Trauma Mon. 2018 November; 23(6):e79490. doi: 10.5812/traumamon.79490.

Published online 2018 September 18. **Research Article**

The Correlation Between Intracranial Pressure Amplitude and Glasgow Outcome Scale in Patients with Traumatic Brain Injury

Hamid Behzadnia [1], Mohammadreza Emamhadi [2], Shahrokh Yousefzadeh Chabok [3, 4], Babak Alijani [1, 4, **], Seifollah Jafari [1] and Sasan Andalib [3, *]

[1] Department of Neurosurgery, Poursina Hospital, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran
[2] Brachial Plexus and Peripheral Nerve Injury Center, Guilan University of Medical Sciences, Rasht, Iran
[3] Neuroscience Research Center, Department of Neurosurgery, Poursina Hospital, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran
[4] Guilan Road Trauma Research Center, Poursina Hospital, Guilan University of Medical Sciences, Rasht, Iran

[*] *Corresponding author*: Neuroscience Research Center, Department of Neurosurgery, Poursina Hospital, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran. Tel/Fax: +981333322444, E-mail: andalib@gums.ac.ir
[**] *Corresponding author*: Department of Neurosurgery, Poursina Hospital, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran. Tel/Fax: +981333322444, E-mail: neurosurgery95@yahoo.com

Received 2018 May 21; **Revised** 2018 July 02; **Accepted** 2018 July 13.

Abstract

Background: Considering the role of Intracranial Pressure Amplitude [AMP(ICP)] in evaluating the rate of craniospinal compliance (CC) and intracranial pressure (ICP) and in estimating the degree of brain damage, the aim of the present study was to evaluate the correlation of AMP(ICP) with the degree of brain damage in patients with traumatic brain injury (TBI).
Methods: Thirty-four patients were enrolled in the present study. Patients underwent intraventricular ICP monitoring. During the first 24 hours, AMP(ICP) was recorded every hour, and its total mean was calculated. Correlation of AMP(ICP) and Glasgow outcome scale (GOS) was analyzed.
Results: There was a negative correlation between mean AMP(ICP) within 24 hours and GOS values on the first, third, and sixth month (r = -0.476, -0.563, and -0.627, respectively).
Conclusions: The findings of the present study suggest that AMP(ICP) index can determine GOS in patients with TBI.

Keywords: Traumatic Brain Injury, Intracranial Pressure, Glasgow Outcome Scale

1. Background

Traumatic brain injury (TBI), which stands for traumatic brain injury, is a leading cause of death worldwide (1, 2). Factors, such as metabolic problems, cerebrovascular abnormalities, brain herniation, and increased intracranial pressure (ICP) can give rise to secondary injury after TBI (3). Increased ICP is present in 50% of TBI patients with space occupying lesions and 33% of those with diffuse brain injury (4). Increased ICP has a direct correlation with prognosis of TBI patients and is amongst the five most important factors of mortality in TBI (4). Furthermore, without ICP monitoring, prophylactic treatment of ICP has risks, such as prolonged hyperventilation, which worsens outcome (5). Total intracranial volume includes cerebrospinal fluid (CSF), cerebral blood volume (CBV), and parenchyma and there is a balance between them. Any changes in this balance can increase ICP, which in turn results in CBF decrease, neuronal damage, and brain herniation (6, 7). With this in mind, it is important to evaluate any possibility of ICP increase in patients with TBI. To date, various ICP compartments, such as P1 and P2 curves, have been assessed in the prognosis of future ICP; however, none of them showed satisfactory prognostic results (8, 9). Pulse amplitude of ICP [AMP(ICP)] is defined as the difference between minimum and maximum ICP per pulse rate (9-11) (Figure 1).

Furthermore, AMP(ICP) has a direct correlation with arterial pulse pressure and cerebrovascular capacity; however, it is inversely correlated with craniospinal compliance (CC), defined by intracranial volume increase that does not lead to increased ICP (12-14). Even with a normal ICP, if there is increased AMP(ICP) (along with decreased CC), there may be a future risk of increased ICP. It has been demonstrated that AMP(ICP) is correlated with ICP (10, 13). Glasgow coma scale (GCS) (15), and Glasgow outcome scale (GOS) (16) are associated with ICP (3, 4). Nonetheless, correlation of AMP(ICP) with GCS and GOS in patients with TBI is a less divulged topic. Thus, in the present study, the aim

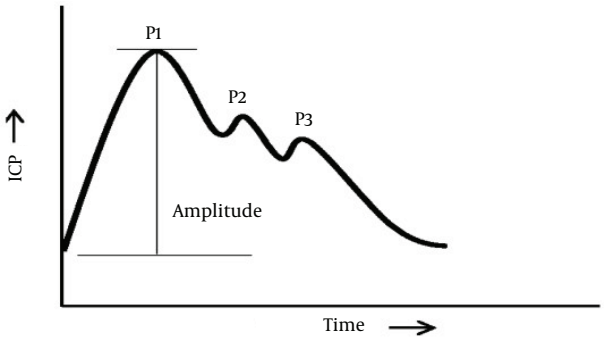

Figure 1. Intracranial pressure waveform reflecting three peaks; P1 (correlated with the arterial pulse); P2 (related to the cerebral compliance); P3 (correlated to aortic valve closure)

was to test the hypothesis of correlation of AMP(ICP) with GOS in these patients.

2. Methods

2.1. Study Design

The present diagnostic study was approved by the Ethics Committee of Guilan University of Medical Sciences (ethics' code: ir.gums.rec.1395.233).

2.2. Study Population

In Poursina Hospital, School of Medicine, Guilan University of Medical Sciences, Guilan, Iran, TBI patients with GCS < 8 are routinely monitored for ICP. The inclusion criteria were being a TBI patient monitored for ICP and referring to Poursina Hospital from 2015 to 2017. The exclusion criteria were dilated or non-reactive pupils, spinal cord injury, space occupying lesions, cardiac arrest, and unstable vital signs.

2.3. Intervention

Under general anesthesia, a ventricular catheter (medtronic external drainage) was placed in the lateral ventricle guided with a Ghajar tripod (17). The catheter with a three-way stopcock was connected to a bag collecting CSF drainage to reduce ICP. The catheter was also connected to a pressure monitoring device to show ICP, non-continuously.

2.4. Data Gathering

In the present study, ICP value of below 12 was considered as favorable. The AMP(ICP) was recorded as the difference between minimum and maximum ICP per pulse rate. During the first 24 hours, AMP(ICP) was recorded every hour, and its total mean was calculated.

If the patient underwent craniotomy during this period, the AMP(ICP) mean before surgery would be calculated. Ultimately, mortality, morbidity, and GOS at discharge, was recorded and thereafter were reexamined at the first-, third-, and sixth-month follow-ups. The ICP monitoring, GCS, and GOS calculations were carried out by a senior neurosurgery resident.

Table 1. Summary of Information of the TBI Patients

Variable	No. (%)	Mean ± SD
Gender		
Male	31 (91.2)	-
Female	3 (8.8)	
Age, years		
< 20	5 (14.7)	-
21 - 30	12 (35.3)	-
31 - 40	7 (20.6)	-
41 - 50	4 (11.8)	-
> 50	6 (17.6)	-
Trauma		
Car accident	14 (41.2)	-
Motorcycle accident	12 (35.3)	-
Pedestrian	8 (23.5)	-
Length of hospitalization in ICU (day)	-	11.14 ± 5.58
Length of hospitalization (day)	-	16.94 ±8.14
Length of ICP monitoring (hour)	-	35.64 ± 25.79

2.5. Statistical Analysis:

Spearman correlation coefficient was calculated using GOS and AMP(ICP) by the SPSS (version 19) software.

3. Results

A total of 34 patients were enrolled in the study. Mean ± SD of age of the patients was 34.97 ± 14.13 years, ranging from 16 to 64 years. The ICU stay duration ranged from 3 to 30 days. Hospitalization duration ranged from 5 to 50 days. The mean ± SD of duration of ICP monitoring was 35.64 ± 25.79 hours, ranging from 24 to 120 hours (Table 1).

There was a significant difference between GCS values on admission and at discharge in patients with TBI (P = 0.0001). A significant difference was found between ICP values and GCS values after 24 hours in the patients (P = 0.0001). There was no significant difference between

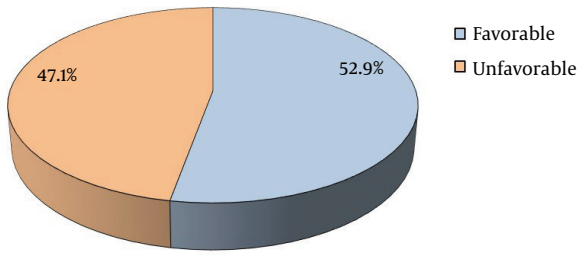

Figure 2. Proportion of patients with favorable and unfavorable ICP after 24 hours

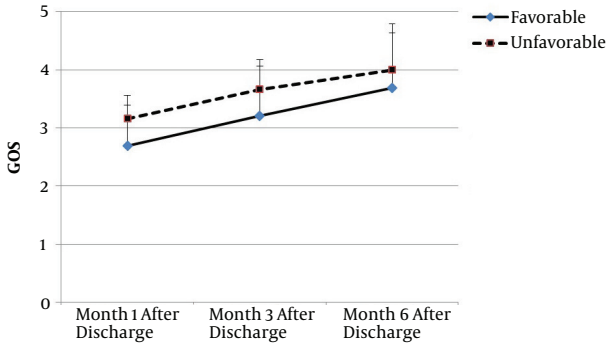

Figure 3. GOS values in the patients with favorable and unfavorable ICP

Table 2. Correlation Between Mean ICP and Mean AMP(ICP)

Variable	AMP(ICP)
ICP	
Pearson correlation coefficient	r = 0/465
P value	P = 0/006
correlation	Positive

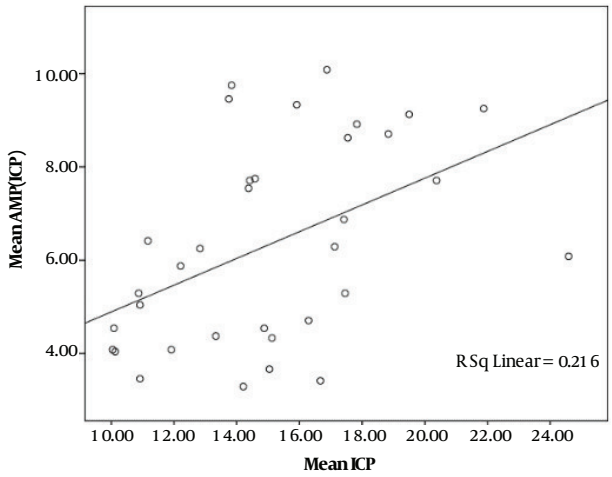

Figure 4. Correlation between mean ICP and mean AMP(ICP)

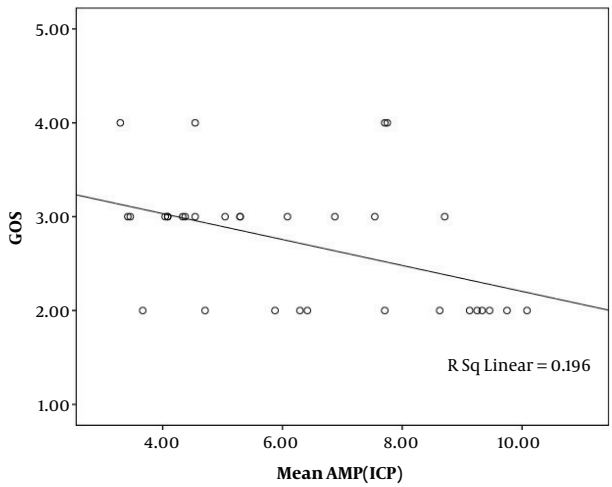

Figure 5. Correlation between mean AMP(ICP) within 24 hours with GOS values on the first month

AMP(ICP) values and GCS values after 24 hours in the patients (P = 0.057). Figure 2 shows the proportion of patients with favorable and unfavorable ICP after 24 hours.

Analysis of variance (ANOVA) test showed no significant difference in GOS values between the patients with favorable and unfavorable ICP (P = 0.154) (Figure 3).

There was a positive correlation between mean ICP and mean AMP(ICP) measured (r = 0.465) within 24 hours (Figure 4 and Table 2).

A negative correlation was seen between mean AMP(ICP) within 24 hours with GOS values on the first, third, and sixth month (r = -0.476, -0.563, and -0.627, respectively) (Figures 5 - 7).

4. Discussion

In conclusion, TBI is a major health problem worldwide. The prognosis of patients with TBI is affected by several factors, amongst which increased ICP is one of the most important (18). For this reason, ICP monitoring is currently a key element in evaluation of TBI patients, although there is no conclusive evidence of the usefulness of ICP monitoring in TBI and in the US, ICP monitoring is performed in only 58% of TBI patients with its indication (19). Several studies have recommended it in TBI guidelines (3, 20, 21). Amplitude (ICP) is a metric of ICP. Several studies have focused on ICP assessment in patients with

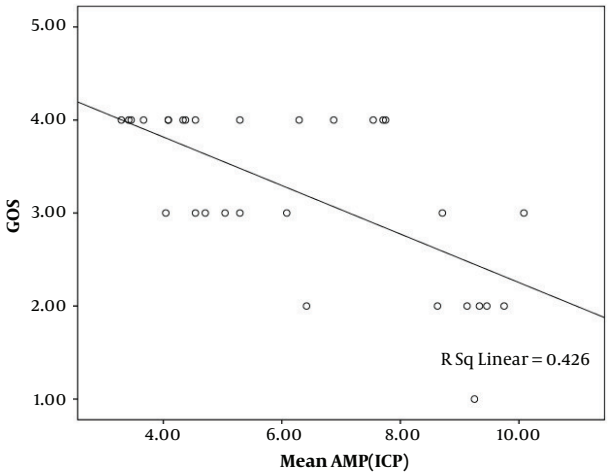

Figure 6. Correlation between mean AMP(ICP) within 24 hours with GOS values on the third month

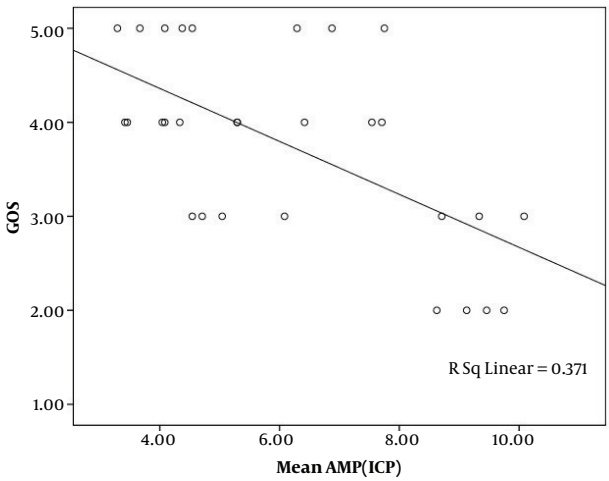

Figure 7. Correlation between mean AMP(ICP) within 24 hours with GOS values on the sixth month

TBI. However, AMP(ICP) has not been sufficiently investigated. Thereby, the present research studied the correlation of AMP(ICP) and GOS in patients with TBI. In the current study, there was a significant decreasing trend in ICP during the 24 hours of monitoring. Similarly, Ebrahiminejad et al. found a significant difference in ICP values during a 24-hour monitoring period in TBI patients (22). In the present study, there was no significant difference in the GOS values between the two groups (low ICP > 12 and high ICP $\leq$ 12) in the follow-ups carried out after one, three, and six months, which is similar to Deepak Kumar Gupta et al. study, although they considered ICP of < 20 favorable (23). Despite changes in ICP, there was a non-significant decrease in AMP(ICP) levels within 24 hours, which showed sustainability of AMP(ICP). There was a positive correlation between mean 24-hour ICP and mean 24-hour AMP(ICP) during monitoring. Therefore, AMP(ICP) changes can reflect that of ICP. Additionally, the mean 24-hour AMP(ICP) during monitoring was negatively correlated with GOS values in the follow-ups after one, three, and six months, which is similar to other studies (10, 13, 24, 25) and indicates the usefulness of this indicator in predicting patients' outcome. There were limitations in this study. ICP comparisons were not performed continuously. Furthermore, extra-ventricular drainage was used for ICP monitoring and the results may not be useful for intraparenchymal ICP monitoring.

4.1. Conclusion

ICP may not always be an acceptable indicator of evaluation of outcome in patients with TBI. The findings of the present study suggest that AMP(ICP) can determine GOS in patients with TBI. Further investigations with larger sample sizes would be helpful in this regard.

Footnote

Conflict of Interests: The authors declare no conflict of interest with respect to the present study.

References

1. Bruns J Jr, Hauser WA. The epidemiology of traumatic brain injury: A review. *Epilepsia*. 2003;**44**(s10):2–10. [PubMed: 14511388].
2. Cole TB. Global road safety crisis remedy sought: 1.2 million killed, 50 million injured annually. *JAMA*. 2004;**291**(21):2531–2. doi: 10.1001/jama.291.21.2531. [PubMed: 15173131].
3. Winn RH. *Youmans text book of neurosurgery*. Saunders; 2011. p. 3283–6.
4. Miller JD, Becker DP, Ward JD, Sullivan HG, Adams WE, Rosner MJ. Significance of intracranial hypertension in severe head injury. *J Neurosurg*. 1977;**47**(4):503–16. doi: 10.3171/jns.1977.47.4.0503. [PubMed: 903804].
5. Omar S. Akbik OS, Carlson AP, Howard Yonas H. The roles of ventricular and parenchymal intracranial pressure monitoring. *Curr Neurobio*. 2016;**7**(1):1–6.
6. Monro A. *Observations on the structure and functions of the nervous system*. 1783. Available from: http://hdl.handle.net/10250/2433.
7. Hickey JV, Olson DM, Turner DA. Intracranial pressure waveform analysis during rest and suctioning. *Biol Res Nurs*. 2009;**11**(2):174–86. doi: 10.1177/1099800409332902. [PubMed: 19398416].
8. Avezaat CJ, van Eijndhoven JH. Clinical observations on the relationship between cerebrospinal fluid pulse pressure and intracranial pressure. *Acta Neurochir (Wien)*. 1986;**79**(1):13–29. [PubMed: 3953320].
9. Fan JY, Kirkness C, Vicini P, Burr R, Mitchell P. Intracranial pressure waveform morphology and intracranial adaptive capacity. *Am J Crit Care*. 2008;**17**(6):545–54. [PubMed: 18978239].

10. Carrera E, Kim DJ, Castellani G, Zweifel C, Czosnyka Z, Kasparowicz M, et al. What shapes pulse amplitude of intracranial pressure? *J Neurotrauma*. 2010;**27**(2):317–24. doi: 10.1089/neu.2009.0951. [PubMed: 19852586].
11. Unnerback M, Bloomfield EL, Soderstrom S, Reinstrup P. The intracranial pressure curve correlates to the pulsatile component of cerebral blood flow. *J Clin Monit Comput*. 2018. doi: 10.1007/s10877-018-0129-0. [PubMed: 29549499].
12. Cardoso ER, Rowan JO, Galbraith S. Analysis of the cerebrospinal fluid pulse wave in intracranial pressure. *J Neurosurg*. 1983;**59**(5):817–21. doi: 10.3171/jns.1983.59.5.0817. [PubMed: 6619934].
13. Chopp M, Portnoy HD. Systems analysis of intracranial pressure. Comparison with volume-pressure test and CSF-pulse amplitude analysis. *J Neurosurg*. 1980;**53**(4):516–27. doi: 10.3171/jns.1980.53.4.0516. [PubMed: 7420174].
14. Germon K. Interpretation of ICP pulse waves to determine intracerebral compliance. *J Neurosci Nurs*. 1988;**20**(6):344–51. [PubMed: 2975310].
15. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet*. 1974;**2**(7872):81–4. [PubMed: 4136544].
16. Jennett B. Assessment of the severity of head injury. *J Neurol Neurosurg Psychiatry*. 1976;**39**(7):647–55. [PubMed: 993796]. [PubMed Central: PMC492395].
17. O'Leary ST, Kole MK, Hoover DA, Hysell SE, Thomas A, Shaffrey CI. Efficacy of the Ghajar Guide revisited: A prospective study. *J Neurosurg*. 2000;**92**(5):801–3. doi: 10.3171/jns.2000.92.5.0801. [PubMed: 10794294].
18. Maas AI, Stocchetti N, Bullock R. Moderate and severe traumatic brain injury in adults. *Lancet Neurol*. 2008;**7**(8):728–41. doi: 10.1016/S1474-4422(08)70164-9. [PubMed: 18635021].
19. Smith M. Monitoring intracranial pressure in traumatic brain injury. *Anesth Analg*. 2008;**106**(1):240–8. doi: 10.1213/01.ane.0000297296.52006.8e. [PubMed: 18165584].
20. Agbeko RS, Pearson S, Peters MJ, McNames J, Goldstein B. Intracranial pressure and cerebral perfusion pressure responses to head elevation changes in pediatric traumatic brain injury. *Pediatr Crit Care Med*. 2012;**13**(1):e39–47. doi: 10.1097/PCC.0b013e31820ac2ad. [PubMed: 21242856].
21. Andriessen TM, Horn J, Franschman G, van der Naalt J, Haitsma I, Jacobs B, et al. Epidemiology, severity classification, and outcome of moderate and severe traumatic brain injury: A prospective multicenter study. *J Neurotrauma*. 2011;**28**(10):2019–31. doi: 10.1089/neu.2011.2034. [PubMed: 21787177].
22. Ebrahiminejad A, Karamouzian S, Keykhosravi E. Intracranial pressure monitoring in patients with traumatic head injuries in kerman bahonar hospital: A short report. *J Rafsanjan Univ Med Sci*. 2015;**14**(1):69–76.
23. Gupta DK, Kumar H, Mahapatra A. Role of invasive ICP monitoring in patients with traumatic brain injury: An experience of 98 cases. *Indian J Neurotrauma*. 2006;**3**(1):31–6.
24. Budohoski KP, Schmidt B, Smielewski P, Kasprowicz M, Plontke R, Pickard JD, et al. Non-invasively estimated ICP pulse amplitude strongly correlates with outcome after TBI. *Acta Neurochir Suppl*. 2012;**114**:121–5. doi: 10.1007/978-3-7091-0956-4_22. [PubMed: 22327676].
25. Eide PK, Czosnyka M, Sorteberg W, Pickard JD, Smielewski P. Association between intracranial, arterial pulse pressure amplitudes and cerebral autoregulation in head injury patients. *Neurol Res*. 2007;**29**(6):578–82. doi: 10.1179/016164107X172167. [PubMed: 17535570].