Short Term Clinical Outcomes of Intracranial Pressure Monitor Placement in Severe Traumatic Brain Injury

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Abstract

Background

Intracranial pressure (ICP) monitoring has been recommended as a guiding tool for ICP treatment; however, data suggests invasive ICP monitoring had no better outcomes than those patients without it. We hypothesized that there is no difference in short term outcomes in patients with severe traumatic brain injury (TBI) who received invasive ICP monitoring compared to those who did not.

Methods

The trauma registry of a community Level II trauma center was queried from January 2015 to June 2020. Patients with severe TBI identified as Glasgow Coma Scale (GCS) ≤ 8 upon admission with an abnormal computed tomography (CT) scan, and those meeting Brain Injury Guideline (BIG) 3 (severe) were included. The data was analyzed in a logistic regression model to predict mortality, and a linear model to predict (log-transformed) hospital and ICU length of stay (LOS). Analyses were done in Rv4.0.2 software.

Results

A total of 7,787 trauma patients were admitted during the study period, 592 were found to have $GCS \leq 8$ and of those, 118 met inclusion criteria. Forty-seven percent ($n=55$) received invasive ICP monitoring and 53 percent ($n=63$) did not. The majority ($n=78$, 66%) of patients were male. Median age was 35 for the ICP monitored group and 54 for the group with no ICP monitoring. The median GCS was 3 (IQR= 3,6) and the median ISS was 25 (IQR=17,26 or 27) for both groups. The ICU LOS was 5.3 days and hospital LOS 6.2 days longer for patients with ICP monitor compared to those without ICP monitor ($p=0.001$). The mortality rate of patients who received an ICP monitor was 19 in 55 (35%) compared to 27 of 63 (42%) for those who did not ($p=0.84$).

Conclusions

Patients with severe traumatic brain injury who received invasive ICP monitors had an increased ICU and hospital length of stay and no mortality difference when compared to those who did not. The use of an ICP monitor did not improve outcomes in this population of severe TBI patients, particularly for those who did not require neurosurgery.

Level of Evidence: Level IV

Background

Traumatic brain injury (TBI) is a major health problem leading to death and disability worldwide. In the United States, during 2016-2017, TBI accounted for 2.5 million emergency department visits, 227,000 hospitalizations and 61,000 TBI-related deaths annually according to the Centers for Disease Control and

Prevention [1]. The severity of TBI can be classified as mild, moderate or severe based on clinical presentation of a patient's neurologic signs and symptoms. The Brain Trauma Foundation (BTF) has published numerous guidelines for severe TBI management, including avoidance of hypotension and hypoxia, hyperosmolar therapy for increased intracranial pressure (ICP), use of chemical and mechanical deep vein thrombosis (DVT) prophylaxis, and invasive ICP monitoring in patients with severe TBI. ICP monitoring has been recommended to "reduce in-hospital and 2 week post injury mortality based on updated recommendations not supported by evidence meeting current standards" [2].

ICP monitoring is indicated in patients with severe TBI (GCS <8) and an abnormal computed tomography (CT) scan of the brain (i.e., hematomas, contusions, swelling, herniation or compressed basal cisterns) or patients with a normal brain CT, and any of the following: unilateral or bilateral motor posturing, age > 40 years, or Systolic Blood Pressure (SBP) < 90 [2]. There are validated criteria for initial prognosticating with mortality such as the Rotterdam and Marshall Scores, however these were not designed to guide treatment decisions [4, 5]. Joseph et al. developed a guideline based on clinical and radiologic findings for managing patients with TBI. The Brain Injury (BIG) guidelines criteria was designed to look at the need for additional imaging and duration of monitoring. The BIG guidelines consisted of three categories, BIG 1 (minor head injury), BIG 2 (moderately injured) patient and BIG 3 (severe) defined as patients with antiplatelet or anticoagulation medication, had an abnormal neurologic examination, and a concerning CT finding (displaced skull fracture and diffused intracranial hemorrhage (ICH) > 8mm) [3].

Data suggests despite poor compliance with the BTF guidelines, there was no survival benefit and was associated with complications and increased use of hospital resources [6]. This was also studied in 2012 by Chestnut et al. in a randomized controlled trial that found ICP monitoring not to be superior to imaging or clinical examination [7]. In our study, we completed a retrospective review of ICP monitor utilization amongst patients with severe TBI defined by BTF guidelines and radiologic BIG 3 and compared mortality as well as short term and clinical outcomes.

Methods

After obtaining Investigational Review Board (IRB) exemption from Western IRB, the trauma registry of a community American College of Surgeons (ACS) verified Level II trauma center was queried from January 2015 to June 2020. Inclusion criteria were: patients with severe TBI identified as Glasgow Coma Scale (GCS) ≤ 8 upon admission with an abnormal computed tomography (CT) scan, or those with normal CT and two or more of the following: age > 40, unilateral or bilateral motor posturing, or systolic blood pressure < 90 mm Hg. Patients with severe TBI were further classified according to the imaging characteristics set forth by BIG study and only patients with subdural hematoma (SDH) > 8 mm, epidural hematoma (EDH) > 8 mm, intra-parenchymal hematoma (IPH) > 8 mm and multiple locations, scattered subarachnoid (SAH), and intraventricular hemorrhage (IVH) were included [3].

Patients were then categorized into groups who either received ICP monitoring or did not receive ICP monitoring. Outcomes, which included hospital and Intensive Care Unit (ICU) length of stay (LOS) as well

as mortality, were compared between groups. Covariates included gender, age, type of intracranial hemorrhage, injury severity score (ISS), and neurosurgical intervention (craniotomy or craniectomy).

The relationship between ICP monitoring and mortality was analyzed in a logistic regression model, and the relationships between ICP monitoring and (log-transformed) hospital and ICU LOS were analyzed by analyses of variance (ANOVAs). For all three outcomes variables, three separate models were fit: (1) ICP monitoring alone, (2) ICP with covariates, but no interactions, and (3) ICP, covariates, and the two-way interactions between ICP and each covariate. Models were compared using a Log likelihood test and Akaike Information Criterion (AIC). The best model using each outcome variable is reported. Covariates tested in the models were age, gender, GCS, ISS, intracranial hemorrhage (ICH) type (SAH, SDH, IPH), or craniotomy. Craniectomies and craniotomies were combined into a single category for analysis. The ICH categories EDH, IVH and extra-axial were excluded from the analysis due to their rarity ($n < 10$) in the data set (Table 1). Descriptive statistics were back-transformed to the original scale. Analyses were done in Rv4.0.2 software, and the significance cut-off for p-values was set at < 0.05 .

Table 1
Breakdown of patient information.

	No ICP Monitoring (n=63)			ICP Monitoring (n=55)			p-value
	Median	IQR	Min, Max	Median	IQR	Min, Max	
Age	54	28, 72	0, 92	35	22, 63	1, 94	0.027
Gender							
Female (34%)	72 (n=22)	40, 80	2, 92	43 (n=18)	22, 74	1, 94	
Male (66%)	50 (n=41)	26, 63	0, 85	34 (n=37)	24, 48	6, 84	
GCS Admission	3	3, 6	3, 8	3	3, 6	3, 8	0.799
ISS	25	17, 27	4, 45	25	17, 26	9, 45	0.533
		Number	Percent		Number	Percent	
Intracranial Hemorrhage							
SAH		41	65%		27	49%	0.096
SDH		35	56%		40	73%	0.058
EDH		9	14%		3	5%	0.137
IPH		16	25%		16	29%	0.683
IVH		5	8%		5	9%	1.000
Extra-axial		4	6%		5	9%	0.732
Neurosurgery							
Craniotomy/Craniectomy		10	16%		45	82%	<0.001
Type of ICP Monitor							
EVD					31	56%	
Bolt					12	22%	
Information for sampled population of severe TBI patients, including the median, interquartile range (IQR), and range (minimum, maximum) for numerical data or the number and percent for categorical data within each group (with and without ICP monitoring). P-values were from Mann-Whitney tests or Fisher's exact tests comparing the two groups. (ICP: intracranial pressure, GCS: Glasgow Coma Scale, ISS: Injury severity score, SAH: subarachnoid hemorrhage, SDH: subdural hemorrhage, EDH: epidural hemorrhage, IPH: intraparenchymal hemorrhage, IVH: intraventricular hemorrhage, EVD: external ventricular drain)							

Results

A total of 7,787 trauma patients were admitted during the study period; 592 were found to have $GCS \leq 8$ and of those, 118 fully met inclusion criteria. Forty-seven percent, (n=55) received invasive ICP monitoring, and 53 percent (n=63) did not. The majority of patients were male: n= 78 (66%) compared to female: n= 40 (34%) (Table 1). Female patients were generally older than male patients, and there was statistical evidence that those who received invasive ICP monitoring were younger (median age: female 43, male 34) than those who did not receive invasive ICP monitoring (median age: female 72, male 50; $p=0.027$). The groups with and without invasive ICP monitoring had the same median GCS of 3 (IQR 3, 6) and median ISS of 25 (IQR 17, 27 or 26), and there was no evidence that the percent of patients with ICH designations differed between monitored and unmonitored groups (Table 1, $p<0.05$). Patients who were invasively monitored were also more likely to have had neurosurgical intervention compared to those who were unmonitored (Table 1).

Monitored patients stayed longer in the hospital (ANOVA coefficient = 0.41, standard error (SE) = 0.09, $p<0.001$) and in the ICU (ANOVA coefficient = 0.36, SE = 0.08, $p<0.001$). (Figure 1). For hospital stay, monitored patients (n=25) stayed 10.5 days (95% confidence interval (CI) [8.0, 13.9]) compared to 4.3 days (95% CI [3.2, 5.7]) for those without ICP monitoring (n=9; Figure 1). For the ICU stay, monitored patients stayed 8.7 days (95% CI [6.7, 11.43]), significantly longer compared to 3.4 days (95% CI [2.4, 4.6]) for those without ICP monitoring (Figure 1). The addition of covariates did not improve the model (Hospital LOS: AIC no covariates = 166, AIC with covariates = 170; ICU LOS: AIC no covariates=128, AIC with covariates=131, where lower values of AIC indicate a better model), nor was there any evidence that the covariates interacted with ICP monitoring to impact the results (Hospital LOS: AIC=162; ICU LOS: AIC=123).

The existing differences in neurosurgery frequency between the ICP monitoring and no ICP monitoring groups (Table 1) led to exploratory analysis of the LOS outcomes relative to neurosurgical intervention. Patients who had neither surgery nor ICP monitoring had the shortest hospital LOS (mean=3.8 days, 95% CI [2.8, 4.6], n=53), while those who did not have neurosurgical intervention but had an ICP monitor had a longer stay (mean=12.4 days, 95% CI [6.8, 22.6], n=10). Neurosurgical intervention patients had the same, or slightly longer, LOS in the hospital with ICP monitoring (mean=10.2 days, 95% CI [7.4, 13.9], n=45) compared to those without ICP monitoring (mean=7.5 days, 95% CI [4.6, 12.2], n=10). The pattern was similar for ICU LOS, where patients who had neither surgery nor ICP monitoring had the shortest LOS in the ICU (mean=2.9 days, 95% CI [2.0, 4.2], n=53), while those who did not have neurosurgery but had an ICP monitor had a longer stay (mean=10.5 days, 95% CI [5.8, 18.3], n=10). Patients who had a neurosurgical intervention also had the same, or slightly longer, LOS in the ICU with ICP monitoring (mean=8.4 days, 95% CI [6.2, 11.2], n=45) compared to those without ICP monitoring (mean=7.0 days, 95% CI [3.9, 12.2], n=10).

During the study period, mortality was observed in 19 of 55 (35%) of patients who received an invasive ICP monitor, compared to 27 of 63 (43%) for those who did not ($p=0.45$). In the analysis relating mortality

to ICP monitoring, the model which included covariates (AIC=138) was a better fit than either the invasive ICP monitoring alone (AIC=147) or the model including interactions between invasive ICP monitoring and covariates (AIC=144). There was no evidence that the difference in mortality between invasive ICP monitoring groups was statistically significant, whether the invasive ICP monitoring groups were considered alone (Odds ratio (OR) =0.61, 95% CI [0.28, 1.34], $z=-0.22$, $p=0.61$) or with covariates (OR=0.86; Table 2). Predictably, the odds of death were higher for patients who were older (OR=1.02, 95% CI [1.00, 1.04]) or who had higher injury severity scores (OR=1.06, 95% CI [1.00, 1.13], Table 2). Odds of death were also higher for patients with lower GCS, which indicates more severe injury (OR=0.66, 95% CI [0.50, 0.87]). Discharge disposition was the same in monitored and unmonitored groups (Table 3; Fishers exact test $p=0.388$). The majority of patients who survived, with or without invasive ICP monitors were discharged home (36% compared to 27% on the non ICP group (Table 3).

Table 2
Mortality outcomes.

	Odds ratio	Coefficient	z	p-value
Age	1.02	(1.00, 1.04)	2.2	0.030
Gender (M)	1.17	(0.43, 3.16)	0.3	0.764
Glasgow Coma Score on Admission	0.66	(0.50, 0.87)	-2.9	0.004
Injury Severity Score	1.06	(1.00, 1.13)	2.1	0.037
ICH Type SAH	1.36	(0.54, 3.46)	0.7	0.512
ICH Type SDH	1.66	(0.61, 4.49)	1.0	0.322
ICH Type IPH	1.16	(0.42, 3.24)	0.3	0.776
Neurosurgery	0.64	(0.19, 2.21)	-0.7	0.482
ICP Monitor	0.86	(0.25, 2.99)	-0.2	0.816
Mortality outcomes relative to ICP monitoring and covariates. The odds ratios, 95% confidence intervals, and p-values based on the logistic regression are reported. (M: male, ICH: intracranial hemorrhage, SAH: subarachnoid hemorrhage, SDH: subdural hemorrhage, IPH: intraparenchymal hemorrhage, ICP: intracranial pressure)				

Table 3
Discharge disposition.

	No ICP Monitoring (n=63)	ICP Monitoring (n=55)
Discharge		
Dead	27 (43%)	19 (35%)
Home	16 (25%)	20 (36%)
Inpatient Rehabilitation	4 (6%)	6 (11%)
SNF or LTAC	16 (25%)	10 (18%)
Discharge disposition for study population, reported as number and percent. (ICP: intracranial pressure, SNF: Skilled nursing facility, LTAC: long-term acute care.)		

Discussion

An important and controversial aspect of TBI management is the use of ICP monitors since sustained elevated ICP has been associated with increased mortality and poor outcomes. To the best of our knowledge, this is the first study to report that patients diagnosed with severe TBI by both BTF guidelines and the BIG who received ICP monitor had an increase in ICU and hospital LOS. Based on our observational data, there are patients who recover well without ICP monitoring despite meeting BTF criteria for ICP monitoring and reaching the most severe BIG group, particularly if they do not require neurosurgical intervention.

The longer hospital and ICU LOS for patients who had ICP monitoring agrees with results from other studies. In patients greater than 65 years old, Dang et al, found that ICP monitoring had no better outcome than those who had no ICP monitor and patients with an ICP monitor had longer ICU and hospital LOS [8]. Aiolfi, et al., further demonstrated that ICP monitoring does not have any survival benefit in patients with isolated severe blunt TBI and is associated with more complications and increased utilization of hospital resources [6]. Talving, et al. demonstrated shorter hospital LOS in patients without ICP monitoring compared to those with ICP monitoring [9]. In this study, we explored covariates to gain insight into why the differences between ICP monitoring group exist.

This is a retrospective study, so the possibility that there were pre-existing differences in the two groups deserves additional attention. There were two notable differences between the ICP monitoring groups. Patients in the invasive ICP monitoring group were on average younger than patients in the non-monitored group. Since LOS was greater in the ICP monitored group (with the younger patients), it is possible that the difference in age between ICP groups may have caused an underestimate of the differences between

groups, as older patients generally have worse outcomes with severe TBI [10]. The other difference between groups was in the number of patients who had neurosurgical intervention, with the majority of patients having neurosurgical intervention in the invasive ICP monitored groups, and only 16% in the non-invasive monitored group. The very small sample sizes associated with the groups create uncertainty regarding the effect of neurosurgery on LOS relative to ICP monitoring. Even with the small sample size available, it was apparent that patients that had not undergone a neurosurgical procedure had much longer LOS in the hospital and ICU if they had an ICP monitor. The effect of ICP monitoring on LOS in neurosurgery patients was more equivocal. A follow up study is clearly indicated to explore the interaction between the different types of neurosurgical intervention and ICP monitoring in affecting LOS in the hospital and ICU.

Mortality was not related to the use of an ICP monitor in this population of severe TBI patients, whereas studies that targeted other populations have suggested that ICP monitoring is associated with mortality. In a 2000 retrospective study by Lane, et al., univariate analysis showed invasive ICP insertion was associated with increased mortality; however, multivariate analyses controlling for ISS and mechanism, associated invasive ICP monitoring with improved survival [11]. More recent data suggests that the overall mortality in elderly patients (>65 years old) who had ICP monitoring was higher and less likely to have a favorable disposition [8]. Furthermore, Tang et al., found a higher survival rate in patients with no ICP monitoring compared to the ICP monitor group [12]. In this study, it is possible that the existing differences in age between the ICP monitored groups were confounded with a higher probability of mortality in the ICP monitored group.

Most patients with ICP monitoring were discharged home. This is in contrast to the study by Tang, et al. that found most patients without ICP monitoring were discharged home [12]. This finding may be specific to our institution since the patient population in this study was primarily an uninsured minority population. Being uninsured severely limits the options patients have for post hospital care and follow up. Forcing healthcare providers to discharge patients with severe TBI home under the care of a family member, therefore monitoring long term outcomes are challenging.

The results from this study have sparked discussion on changing local practice guidelines because they support neurosurgeons limiting placement of invasive ICP monitors in TBI patients. Despite meeting BTF criteria, Sixty three patients didn't received an ICP monitoring. Placement of the monitor is based on neurosurgical judgement and their expert opinion guided discussion with families and management decisions. However, there are limitations to this study. It took place at a single institution, where local practices may have confounded unreported variables with ICP monitoring. Most importantly, this is a retrospective study, with corresponding demographic and medical differences between the ICP monitored and non ICP monitored groups. There were some simple exploratory analyses in this study to gain insight into how variation between the groups might have affected the outcomes, but a prospective study of this population which equalizes allocation of patients with regards to neurosurgery and age is required to reliably estimate the effect of ICP monitoring. This study also did not have long term follow up and the relatively small sample size, particularly for the sub-group associated with neurosurgery. This provided

low statistical power to detect additional existing differences. This study also did not include an analysis of compliance to ICP monitoring guidelines.

Conclusions

Patients with severe TBI based on BTF and radiologic BIG 3 who received invasive ICP monitoring had increased ICU and hospital LOS. No mortality difference was identified between either groups.

Abbreviations

ACS
American College of Surgeons
AIC
Akaike Information Criterion
ANOVA
analysis of variance
BIG
Brain Injury Guidelines
BTF
Brain Trauma Foundation
CI
confidence interval
CT
computed tomography
DVT
deep vein thrombosis
EDH
epidural hemorrhage
EVD
external ventricular drain
GCS
Glasgow Coma Scale
ICP
intracranial pressure
ICU
intensive care unit
IPH
intraparenchymal hemorrhage
IQR
Interquartile range
IRB

Investigational review board
ISS
injury severity scale
IVH
intraventricular hemorrhage
LOS
length of stay
OR
odds ratio
SAH
subarachnoid hemorrhage
SBP
systolic blood pressure
SDH
subdural hemorrhage
SE
standard error
TBI
traumatic brain injury

Declarations

Ethics approval and consent to participate

We obtained IRB approval from Western (WCG) IRB study #1321106.

Consent for publication

Waiver of consent was obtained via Western (WCG) IRB.

Availability of data and material:

The datasets generated and/or analyzed during the current study are not publicly available, as they were compiled from our own patient records, but are available from the corresponding author on reasonable request.

Competing Interests:

We know of no conflicts of interests associated with the publication and there has been no financial support for this work that could influence its outcome. The opinions or assertions contained herein are the private views of the authors and do not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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Author contributions:

CF wrote the manuscript. XD did acquisition of data and wrote manuscript. JG and AB did the conception and design. CV did the data analysis and interpretation. CHP and BC did the planning and conduct of the paper. All authors read and approved the final manuscript.

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Figures

Figure 1

Length of stay; hospital and ICU Length of Stay (LOS) was longer for patients with ICP monitoring. Back-transformed mean number of days and associated 95% confidence intervals are shown. P-values associated with testing differences in length of stay between those with and without monitoring are reported above each pair.