Turk J Anaesth Reanim 2015; 43: 412-7 DOI: 10.5152/TJAR.2015.56933

Original Article

Intracranial Pressure Monitoring as a Part of Multimodal Monitoring Management of Patients with Critical Polytrauma: Correlation between Optimised Intensive Therapy According to Intracranial Pressure Parameters and Clinical Picture

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Abstract

Objective: Trauma patient requires a complex therapeutic management because of multiple severe injuries or secondary complications. The most significant injury found in patients with trauma is head injury, which has the greatest impact on mortality. Intracranial pressure (ICP) monitoring is required in severe traumatic head injury because it optimises treatment based on ICP values and cerebral perfusion pressure (CPP).

Methods: From a total of 64 patients admitted in the intensive care unit (ICU) 'Casa Austria', from the Polytraumatology Clinic of the Emergency County Hospital "Pius Brinzeu" Timisoara, Romania, between January 2014 and December 2014; only patients who underwent ICP monitoring (n=10) were analysed. The study population was divided into several categories depending on the time passed since trauma to the time of installation of ICP monitoring (<18 h, 19–24 h and >24 h). Comparisons were made in terms of the number of days admitted in the ICU and mortality between patients with head injury who benefited and those who did not benefit from ICP monitoring.

Results: The results show the positive influence of ICP monitoring on the number of admission days in ICU because of the possibility that the number of admission days to augment therapeutic effects in patients who benefited from ICP monitoring reduces by 1.93 days compared with those who did not undergo ICP monitoring.

Conclusion: ICP monitoring and optimizing therapy according to the ICP and CPP has significant influence on the rate of survival. ICP monitoring is necessary in all patients with head trauma injury according to recent guidelines. The main therapeutic goal in the management of the trauma patient with head injury is to minimize the destructive effects of the associated side effects.

Keywords: Intracranial pressure, cerebral perfusion pressure, cerebral blood flow, head injury, traumatic brain injury, multiple trauma patients

Introduction

Trauma patient requires complex therapeutic management because of multiple and severe injuries or because of their association with post-traumatic complications (1). The most common as well as the most significant injuries found in patients with trauma are head, spinal, thoracic, abdominal, pelvic, extremity and soft tissue injuries (2-5).

Severe polytrauma cases are often accompanied by traumatic brain injury (TBI). TBI can cause cerebral lesions directly or indirectly because of side-effects and complications of post-traumatic brain injury. Secondary brain lesions are represented by impaired cerebral blood flow [impaired autoregulation, brain oedema, increased intracranial pressure (ICP)], energy flow (glucose availability, mitochondrial dysfunction) or tissue oxygenation (hypoxia/ischaemia, impaired oxygen regulation, impaired microcirculation) (3-5). TBI initiates a series of pathophysiological pathways that are responsible for systemic complications and decreased survival rate. Severe TBI contributes to reduced cerebrovascular reserve, affecting normal cerebral perfusion pressure (CPP; 50–70 mmHg) and cerebral blood flow. Moreover, impaired cerebral microvascular system is responsible for secondary brain damage. Numerous studies report that increased ICP aggravates cerebral ischaemia (6-9). Knowing the above, it is our opinion that prompt therapy should be associated with ICP monitoring (10-13).

In this study, we wish to emphasise the importance of ICP monitoring in patients with TBI. Moreover, we wish to correlate therapy, clinical picture and survival rate to a series of specific TBI parameters (14-16).

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Received : 18.04.2015
Accepted : 06.07.2015

Methods

In this retrospective study from a single centre, patients with polytrauma admitted to the intensive care unit (ICU) 'Casa Austria' in the Polytraumatology Clinic of the Emergency County Hospital 'Pius Brinzeu' Timisoara, Romania, were included. Being a retrospective study in which the name or any other identification data of the patients are not presented, a database was created with the approval of the ethical committee of the hospital that has considered all the criteria associated with the right of privacy of our patients and medical staff. The consent form released by the ethical committee of the hospital can be provided on request from the Editor or from the corresponding author of the article.

Patients and inclusion criteria

All data was collected from the hospital records of patients admitted to the ICU between January 2014 and December 2014. Inclusion criteria were as follows: Injury Severity Score (ISS) of ≥16, age >18 years, traumatic head injury (Abbreviated Injury Scale; AIS≥3), abnormal computed tomography (CT) at admission and ICP monitoring. Patients who did not benefit from ICP monitoring but were eligible for inclusion in the study served as the control group. Imaging diagnosis was made by CT scans, nuclear magnetic resonance (NMR) and X-rays by the hospital's imaging centre. Laboratory analyses were performed in the clinical laboratory of the hospital.

Data collection and processing

Patient details were as follows: age, ISS and Acute Physiology and Chronic Health Evaluation II scores (APACHE II), Glasgow Coma Scale (GCS), cause of trauma, associated injuries, sex, systolic blood pressure (SBP), ICP values, time elapsed from trauma to catheter insertion, duration of stay in ICU and duration of stay in hospital. CPP was calculated as reported in the following Eq. (1): CPP=MAP–ICP, where MAP is mean arterial pressure. MAP was calculated as reported in the following Eq. (2): MAP=[(2×DBP)+SBP]/3, where DBP is diastolic arterial pressure and SBP is systolic arterial pressure. All variables that formed the database of the study were taken from the hospital archive with the approval of the ethical committee.

Statistical analysis

This analysis comprised the calculation of frequencies and the percentages for qualitative variables. Qualitative results are reported as mean±standard deviation (SD). The statistical comparison of the means of samples was made by unpaired t-test and of the percentages was made by chi-square test. Statistical significance was defined as $p<0.05$. The statistical analysis of data was performed using the Microsoft Office Excel for Mac 2011 v.14.4.7. (Microsoft Corporation, Bucharest, Romania) and Prism 6 for Mac OS X v.6.0. (GraphPad Software, Inc., San Diego, CA).

Results

During January 2014 and December 2014, 64 patients were admitted in ICU. A total of 46.87% (n=30) met the selection criteria and their parameters were introduced into the study database. Patients who did not meet the selection criteria (n=34) were excluded from the study. Of the 30 patients included in the study, 33.33% (n=10) underwent ICP monitoring and the remaining 20 served as the control group. The decision to insert ICP catheter was made by the on-call medical team based on the severity of the case.

The average age of the group analysed was 38.5±17.37 years. At admission, 60% of the patients had SBP of >89 mmHg and 40% had SBP of <89 mmHg. Also, 90% of the patients had admission GCS of <8. The mean ISS score for patients included in the study was 29 (7.31). Patients who underwent ICP monitoring showed no statistically significant differences from the control group in terms of ISS (p=0.6460) and APACHE II (p=0.3063). Statistically significant differences were observed in terms of the body temperature at admission. The group of patients who underwent ICP monitoring at admission in ICU had a median (SD) of 34.12 (2.10)°C (p=0.0475). The most relevant demographic and clinical characteristics of the study population are presented in Table 1.

The mean elapsed time from trauma to the insertion of ICP monitoring device was 25.1±17.4 h. The mean ICP monitoring time was 168±17.4 h. None of the patients developed complications related to catheter insertion. All patients had non-invasive monitoring of heart rate (HR) and peripheral capillary oxygen saturation (SpO_2) as well as invasive monitoring of systolic and diastolic blood pressures. The relationship between ICP and ISS was not statistically significant (p=0.3766). Also, the relationship between ICP and GCS was not significant (p=0.6563).

Average duration of stay in ICU was 15.9±8.54 days. When comparing the duration of stay in ICU and time elapsed from trauma to insertion of ICP catheter, there was a direct and strong correlation (p=0.0012). Statistical significant correlation between ICP and MAP values (p=0.0008), respective ICP and CPP (p=0.0284) were observed. There were no direct and significant correlations between MAP and CPP values (p=0.0988).

Depending on the number of hours after trauma and insertion of the catheter for ICP monitoring, the study group was divided into the following three categories: Group 1 (catheter inserted after <18 h of trauma), Group 2 (catheter inserted between 19 h and 24 h after trauma) and Group 3 (catheter inserted after 24 h of trauma).

Thus, Group 1 comprises four patients (40%), Group 2 comprises two patients (20%) and Group 3 comprises four patients (40%). There was no statistical significance that supports a minimum elapsed time from trauma to inserting

Table 1. Demographic and clinical characteristics of the study population

Characteristics		Control (n=20)	ICP monitoring (n=10)	p
Age, mean (SD) (years)		43.96 (18.36)	38.5 (17.37)	0.4413
Male, n (%)		21 (84)	9 (90)	0.6672
SBP (mmHg) at admission in ICU, n (%)	>89	12 (60)	6 (60)	0.7039
	76–89	3 (15)	3 (30)	0.6599
	50–75	4 (20)	1 (10)	0.8181
	1–49	1 (5)	0 (0)	-
ISS, mean (SD)		28 (4.5)	29 (7.31)	0.6460
APACHE II, mean (SD)		10.2 (7.02)	12.6 (2.45)	0.3063
GCS at admission in ICU, n (%)	13–15	7 (35)	0 (0)	-
	9–12	8 (40)	1 (10)	0.4413
	6–8	3 (15)	8 (80)	0.0477*
	4–5	2 (10)	1 (10)	-
Temperature (°C) at admission in ICU, mean (SD)		35.41 (1.31)	34.12 (2.10)	0.0475*
Cause of trauma, n (%)	Road traffic accident	8 (40)	5 (50)	0.7263
	Fall from <3 m	4 (20)	0 (0)	-
	Fall from >3 m	2 (10)	4 (40)	0.4472
	Others	2 (10)	1 (10)	-
Associated injuries, n (%)	Abdominal	3 (15)	1 (1)	0.8965
	Thoracic	11 (55)	8 (80)	0.2584
	Orthopaedic	6 (30)	1 (10)	0.6744
Duration of stay in ICU (days), mean (SD)		14.83 (16.69)	15.9 (8.45)	0.8509
Duration of stay in hospital (days), mean (SD)		30.8 (31.14)	25.7 (15.1)	0.6301
Mortality, n (%)		6 (30)	2 (20)	0.7871

ISS: Injury Severity Score; GCS: Glasgow Coma Scale; SBP: systolic blood pressure; AIS: Abbreviated Injury Scale; APACHE II: Acute Physiology and Chronic Health Evaluation II Score; ICU: intensive care unit; SD: standard deviation

the catheter. During ICU admission, clinical and biological investigations were performed on a regular basis. Routinely measured investigations were as follows: paO_2, $paCO_2$, glucose level and lactate. Figure 1 presents the relationships between paO_2 and CPP, $paCO_2$ and CPP, glucose and CPP as well as lactate and CPP. Data analysis reported a significant correlation between ICP and $paCO_2$ (p=0.0044).

Discussion

Aggressive treatment in case of patients with polytrauma having increased ICP may lead to significant improvement in lowering the rate of mortality. Tsai et al. (17) reported in their study that invasive monitoring of ICP and treatment based on ICP values lead to decrease in the rate of mortality.

In the present study, measuring ICP and CPP in patients with severe head injury showed that these values depend on several factors. CPP was calculated using the difference between MAP and ICP; therefore, it reflects the systemic evolution of these systemic and local factors. A series of studies demonstrated the fact that monitoring and correlation of some haemodynamic factors, such as MAP, HR and central venous pressure cannot provide sufficient data regarding the evolution of patients with head injury.

In our study, we monitored, analysed and correlated the values of ICP, CPP and MAP in patients with head injury that benefited from ICP at different moments after trauma. We found strong, direct and significant correlation between ICP and CPP as well as ICP and MAP in all moments of monitoring. A total of 90% of the patients had values of >20 mmHg, with a maximum of 71 mmHg at the time of insertion of ICP catheter. The aim of ICP monitoring is to guide treatment to ensure oxygen delivery for optimizing CPP and CBF. In patients with head injury, autoregulation of CPP is impaired, leading to secondary injuries of the brain (cerebral ischaemia and oedema) (14-17). Our patients had a constant CPP equal to 63.76±4.06 mmHg, with a minimum mean value of 57.5 mmHg and a maximum mean value of 69.5 mmHg. Mean ICP value was 26.33±16.73 mmHg, with a minimum mean value of 12.83 mmHg and a maximum mean value of 55.33 mmHg. Our patients received an optimised therapeutic management and CPP values being in the range recommended by Brain Trauma Foundation (50–70 mmHg) (9, 18-21).

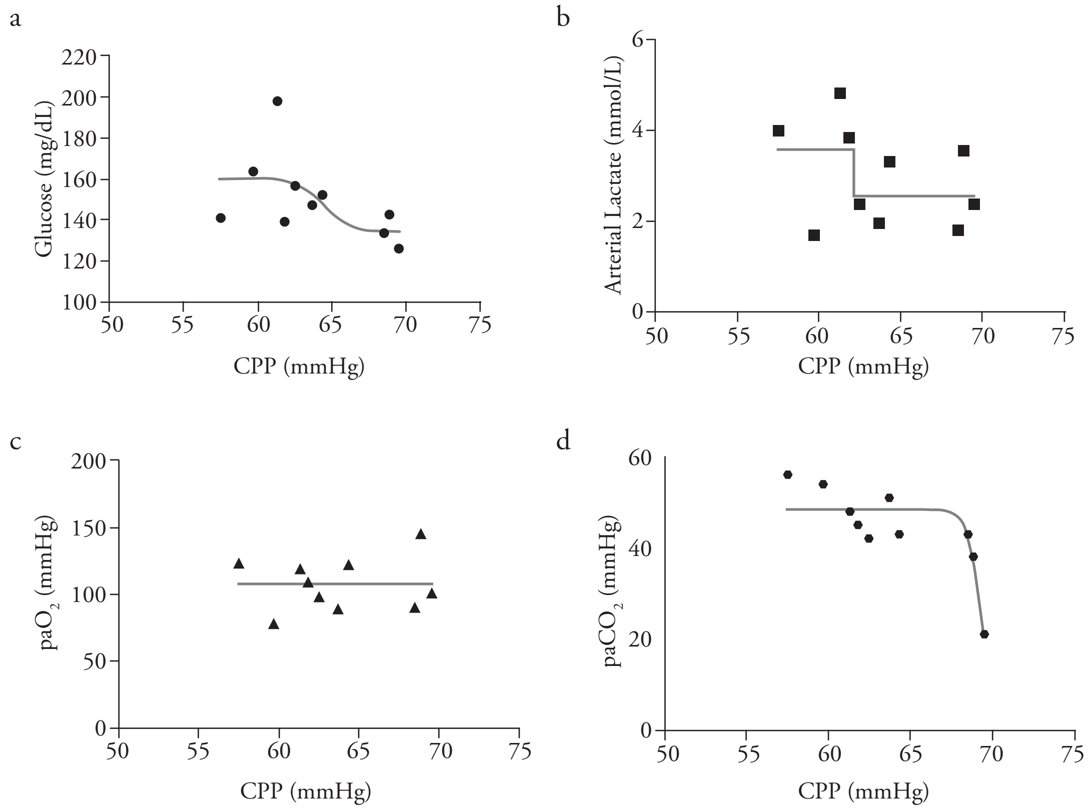


Figure 1. a-d. Relationship between glucose level (a) and CPP, arterial lactate level and CPP (b), paO_2 and CPP (c) as well as $paCO_2$ and CPP (d).
CPP: cerebral perfusion pressure; paO_2: partial pressure of oxygen in arterial blood; $paCO_2$: partial pressure of carbon dioxide in arterial blood.

Between the Group 1, Group 2 and Group 3, there were no significant differences in terms of mortality but there was a significant difference in terms of the duration of stay in ICU and the time of insertion of the ICP catheter; the results demonstrate the benefit of ICP monitoring upon the management of this type of patients. In Group I, the mean duration of stay in ICU was 12.5±5 days, whereas those for whom ICP monitoring was started after 24 h of insertion of the monitoring device, the mean duration of stay in ICU was 21.75±9.64 days. Moreover, we did not detect a significant correlation regarding the duration of stay in ICU between patients who had the monitoring device inserted for <18 h and those with the device for up to 24 h.

Therefore, we can say that ICP monitoring is ideal to be inserted in the first 24 h after the trauma. This ‘waiting time’ between trauma and ICP device insertion results in significant changes in the evolution of the clinical picture of patients with severe head injury.

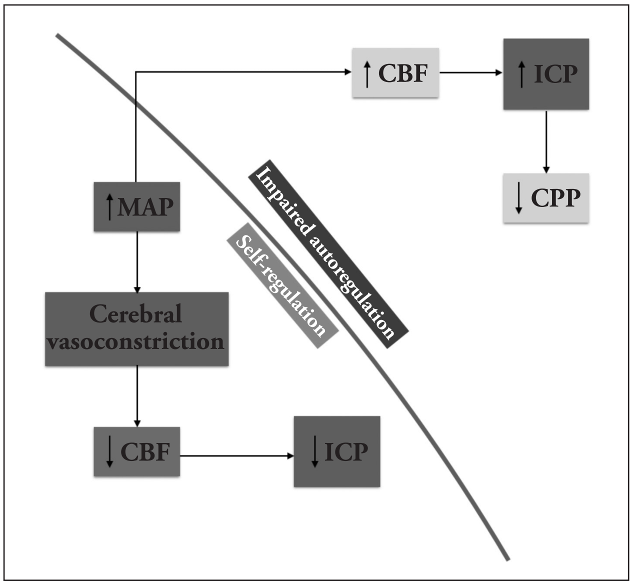
In Group 3, ICP values were significantly elevated compared with those in other patients. This is understandable because of poor therapeutic management performed in the absence of haemodynamic parameters specific for head injury (ICP or CPP).

Also, we compared the number of days of ICU stay between patients who underwent and who did not undergo ICP monitoring. Results show a reduction of 1.93 days in terms of ICU admission time. In terms of mortality, the difference was statistically significant, being reduced up to 14.14% in patients who underwent ICP monitoring. A total of 90% of patients underwent therapy to reduce ICP values, 10% did not require therapeutic intervention to modify the ICP, 20% needed an increase in CPP values and 70% needed a decrease in CPP values.

Given that cerebral autoregulation is preserved, increased MAP causes cerebral vasoconstriction with decreased ICP, thereby maintaining optimal CPP (within target). In terms of the loss of cerebral self-regulation, increased MAP increases ICP by increasing CBF and consequently decreases CPP. These issues explain the phenomenon found in our study, which does not highlight significant differences between the mean values of CPP and MAP (Figure 2).

Study limitations

The following limitations should be highlighted: low number of patients who underwent ICP monitoring did not allow a wide statistical analysis, lack of data for calculating CBF and lack of subsequent correlation with values provided by other methods of monitoring the degree of oxygenation/ischaemia of the brain.



Figgure 2. Haemodynamic autoregulation mechanism. 'Self-regulation vs. impaired autoregulation' based on ICP values and CPP.
MAP: median arterial pressure; CBF: cerebral blood flow; ICP: intracranial pressure; CPP: cerebral perfusion pressure

Conclusion

Patients with trauma presenting with head injury require a complex and individualised therapeutic management because of haemodynamic and physiological imbalances. Secondary brain injuries lead to significant worsening of clinical status and, thus, to increased mortality. Monitoring and optimizing therapy according to ICP and CPP represent a significant help for the clinician.

Finally, we can say that ICP monitoring is required for a high percentage of patients with head injury based on the guidelines.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Emergency County Hospital "Pius Brinzeu".

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.F.R., L.L.; Design - A.F.R.; Supervision - O.H.B., M.P.; Materials - M.S., A.C.C.; Data Collection and/or Processing - A.G., R.P.; Analysis and/or Interpretation - A.F.R., O.H.B., M.S., A.C.C.; Literature Review - C.M.D., A.F.R., L.L.; Writer - A.F.R.; Critical Review - O.H.B., M.S., A.C.C., M.P., D.S.

Acknowledgements: The authors wish to thank the Emergency County Hospital "Pius Brinzeu," Timisoara, for their support in conceiving this work.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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