically significant ( $P > 0.05$ ) on admission but highly significant ( $P < 0.001$ ) on each of day 3, day 7 and on discharge (Figures 3A & 3B).



**Figure 3A:** Mean blood flow velocity changes in RT MCA in children in relation to post-traumatic vasospasm during the monitoring period.



**Figure 3B:** Mean blood flow velocity changes in LT MCA in children in relation to post-traumatic vasospasm during the monitoring period.

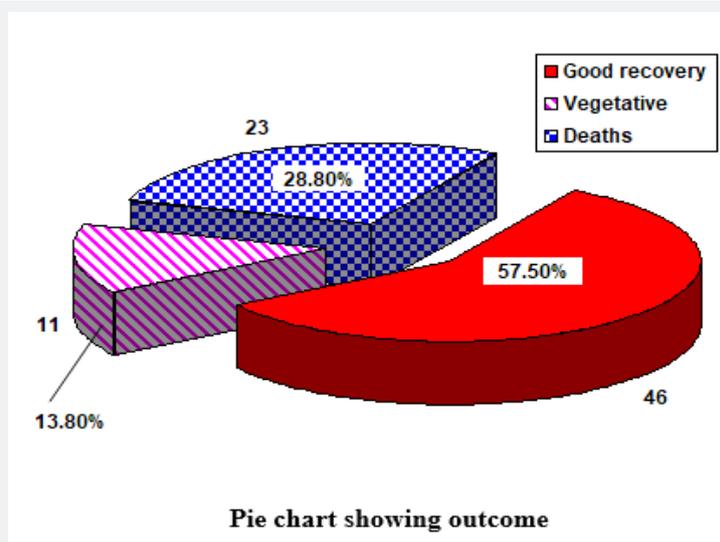
**VII. Table 4:** On discharge, children with post-traumatic vasospasm (MCA/ICA ratio above 3) who were given calcium channel blocker (nimotope) showed a significantly lower mean blood flow velocity in the right and left middle cerebral arteries compared to the children with post-traumatic vasospasm who

were not given the drug. The improvement of the post-traumatic vasospasm (MCA/ICA ratio less than 3) in children who were given the calcium channel blocker did not differ significantly from those who were not given.

**Table 4:** Effect of calcium channel blocker (nimotope) on cerebral blood flow velocity in MCAs on discharge in children with post-traumatic vasospasm.

Variables	Children with Post- traumatic Vasospasm				Test of sig.	P Value
	Given Nimotope n=8		Not given nimotope n=6			
<b>Mean Blood flow Velocity (Cm/s) in MCA on discharge</b>						
RT	104±19.6		146.5±32.1		t= 2.93	0.014**
LT	121.9±40.5		161.8±15.4		t=2.27	0.044**
<b>Posttraumatic vasospasm</b>	<b>No</b>	<b>(%)</b>	<b>No</b>	<b>(%)</b>		
Improved (MCA/ICA < 3)	6	(75.0)	2	(33.3)	X <sup>2</sup> 2.26	0.13
Not improved (MCA/ICA > 3)	2	(25.0)	4	(66.7)		

\*\*Highly significant.



**Figure 4:** Outcome of children with severe head trauma.

**VIII. Figure 4:** The outcome of the 80 children with severe head trauma was good recovery in 46 (57.5%), vegetative state in 11 (13.8%) and deaths in 23 cases (28.8%).

**IX. Table 5:** The outcome in relation to demographic characteristics showed that good recovery was the most evident outcome in children with severe head trauma in relation to age, gender and mode of trauma. The highest recovery rate (68%) was for the age from 4-6 years old and the highest mortality rate (40%) was in the age of 7-9 years and unfavorable outcome (vegetative state and deaths ) was more pronounced in the age of 1-3 years.

However, the difference in outcome in the different age groups was not statistically significant. As regard the gender, girls had statistically significant higher recovery rate (62.1%) compared to boys (54.9%). Concerning the type of trauma, good recovery was the most evident outcome for all causes of trauma and accounted for 100% for each of falling downstairs and blows to the head followed by 69.6% for the falling from height and 47.1% for the motor vehicle accidents. The highest mortality rate (37.3%) was for motor vehicle accidents. The difference in the outcome in relation to the mode of trauma was not statistically significant.

**Table 5:** The outcome of children with severe head trauma in relation to demographic characteristics.

Characteristics	No. of patients 80	Outcome						Test of sig.	P value
		Good recovery n=46		Vegetative n= 11		Deaths n= 23			
		No.	(%)	No.	(%)	No.	(%)		
<b>Age in years</b>									

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1-3	14	6	942.9)	3	(21.4)	5	(35.7)	F=1545	0.22
4-6	25	17	(68.0)	2	(8.0)	6	(24.0)		
7-9	10	6	(60.0)	0	(0)	4	(40.0)		
10-12	31	17	(54.8)	6	(19.4)	8	(25.8)		
<b>Gender</b>									
Boys	51	28	(54.9)	8	(15.7)	15	(29.4)	X <sup>2</sup> =133	0.0004**
Girls	29	18	(62.1)	3	(10.3)	8	(27.6)		
<b>Mode of trauma</b>									
Motor vehicle accidents	51	24	(47.1)	8	(15.7)	19	(37.3)	X <sup>2</sup> =8.44	0.207
Falling from height.	23	16	(69.6)	3	(13.0)	4	(917.4)		
Falling downstairs	4	4	(100)	0	(0)	0	(0)		
Blow to head	2	2	(100)	0	(0)	0	(0)		

\*\* Highly significant.

**Table 6:** Outcome of children with severe head trauma in relation to the neurological assessment

Neurological assessment	No. of patients = 80	Outcome						Test of sig.	P value
		Good recovery n=46		Vegetative n= 11		Deaths n= 23			
		No.	(%)	No.	(%)	No.	(%)		
<b>CGS Score</b>									
3-5	12	0	(0)	1	(8.3)	11	(91.7)	X <sup>2</sup> = 2.567	0.633
6-8	68	46	(67.6)	10	(14.7)	12	(17.6)		
<b>Pupillary reaction</b>									
Round reactive	44	40	(90.9)	4	(9.1)	0	(0)	X <sup>2</sup> =53.32	0.0001**
Sluggish	25	2	(8.0)	5	(20.0)	18	(72.0)		
Unequal	11	4	(8.0)	2	(18.2)	5	(45.5)		

\*\* Highly significant.

**X. Table 6:** Regarding the GCS score, it was found that all children with severe head trauma with a score of (3-5) had unfavourable outcome (deaths 91.7 %) and vegetative (8.3%). However, the majority (67.6%) of children with a score of (6-8) had good recovery. Concerning the outcome in relation to the

pupillary reaction, children with round reactive pupil had the highest good recovery rate (90.9%) whereas those with sluggish and unequal pupils had the worst outcome (72% and 45.5% deaths respectively). The difference in the outcome was highly statistically significant (P<0.0001).

**Table 7:** Outcome of children with severe head trauma in relation to radiological findings. (A): Outcome in relation to CT scan findings.

CT scan findings	No. 80	Outcome						Test of sig.	P value
		Good recovery n=46		Vegetative n= 11		Deaths n= 23			
		No.	(%)	No.	(%)	No.	(%)		
No pathology	5	4	(80.0)	1	(20.0)	0	(0)	X <sup>2</sup> = 29.4	0.021*
Single lesion	59	36	(61.0)	10	(16.9)	13	(22.0)		
Oedema	29	18	(62.0)	4	(13.8)	7	(24.1)		
Fracture	3	2	(66.7)	1	(33.3)	0	(0)		
Hemorrhage	27	16	(59.3)	5	(18.5)	6	(22.2)		
Epidural	6	5	(83.3)	0	(0)	1	(16.7)		
Subdural	4	2	(50.0)	2	(50.0)	0	(0)		
Subarachnoid	1	0	(0)	1	(100.0)	0	(0)		
Intracerebral	3	2	(66.7)	1	(33.3)	0	(0)		
Contusion	13	7	(53.8)	1	(7.7)	5	(38.5)		
<b>Combined</b>	16	6	(37.5)	0	(0)	10	(62.5)		

\*Significant.

**XI. Table 7 (A):** The outcome of children with severe head trauma in relation to CT scan findings showed that cases with no pathology detected had a good recovery rate (80%) with no mortality. Those with singular lesion had a good recovery rate 61% and 22% deaths. Cases with combined lesions had the highest mortality rate (62.5%).

**XII. Table 7 (B):** The outcome of children with severe head trauma in relation to the initial blood flow velocity in the middle cerebral arteries showed that the majority of cases (69.6%) with

blood flow velocity between 50-90 cm/s had good recovery. The only case with blood flow velocity of less than 50 cm/s also showed good recovery. However, more than half (56.5%) of those with blood flow velocity above 90 cm/s had poor outcome. The outcome of the cohort in relation to the initial blood flow velocity was highly statistically significant ( $P < 0.001$ ). Good recovery cases had initially lower insignificant mean blood flow velocity in the right and left middle cerebral arteries compared to those of vegetative state and deaths.

**Table 7B:** Outcome in relation to the initial blood flow velocity in MCA (cm/s) assessed by Transcranial Doppler (TCD).

Blood flow velocity in MCA (cm/s)	No. of patients = 80	Outcome						Test of sig.	P value	
		Good recovery n=46		Vegetative n= 11		Deaths n= 23				
		No.	(%)	No.	(%)	No.	(%)			
< 50	1	1	(100)	1	(8.3)	11	(91.7)	$X^2 = 12.74$	0.001**	
50-90	56	39	(69.6)	10	(14.7)	12	(17.6)			
>90	23	6	(26.1)	4	(9.1)	0	(0)			
RT (Mean $\pm$ SD)	80	77.2 $\pm$ 18.2		82.5 $\pm$ 16.9		88.4 $\pm$ 33.4		F=1.774	0.177	88.4 $\pm$ 33.4
LT (Mean $\pm$ SD)	80	79.8 $\pm$ 19.4		83.1 $\pm$ 21.1		84.7 $\pm$ 28.4		F=0.387	0.681	84.7 $\pm$ 28.4

SD: Standard deviation \*\*Highly significant.

**XIII. Table 7 (C):** The outcome of children with severe head trauma in relation to ischemic factors assessed by transcranial Doppler revealed that less than half of the cases with vasospasm had a good recovery rate (45.5%) compared to 18.2% vegetatives and 36.4% deaths. The difference in the outcome, however, was

not statistically significant ( $P > 0.05$ ). As regard hyperemia, more than half of the cases 57.1% had good recovery and the poor outcome accounted for 21.4% for each of the vegetatives and deaths. However, the difference in the outcome was not statistically significant.

**Table 7C:** Outcome in relation to the ischemic factors assessed by Transcranial Doppler (TCD).

Ischemic factors	No. of patients = 80	Outcome						Test of sig.	P value
		Good recovery n=46		Vegetative n= 11		Deaths n= 23			
		No.	(%)	No.	(%)	No.	(%)		
Vasospasm	22	10	(45.5)	4	(18.2)	8	(36.4)	$X^2 = 1.81$	0.4
Hyperemia	14	8	(57.1)	3	(21.4)	3	(21.4)	$X^2 = 1.04$	0.55

**XIV. Table 7 (D):** The outcome of children with severe head trauma in relation to post-traumatic vasospasm showed that cases with vasospasm had good recovery rate of (45.5%) and (36.4%) mortality compared to (62.1%) good recovery and (25.9%) deaths in those free from spasm. The difference in the outcome, however,

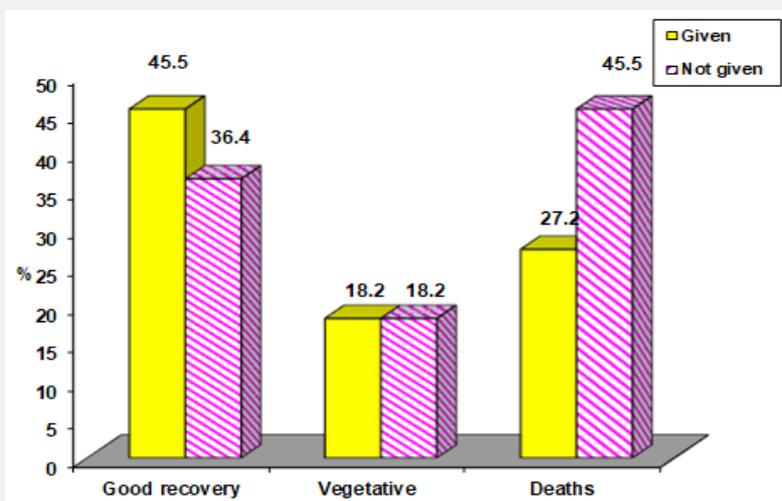
was not statistically significant. The late onset of vasospasm had a better recovery rate (66.7%) and lower mortality (16.7%) compared to early onset of vasospasm which showed (37.5%) recovery and (43.8%) mortality with insignificant difference.

**Table 7D:** Outcome in relation to post-traumatic vasospasm.

Post-traumatic vasospasm	No. of patients 80	Outcome						Test of sig.	P value
		Good recovery n=46		Vegetative n= 11		Deaths n= 23			
		No.	(%)	No.	(%)	No.	(%)		
Present	22	10	(45.5)	4	(18.2)	8	(36.4)	$X^2 = 1.81$	0.40
Absent	58	36	(62.1)	7	(12.1)	15	(25.9)		
Onset of vasospasm									
Early	16	6	(37.5)	3	(18.7)	7	(43.8)	$X^2 = 1.69$	6.06
Late	6	4	(66.7)	1	(16.7)	1	(16.7)		

**XV. Figure 5:** The outcome of children with severe head trauma in relation to the administration of calcium channel blocker (nimotope) revealed that the group which was treated with the drug showed good recovery in 45.5% and deaths in 27.2% of cases

compared to 36.4% good recovery and 45.5% deaths in the group not given the drug. However, the beneficial effect of nimotope on the outcome was not statistically significant ( $P > 0.05$ ).



**Figure 5:** Outcome of children with severe head trauma in relation to calcium channel blocker (nimotope).

### Discussion

In the present study the mean age of 80 children with severe head trauma was  $7.4 \pm 3.2$  years and the highest percentage of children (38.8%) were in the age of 10-12 years. Boys constituted the majority of cases (63.8%) with traumatic brain injury and surpassed the female rate in all age groups with a boys to girls ratio of 1.8:1. Among the study cohort motor vehicle accidents were the commonest causes (63.8%) of pediatric head trauma even in all age groups. Jager et al. [11] stated the highest incidence rate of traumatic brain injury occurred in the less than 5 years age group and males suffered traumatic brain injury at a rate 1.6 times the female rate. Pillais et al. [12] on their study on 74 patients (57%) with severe diffuse brain injury aged 15 years and less admitted to National Institute of Mental health and Neurosciences between 1992 and 1998 found that most of the patients were in the age group of 4-10 years and the majority of them were males. They also reported that the nature of trauma was either road traffic accidents or fall from height (52 and 22 patients) respectively, males are twice as likely to sustain head injuries as females and the distribution of head trauma is relatively stable throughout childhood. The authors stated that motor vehicles accident account for 27-37% of all pediatric head injuries. In most of children younger than 12 years, the victim was a pedestrian or bicyclist. Government policy and road safety campaigns, in conjunction with the help of schools, motoring organization and parental education and cooperation, must be the key to success in preventing road accidents. Despite the limitation of the GCS score to assess injury severity, standard classification of head trauma into mild moderate and severe categories is based on the GCS score GCS score of  $\leq 8$  indicate severe head trauma [13].

In the present study the majority (85%) of children with severe head trauma had an admission GCS score of 6-8. Teasdal et al. [14]

stated that GCS scores obtained during the first few days after injury are much better predictors than admission scores. Shepard et al. [15] reported that CT scan is the diagnostic study of choice in the evaluation of traumatic brain injury because it has a rapid acquisition time, is universally available, is easy to interpret, and is reliable. In the present study single lesion was the commonest (3.8%) Parizel et al. [16] stated that CT scan may identify most, but not all, such small areas of focal edema, as a result of the small density grades between edema and parenchyma. However, the case of a more traumatic impact involving tearing of nerve fibers can be indicated by minimal focal parenchymal hemorrhage in 20% of diffuse axonal injury [12,17] Pillai et al. found that diffuse brain swelling was the commonest CT findings in children with severe head injury ranging from 26% to 44%. Hirsch et al. [9] on their study on 248 children with severe head trauma reported that approximately one third (29%) of the children showed no changes in the CT, in 40.3% just one isolated CT findings mainly hemorrhages in the subdural and epidural areas were found. Focal contusional hemorrhages were the second most frequent changes Generalized cerebral edema as a single, isolated changes were relatively rare. whereas 30.6% of all children had a combined injury pattern.

Adansbaum et al. [18] stated that children under 2 years of age, head trauma requires a CT scan in case of repeated or prolonged or rapidly increasing vomiting, focal signs, loss of consciousness, unusual behavior, seizures, clinical signs of skull fracture or polytrauma, they also reported that the presence of trauma, intracranial hypertension, persisting disturbances of consciousness or associated focal sign necessitates urgent neuroimaging. The prevalence of post-traumatic increased blood flow velocity was detected in 23 children (28.8%). The mean blood flow velocity on both sides of the MCA of injured children showed a statistically significant increase from admission and day 3 reaching

the peak on day 7 and thereafter the flow velocity decreased on discharge. Similar pattern of posttraumatic significant increase in blood flow velocity of extracranial internal carotid artery, this is in agreement with Weber et al. [19] and Sanker et al. [20] and Goraj et al. [9] concluded that increased blood flow velocity was found to be a frequent sequelae of head trauma (77%). There was no consensus in the literature regarding how soon after injury the process of flow acceleration begins Goraj et al. [9].

Post-traumatic vasospasm is a well-recognized sequelae of head injury. In the present study twenty two out of eighty children with severe head trauma (27.5%) developed post-traumatic vasospasm and the highest percentage of them (40.9%) was in the age of 1-3 years old Zubkov et al. [21] on their study on 119 patients with head injury reported that post-traumatic vasospasm was detected in 32 patients (32.6%). In the present study children with post-traumatic vasospasm who were given nimotope showed a significantly lower mean blood flow velocity in both middle cerebral arteries compared to children with post-traumatic vasospasm who were not given the drug. Reversal of vascular spasm was noted in six out of eight patients (75%) with severe head trauma treated with nimotope orally, however, there was no statistically significant difference ( $P>0.05$ ) in the improvement of vasospasm between children given nimotope and those who were not given the drug. Probably the results did not reach significant level because the small number of patients in each group [22] Xio et al. on their study on 224 patients with head injury reported that nimodipine has a good effect on releasing cerebral vasospasm and diminishing cerebral blood flow velocity. [23] Pillia et al. reported a reversal of vascular spasm and marked neurological improvement were noted in eight patients with severe head trauma treated with intravenous nimodipine.

The overall outcome assessed at discharge revealed a good recovery in 46 (57.5%), vegetative state in 11 (13.8%) and mortality in 23 (28.8%) of the cases Steiger et al. [11] on their study on 86 patients with head trauma stated that 36 patients showed good recovery, 17 were moderately disabled, 6 were severely disabled, 5 remained vegetative and 8 died, 14 patients were lost Cruz et al. [22] reported that 37 children with brain trauma (82.2%) had achieved favorable clinical outcomes, whereas 8 children (17.8%) had not and the mortality rate was (4.4%). In the present study comparison of age defined subgroups of children with severe head trauma to the outcome revealed the highest recovery rate (68%) was for the age from 4-6 years old and the highest mortality rate (40%) was in the age of 7-9 years and unfavorable outcome (vegetative state and deaths) was more pronounced in the age of 1-3 years but the difference in the outcome in different age groups was not statistically significant ( $P>0.05$ ) Michaud et al. [23] on their study on 75 head injured children reported that age is an important factor that may potentially modify the outcome after brain injury in children Pillai et al. [12] found that children who were 3 years of age or less tended to have unfavorable outcome compared to those older than 3 years, but this was not statistically significant [24] Suresh et al. did not find significant contribution of age per se for outcome of head injury.

In our study gender had a significant effect on the outcome at discharge. Girls had a statistically significant higher recovery rate (62.1%) compared to boys (54.9). This result was inconsistent with Michaud et al. [23] and Pillai et al. [12] who reported that gender did not significantly related to the outcome. Our result revealed that mode of trauma did not significantly related to the outcome. This was in agreement with Michaud et al. [23] and Pillai et al. [12] who reported that the nature of trauma was either road traffic accident or fall from height was not found to be a significant predictor of outcome. In our study children with an initial score of (3-5) had unfavorable outcome (91.7%) deaths and (8.3%) vegetative and the majority (67.6%) with a score of (6-8) had a good recovery though the difference in outcome was not statistically significant. Lee et al. [25] found a highly significant difference between good and poor outcome groups for admission GCS score. Liesiene et al. [26] on their study on 43 children with head trauma stated that Glasgow coma scale results alone may have limited prognostic value in absence of other objective neurophysiologic investigation data concerning the coma outcome in children prognosis.

Children with round reactive pupils had the highest good recovery rate (90.9%) whereas those with sluggish and unequal pupils had the worst outcome. The difference in the outcome in relation to pupillary reaction was statistically significant, it was in agreement with Suresh et al. [24] who reported that pupillary size and reaction was found to be a good indicator of outcome. The difference in outcome in relation to CT scan findings was statistically significant ( $P<0.05$ ). It was in agreement with Pillai et al. [12] who concluded that CT scan did not have any relation to outcome. The outcome of children in relation to the initial blood flow velocity in the middle cerebral arteries in our study showed that the majority of cases (69.6%) with average blood flow velocity between 50-90cm/sec had good recovery [3] Chan et al. reported that MCA flow velocity at the time of admission of less than 28cm/sec predicted 80% of early fatalities within 72 hours. Our result concerning the outcome of children with severe head trauma in relation to ischemic factors assessed by TCD revealed that less than half of the cases diagnosed as having vasospasm had a good recovery rate of 45.5%, 18.2% vegetative state and 36.4% deaths.

However, the difference in the outcome among cases with vasospasm was not statistically significant ( $P>0.05$ ). Children with post-traumatic vasospasm had a higher mortality (36.4%) and lower good recovery rate (45.5%) compared to spasm free children (25.9% deaths and 62.2% good recovery). However, the difference in outcome between children with post-traumatic vasospasm and those free of spasm was not statistically significant. The onset of vasospasm had no significant effect on the outcome in our study, though late onset vasospasm had a better recovery rate (66.7%) compared to early onset (37.5%). As regard hyperemia, more than half of the cases (57.1%) had good recovery and the poor outcome accounted for 21.4% for each of vegetative state and deaths. However, the difference in the outcome was not statistically significant ( $P>0.05$ ). Lee et al. [25] on their study on head injured patients revealed that patients diagnosed as having

vasospasm by TCD reported a significant worse outcome than patients without vasospasm. Ojha et al. [27] stated that Early (within 24 hours posttrauma) onset of vasospasm is associated with poor outcome; however, delayed (>24 hours after trauma) vasospasm is not associated with poor outcome. The outcome of children with severe head trauma in our study was assessed in relation to administration of calcium channel blocker (nimotope). It was found that the group which was treated with the drug showed good recovery in 45.5% and deaths in 27.2% of the cases compared to 36.4% good recovery and 45.5% deaths in the group not given the drug. However, the beneficial effect of nimotope on the outcome was not statistically significant ( $P>0.05$ ). Lee et al. [25] on their study on 152 head trauma patients reported a good recovery with nimodipine. Pillai et al. [28] on their study on 97 severely head injured patients reported that nimodipine is unlikely improve outcome in patients with severe diffuse head injury [29-31].

### Conclusion

Children with severe head trauma had mean age of 7.4  $\pm$ 3.2years. Boys constituted the majority of cases. Motor vehicle accidents were the commonest cause of pediatric head trauma. Measuring the blood flow velocity by transcranial Doppler ultrasonography in severe pediatric head trauma showed a pattern of increase in the mean blood flow velocity on admission, day 3 reaching the peak on day 7 and thereafter, the flow velocity decreased on discharge in both middle cerebral and extracranial internal carotid artery. The increase in the middle cerebral artery flow velocities was in more pronounced fashion than the increase in the internal carotid artery. Post-traumatic vasospasm was diagnosed in twenty two cases out of eighty children with severe head trauma (27.5%). The mean blood flow velocity in the middle cerebral arteries was higher in children with post-traumatic vasospasm than those without spasm throughout the monitoring period. Children with post-traumatic vasospasm who were given nimotope showed a lower mean blood flow velocity in middle cerebral arteries compared to the children with post-traumatic vasospasm who were not given the drug, However, the beneficial effect of nimotope on the outcome was not statistically significant. Short term outcome in relation to neurological assessment revealed that the pupillary reaction was a significant predictor and the outcome of the cohort in relation to the initial blood flow velocity was highly statistically significant.

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