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Optic Nerve Sheath Diameter versus Transcranial Doppler for Monitoring Intracranial Pressure in Severe Traumatic Brain Injured Patients

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Abstract

Background: Head trauma is defined as any physical hit or blow towards the head, which may or may not lead to an injury of the underlying brain. We consider a traumatic brain injury (TBI) to be a possible consequence of the traumatic event towards the head.

Severe trauma is responsible of more than 5 million deaths every year worldwide and this incidence is expected to increase in the coming decades. To improve outcome of severe traumatic brain injury (TBI) patients this study was be done for monitoring ICP by optic nerve sheath diameter (ONSD) or transcranial doppler (TCD) in the same patient.

Aim of study: This study aimed to improve outcome of patients with severe traumatic brain injury (TBI).

Materials and Methods: This was Prospective cross section studywas conducted in Surgical and emergency ICUs within six months period from 1st November 2019 to 30th April 2020 for Severe traumatic brain injury (TBI) patients (GCS≤8) admittedto Surgical and emergency ICU, Zagazig University Hospitals.The following data have been collected from every patient:baseline measurement of ONSD and TCD (at admission), GCS and CT brain of admission, measurement of ONSD and TCD after 48 hours, GCS and CT brain after 48 hours and monitoring of intracranial pressure.

Results: We found that there is significant correlation and improvement between ONSD and nICP on admission and after 48 hrs.We found that there was significant correlation between TCD and nICP on admission and after 48 hrs.There was positive correlation ONSD and TCD PI with nICP on admission and after 48 h but no correlation between the improvement in ICP and outcome in patient with severe TBI.Many patients were difficult to be monitored by TCD in severe TBI due to difficult window, many patients needing vasopressor.Because the equation used for nICP with TCD (PI) differs from that used for ONSD, so we depended on the increase or decrease value, therefore there was a significance difference between ONSD and TCD.ONSD and TCD both were effective in assessment of ICP in severe TBI on admission and after 48 hrs.

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Conclusion:ONSD and TCD both were effective in assessment of ICP in severe TBI on admission and after 48 hrs.Both can be used as a bedside monitoring for ICP in severe TBI according to ICU equipment and patient condition

Key words: Optic Nerve Sheath Diameter, Transcranial Doppler, traumatic brain injury (TBI)

1. Introduction:

Traumatic brain injury (TBI) case is commonly found in the emergency room. TBI accompanied by increased intracranial pressure (ICP) is a neurological emergency that requires prompt and appropriate management **(1).**

ICP normally ranges from 3-15 mmHg. It depends on cerebral blood flow (CBF) and maintains at constant pressure between mean arterial pressures (MAP) of 60-160 mmHg. Inside close space of cranial cavity, there are fixed volume (total 1400 to 1700 ml) of several substances namely blood (10 percent ~150 ml), cerebrospinal fluid (CSF) (10 percent ~150 ml), and brain tissue (80 percent
~1400ml) **(2).**

Several non-invasive methods based on transcranial Doppler and optic nerve sheath diameter (ONSD) ultrasound are gaining clinical popularity due to their safety, availability, and reliability **(3).**

A trial comparing an invasive intracranial pressure (ICP) monitoring protocol with a protocol based on imaging and clinical examination found no significant differences in patient outcome. **(4).**

ultrasound techniques are abundantly used in emergency departments at present and they are readily available, they can be used to measure the ONSD for the early diagnosis in patients at a high risk for increased ICP so that decision can be made for the use of aggressive ICP monitoring techniques or for selection of patients needing referral to a neurologist **(5).**

Since the optic nerve sheath is continuously connected with the meninges, cerebrospinal fluid (CSF) can move freely between the subarachnoid spaces of the intracranial and intraorbital areas. Therefore, patients who suffer from intracranial hemorrhages or masses can experience an increase of ONSD due to CSF accumulation **(6).**

This study aimed to improve outcome of patients with severe traumatic brain injury (TBI).

2. Patients and Methods:

2.1Technical Design:

Setting:

The study was conducted in Surgical and emergancy ICUs within six months period from 1st november 2019 to 30th april 2020.

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Target population:
Severe traumatic brain injury (TBI) patients (GCS≤8) admittedto Surgical and emergency ICU, Zagazig University Hospitals.

Inclusion criteria:

- Severe traumatic brain injury (TBI) patients (GCS≤8). (Teasdale et al 1974).
- Patient age from 18 to 60 years.
- Both sexes.

Exclusion criteria:

- Spontaneous intracerebral hemorrhage (ICH).
- Patient on vasopressor.

Sample size:
The rate of severe TBI patients in ICU is 8 per month (48 per 6 months) so at least 24 of them will be included in the study.

2.2 Operational Design
Study design:
Prospective cross section study.

Admitted patients:
24 cases were selected randomly from admitted to Surgical and emergency ICUs during a period of sex months. The following data been collected from every patient :

1. Baseline measurement of ONSD and TCD (at admission) .
2. GCS and CT brain of admission.
3. Measurement of ONSD and TCD after 48 hours.
4. GCS and CT brain after 48 hours.
5. nICP by ONSD=5xONSD-14(n=noninvasive) (nICP ONSD in mm Hg, ONSD in mm).**(7)**.
6. nICP by PI of TCD = 10.93 x PI - 1.28 **(8)**.

II- Administrative Design
Approval have obtained from Zagazig University Institutional ReviewBoard (IRB).

2.3. StatisticalAnalysis:
The collected data was revised, coded, tabulated and introduced to a PC using Statistical Package for Social Science **(SPSS 25)** for windows (SPSS Inc., Chicago, IL, USA). Data was presented and suitable analysis was done depending upon the type of data obtained for each parameter.

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3. Results:

The mean age of the studied group with traumatic brain injury (TBI) was 29.63± 8.52 years old, with a range from 18 to 60 years old. most of the studied group were male (79.2%), and 20.8 % were female. (Table 1).

The mean of Optic nerve sheath diameter among the studied patients at admission was (7.40 ± 0.55) and after 48 hrs it was6.13 ± 1.55, There was significant decrease in Optic nerve sheath diameter and nICP 48 hours after admission (Table 2).

The mean of Transcranial Doppler (TCD) among the studied patients at admission was (1.30 ± 0.27) and after 48 hrs significantly decrease to 1.24 ± 0.19, There was significant change in Transcranial Doppler (TCD) and nICP 48 hours after admission (Table 3).

The mean of GCS among the studied patients at admission was (6 ± 1.25) and it ranged from 3-7 while after 48 hrs GCS was 7.2 ± 4.19, ranged from 3-14, with no significant difference (Table 4).

There was no statistical significance difference in CT finding on admission to ICU and after 48 hrs among the studied severe traumatic brain injury (TBI) patients (Table 5).

More than half of the studied severe traumatic brain injury (TBI) patients died (54.2 %) (Table 6).

The mean n ICP at admission using ONSD vs Transcranial Doppler (TCD) among the studied patients was (26.8 ±2.8) vs (12.95±2.97) respectively and after 48 hrs mean n ICP using ONSD vs Transcranial Doppler (TCD) among the studied patients was (22.2±3.75) vs (12.35±2.14) ,There was highly statistically significant difference between ONSD and TCD at admission and 48 hours after admission (Table 7).

Table(1): Demographic data of the studied severe traumatic brain injury (TBI) patients (N=24).

Demographic data	TBI patients (N=24)	
	No.	%
Age (years)		
Mean ± SD	**29.63± 8.52**	
Sex		
Male	**19**	**79.2**
Female	**5**	**20.8**

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Table(2): Optic nerve sheath diameter (ONSD) and ICP (in mm Hg) on admission to ICU and after 48 hrs among the studied traumatic brain injury (TBI) patients (N=24).

Item	Optic nerve sheath diameter (ONSD)		Test	P-value
	at admission	after 48 hrs		
Value				
Mean ± SD	**7.40 ± 0.55**	**6.13 ± 1.55**	**-3.70**	**0.000* (S)**
nICP				
Mean ± SD	**26.8 ±2.8**	**22.2±3.75**	**-3.66**	**0.000* (S)**

Table (3): Transcranial Doppler (TCD) and ICP (in mm Hg) on admission to ICU and after 48 hrs among the studied traumatic brain injury (TBI) patients (N=24).

Item	TranscranialDoppler(TCD)		Test	P-value
	at admission	after 48hrs		
PI				
Mean±SD	1.30±0.27	1.24±0.19	-2.634	0.008* (S)
nICP				
Mean±SD	12.95±2.97	12.35±2.14	-2.646	0.008* (S)

Table (4): GCS on admission to ICU and after 48 hrs among the studied traumatic brain injury (TBI) patients (N=24).

Item	GCS		Test	P-value
	at admission	after 48hrs		
GCS				
Mean±SD	6±1.25	7.2±4.19	-1.51	0.131 (NS)

Table (5): CT findings on admission to ICU and after 48 hrs among the studied traumatic brain injury (TBI) patients (N=24).

CTfindings	CTfinding				P-value
	at admission		after48hrs		
	No.	%	No.	%	
Subarachnoidhemorrhage	16	66.7	15	62.5	1.000
Brainedema	15	62.5	18	75.0	0.375
SDH	4	16.7	2	8.3	0.500
EDH	4	16.7	3	12.5	1.000
Contusion	8	33.3	8	33.3	1.000

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Table (6): Outcome among the studied severe traumatic brain injury (TBI) patients (N=24).

Item	studiedpatients(N=24)	
	No.	%
Outcome		
Death	13	54.2
Discharge	11	45.8

Table (7): Comparison between Optic nerve sheath diameter (ONSD) and Transcranial Doppler (TCD) on admission to ICU and after 48 hrs among the studied traumatic brain injury (TBI) patients (N=24). (Was regarded ONSD, PI, ICP in both).

Item	Comparison		MWT	P-value
	ONSD	TCD		
at admission				
Mean±SD	7.40±0.55	1.30±0.27	0.000	0.000* (HS)
nICPatadmission				
Mean±SD	26.8±2.8	12.95±2.97	12.000	0.000* (HS)
	after 48hrs			
Mean±SD	6.13±1.55	1.24±0.19	0.000	0.000* (HS)
	nICPafter48hrs			
Mean±SD	22.2±3.75	12.35±2.14	8.000	0.000* (HS)

4. Discussion:

Traumatic brain injury (TBI) case is commonly found in the emergency room. TBI accompanied by increased intracranial pressure (ICP) is a neurological emergency that requires prompt and appropriate management **(1).**

Several mechanisms are responsible in increasing ICP after TBI. Disruption of blood brain barrier leads to hemorrhage or exudation of plasma into brain tissue that increases plasma portion of cranial tissue. In addition, inflammatory process caused by injured tissue also aggravates the exudation process by inducing vasodilatation. Injured brain parenchyma itself also contributes to increase ICP. Injured cells tend to have dysfunctional transport mechanism within plasma membrane. This leads to sodium and calcium accumulation in cytoplasm that eventually leads to cellular edema (**1).**

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The non-invasive profile of brain ultrasonology, together with its safety, portability, ease-of-use and relatively low cost as a neuromonitoring tool, has determined its applicability in the non- invasive evaluation of ICP in a number of settings; these include neuro- and general intensive care, the emergency department and the operating room. Different methods and combinations of techniques have been studied to noninvasively assess ICP with contrasting results(**9).**

The measurement of the optic nerve sheath diameter (ONSD) by transorbital ultrasonography is another well reported technique. ONSD measurement has shown strong correlation with ICP assessed invasively in TBI patients (**7).**

ONSD by ultrasonography provides valuable bedside assessment of ICP especially in the emergency setting (**10).**

In our study we tried to assess ICP in severe traumatic brain injury (TBI) patients by optic nerve sheath diameter (ONSD) and transcranial Doppler (TCD) on admission to ICU and after 48 hrs and to compare between both optic nerve sheath diameter (ONSD) and transcranial Doppler (TCD) together in monitoring and follow up of treatment in these patients.

In accordance with our results, Jie Du et al (2020), supported our results after studing the same group of severe TBI patients, they reported that Ultrasound-ONSD/ eyeball transverse diameter (ETD).
may be a reliable indicator for predicting intracranial hypertension in TBI patients. (**11), reported** significant association between ONSD and imaging signs of increased ICP in CT with a high NPV. (**12),** by the study of 40 patient showed that Ultrasound ONSD measurement is a useful investigation tool in a setting where invasive ICP monitoring is not available.

The previous finding is supported by (**13),** by the study of 112 patient showed that Ultrasound performed on the diaphragm of the optic nerve with acceptable sensitivity can detect patients with an increase in ICP and can be efficacious in expediting the action needed to reduce ICP. Due to the sensitivity and specificity of the ultrasound and high accuracy of the diameter of optic nerve sheath in detecting increase in ICP, as well as considering the fact that ultrasound is a noninvasive and available technique; it can be performed at the patient's bedside.

***Our results were supported by (*14),** they studied35 patients showed that ventriculostomy measurements of ICP are directly correlated with ultrasound ONSD measurements. Hence, they conclude that ONSD measured by ocular ultrasound is a simple yet effective method to detect raised ICP.
In another group of patients after decompressive craniotomy (**15),** by the study of 49 patient

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showed that Ultrasonographic ONSD is strongly correlated with invasive ICP measurements and may serve as a sensitive and noninvasive method for detecting elevated ICP in TBI patients after decompressive craniotomy DC.

Our results were supported by two studies compared ONSD with invasive methods of ICP. The first by (**16)**; by the study of 49 patient showed that ONSD as seen on bedside US correlated well with directly measured ICP in Korean adults with brain lesions. The optimal cut-off points of ONSD for detecting ICP was 5.6 mm and the second by (**17)**; by the study of101 patient showed that Ophthalmic ultrasound measurement of ONSD may be a good surrogate of invasive ICP measurement.

Theyconcluded that this non-invasive method may be an alternative approach to predict the ICP value of patients whose ICP measurement via lumbar puncture are in high risk.

On the other hand **(18)**, was showing in his study on 20 patients showed that US-ONSD measurement does not accurately estimate ICP in SAH patients in the intensive care unit because there results indicate that in the specific subsetting of SAH patients US-ONSD was not related to ICP as measured with an EVD. their data also indicate that ICP reductions caused by CSF drainage are not reflected by corresponding changes in the ONSD. These difference between our results and (**18)** can be explained by the different patient group. They studied spontaneous SAH patients, also they reduced the high ICP by dranage of CSF by lumber puncture (LP) which was not included in our study (complete medical control of ICP).

(19), in their study showed that TCD-derived systolic blood flow velocities can be used in the management and follow-up of patients with Idiopathic intracranial hypertension (IIH).

(20), intheir study showed that when invasive ICP monitoring is contraindicated, TCD ultrasound is a reliable, repeatable, and noninvasive bedside method for trending cerebral hemodynamics as a surrogate for ICP. This application is particularly promising to future neurocritical care patients unable to receive invasive ICP monitors due to ongoing anticoagulation or synthetic coagulopathy in hepatic and hematologic disorders and should be a part of standard neurocritical care and vascular neurology education.

On the other hand, (**21),** the study of 36 patient showed that Changes of ICP in time domain during plateau waves were replicated by nICP methods with strong correlations. In addition, the methods presented high performance for detection of intracranial hypertension. However, absolute accuracy for noninvasive ICP assessment using TCD is still low and requires further improvement.

(22), supported out results as they were showing that the advent of intensivist performed ultrasound and availability of ultrasound machines now provides a unique climate where point-of-care TCD is a reality. Intensivists with this skill are able to provide immediate, bedside assessment for midline shift, elevated ICP, vasospasm and intra-cranial hypertension progression.

5. Conclusion

ONSD and TCD both were effective in assessment of ICP in severe TBI on admission and after 48 hrs. Both can be used as a bedside monitoring for ICP in severe TBI according to ICU equipements and patient condition.

6. Conflict of Interest:

No conflict of interest.

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