Title

Respect your elders- age disparities in intracranial pressure monitor use in traumatic brain injury

Authors
Schupper, Alexander J.
Berndtson, Allison E.
Smith, Alan
et al.

Publication Date
2019

Respect Your Elders- Age Disparities in Intracranial Pressure Monitor Use in Traumatic Brain Injury

Alexander J. Schupper B.A.[1,2], Allison E. Berndtson MD[1], Alan Smith Ph.D.[1], Laura N. Godat MD[1], Todd W. Costantini MD[1]

[1]Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, Department of Surgery, San Diego, CA
[2]UC San Diego School of Medicine, La Jolla, CA

Author Email Addresses: aschuppe@ucsd.edu.edu; aberndtson@ucsd.edu; a6smith@ucsd.edu; http://lgodat@ucsd.edu; tcostantini@ucsd.edu

Author Contributions:
Alexander J. Schupper: Data collection and analysis, manuscript generation
Allison E. Berndtson: Data analysis, manuscript generation
Alan Smith: Data collection and analysis
Laura N. Godat: Data analysis, critical review of manuscript
Todd W. Costantini: Study design, data analysis, manuscript generation

Running Title: Age disparities in ICP monitor placement
Word Count: 1856

Keywords: traumatic brain injury, intracranial pressure monitor, surgical disparities, age disparities, neurotrauma

Corresponding Author:
Todd W Costantini, MD
University of California, San Diego, Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery
200 W. Arbor Drive #8896, San Diego, CA 92103
tcostantini@ucsd.edu

All authors have no financial or personal disclosures.

ABSTRACT

Background: The Brain Trauma Foundation recommends intracranial pressure (ICP) monitor placement for patients with severe traumatic brain injury (TBI). Adherence with these guidelines in elderly patients is unknown. We hypothesized that disparities in ICP monitor placement would exist based on patient age.

Methods: Using the National Trauma Data Bank (2010-2014), we identified patients admitted for blunt TBI with admission Glasgow Coma Scale (GCS) 3-8. Patients were excluded if they had a non-head Abbreviated Injury Score (AIS) ≥ 3, hospital length of stay < 24 hours or were discharged from the emergency department. Demographic data, ICP monitor placement, GCS, head AIS, Injury Severity Score (ISS), and outcome measures were collected. Propensity score matching between ICP monitor and non-ICP monitor patients was utilized for logistic regression and Cox multivariate regression analyses.

Results: Of the 30,710 blunt TBI patients with GCS 3-8 included in our study, 4,093 patients were treated with an ICP monitor. ICP monitor placement rates significantly decreased with increasing age. Multivariable analysis demonstrated that patients treated with an ICP monitor were more likely to be younger, male, have private/commercial insurance, and receive care at an institution with 3 or more neurosurgeons.

Conclusion: Patients ≥ 65 years of age with severe blunt TBI are less likely to be treated with an ICP monitor than younger patients. Age disparities in adherence to Brain Trauma Foundation Guidelines may alter outcomes for patients with severe TBI.

INTRODUCTION

Traumatic brain injury (TBI) is a considerable cause of morbidity and mortality in the United States. From 2007 to 2013, the number of TBIs sustained in the US increased significantly.[1] According to the Centers for Disease Control and Prevention (CDC), TBI was responsible for approximately 2.5 million emergency department visits, 300,000 hospitalizations and 56,000 deaths in 2013 alone.[1] In addition to the increasing prevalence of TBI, these injuries significantly add to the national financial burden of healthcare, accounting for direct and indirect costs totaling $60 billion in the year 2000.[2]

Monitoring and control of intracranial pressure (ICP) have been studied as a means of reducing secondary insults after TBI.[3] In the past 40 years many studies have looked at the efficacy of ICP monitor placement, but there is still a lack of consensus on indications for use.[4,5] The Brain Trauma Foundation (BTF) has published guidelines for ICP monitor use, however the impact of these guidelines on patient outcomes remains uncertain.[4] The most recent edition of the BTF guidelines recommends the use of ICP monitoring in patients with a survivable, severe TBI (defined as Glasgow Coma Scale, or GCS, score of 3-8) with an abnormal computed tomography (CT) scan.[6] ICP monitoring may also be indicated in severe TBI patients with a normal CT scan and two of the following features: age > 40, unilateral or bilateral motor posturing, or systolic blood pressure (SBP) < 90 mmHg.[6] Since the publication of these guidelines, many studies have assessed their efficacy, with mixed results. A lack of consensus on the role of ICP monitoring in patients with severe TBI persists.

Elderly patients (age 65 and older) have the highest rate of TBI-related deaths with mortality rates increasing in recent years.[1] This elevated mortality rate has been attributed to the higher risk of falls in this age group. Despite the high risk of mortality in elderly patients with severe TBI, the evidence for ICP monitor efficacy in this subgroup is limited.[7] There is a void in the literature on the effect of ICP monitoring specifically in the elderly, as well as whether or not deferring ICP monitor placement in these patients is appropriate. Our study was developed in order to evaluate for potential age disparities in ICP monitor placement. We hypothesized that ICP monitors would be placed less frequently in elderly patients with severe TBI compared to younger patients.

METHODS

Study population

To assess a widely representative population of isolated traumatic brain injury patients, we utilized records submitted to the National Trauma Data Bank from 2010-2014. Of the 480,347 patients in the trauma registry, we identified those patients admitted for blunt TBI with admission GCS score between 3 and 8. Patients were subsequently excluded if they had a hospital length of stay < 24 hours, were discharged from the emergency department, transferred out to another healthcare facility, or had a non-head Abbreviated Injury Score (AIS) ≥ 3. Our methodology is shown in **Figure 1**.

Covariates

Demographic data collected on our study population included patient age, sex, race and insurance status. Clinical characteristics included mechanism of injury, GCS, head AIS, Injury

Severity Score (ISS), rates of craniotomy/craniectomy and other neurosurgical procedures, types of intracranial injuries, ICP monitor placement, complications, hospital length of stay (LOS), ICU length of stay, and mortality. We also collected hospital teaching status, number of hospital beds and the number of neurosurgeons at the patient's hospital.

Statistical analysis

All statistical analyses were computed via SPSS Statistics® Version 24, with a significance level of $p < 0.05$. We used logistic regression to control for demographic and clinical parameters. To directly compare the ICP monitor versus non-ICP monitor groups we utilized a bivariate analysis followed by a propensity score matching analysis, which consisted of 1,976 case-control pairs, creating two cohorts with approximately the same demographic and clinical characteristics (including age, sex, race, insurance status, diagnoses and procedures).

<u>RESULTS</u>

Demographics and clinical characteristics

The clinical characteristics of our study population can be found in **Table 1**. After applying our study inclusion and exclusion criteria, we identified 4,093 blunt TBI patients with GCS 3-8 who received an ICP monitor (**Table 2**). Patients who received an ICP monitor were significantly younger than those not receiving a monitor ($p < 0.001$). Patients who received an ICP monitor also had higher ISS scores ($p < 0.001$), higher Head AIS scores ($p < 0.001$), and higher rates of neurosurgical procedures including craniotomy and craniectomy (both $p < 0.001$). In addition, ICP monitor use was associated with a longer hospital stay (median 15 versus 12 days, p <

0.001), ICU stay (median 11 versus 4 days, $p < 0.001$), and more ventilator days (median 9 versus 3 days, $p < 0.001$). Patients treated with an ICP monitor were more likely to have private insurance, while a lower rate of ICP monitor placement was seen in Medicare patients (**Table 3**). Hospitals staffed with at least three neurosurgeons favored ICP monitor placement. Finally, ICP monitor placement was associated with a higher rate of mortality (30.7% versus 27.2%, $p < 0.001$, **Table 2**).

ICP monitor placement decreases with age

We evaluated ICP monitor use stratified by age and TBI severity. For patients with admission GCS 3-8, ICP monitor placement decreased with increasing patient age (**Figure 2A**). For example, 17% of patients age 45-44 with admission GCS 3-8 had an ICP monitor placed as compared to 10% of patients age 65-74, and only 6% of patients age 75-84. We also examined ICP monitor placement rates stratified by age group and Head AIS scores (**Figure 2B**), finding decreased rates of ICP monitor placement with increasing age for all Head AIS groups (each $p < 0.001$). The decrease in monitor placement rates by age was most significant for patients with AIS 4 and 5. Next, we performed multivariable analysis to identify predictors for ICP monitor placement (**Table 4**). Patients age 65 and over were significantly less likely to have a monitor placed than those < 65 years of age (adjusted odds ratio [OR] 0.41, confidence interval [CI] 0.36-0.46). Male patients were also more likely to have an ICP monitor placed (Adjusted OR 1.10, CI 1.02-1.19). Additional predictors of ICP monitor placement included private insurance and treatment at an institution staffed by 3 or more neurosurgeons (**Table 4**).

DISCUSSION

For acute management of traumatic brain injury, providers rely on literature including the BTF guidelines to support their clinical decision-making. In the 2016 4th edition of the *Guidelines for the Management of Severe Traumatic Brain Injury*, the BTF provides a Level IIB recommendation for ICP monitoring in severe TBI patients to reduce in-hospital and two-week mortality.[6] The previous (3rd) edition guidelines discussed the recommendation of ICP monitoring for severe TBI (GCS 3-8) with either an abnormal CT scan, or two or more of the following: "age over 40 years, unilateral or bilateral motor posturing, or systolic blood pressure (BP) < 90 mmHg."[8] Since the third edition was published, there have not been any new studies providing further guidance on which patients should receive ICP monitoring.[6] In our study we demonstrated that despite the universal inclusion of all severe TBI patients, there is in fact an age disparity in ICP monitor placement.

Studies attempting to show a benefit after ICP monitor placement have produced mixed results. Recent studies by MacLaughlin and Agrawal have shown significant survival benefit in patients who meet BTF guideline criteria and receive an ICP monitor.[9,10] Unfortunately, several additional papers assessing patients who met BTF ICP monitor placement guidelines found higher mortality rates in patients who received an ICP monitor.[4,11,12] A recent meta-analysis by Shen et al. of eighteen studies including over 25,000 severe TBI patients concluded that ICP monitoring significantly reduced overall mortality, hospital mortality, and 2-week and 6-month mortality rates.[13] However, another recent meta-analysis of patients with TBI showed that ICP monitors improve prognosis, but do not affect hospital mortality rates.[14] This wide range of outcomes has led to the weak level of evidence regarding monitor use in recent guidelines, though the recommendation for monitor use remains. This knowledge deficit is particularly acute in trauma subpopulations, such as elderly patients, and leaves many questions unanswered. Elderly patients who suffer from a traumatic brain injury have a one-year mortality or morbidity rate of over 80%; it is unclear if this could be improved by avoiding the discrepancy in monitor use that we identify.[15] Recent studies focusing on specific age demographics again had mixed results, however. These include an observational study showing improved hospital and six-month mortality with ICP monitor placement in the elderly,[7] as compared to a 2007-2008 NTDB study that did not find a survival benefit in patients over 55 years.[5]

ICP monitor placement is a safe procedure with a low risk profile. ICP monitors are associated with some complications, including cerebrospinal fluid (CSF) leak and infection, with reported rates between 0-5%.[16,17,18] Placement may be performed by a wide array of specialists, with studies showing excellent outcomes with placement by trauma surgeons, neurosurgeons, general surgeons and midlevel practitioners.[16,17,18] It is unclear whether the risks of monitor placement or the risk-to-benefit ratio changes with age.

This strength of this study lies on its sampling population. Utilizing the National Trauma Data Bank, we analyzed close to half a million trauma patients across the country over a five-year period. Our sample comes from the largest national trauma registry, providing the best possible representation of trauma patients in the United States. This large study cohort allowed adjustment of patient demographics, creating matched patient pairs, which greatly limited potential sampling biases. A potential limitation to this study is the reliance on GCS as a marker of traumatic brain injury. Previous studies have questioned the utility of GCS in classifying degrees of central nervous system (CNS) injury, and a JAMA Surgery study by Salottolo et al. showed that GCS can be significantly affected by age, as older patients tend to have higher GCS scores for the same severity of TBI than younger patients.[19] While we used both Head AIS and GCS as measures for brain injury severity, this potential variance does question the validity of using admission GCS 3-8 as an inclusion criterion in the study as well as in the BTF guidelines. Substance abuse, in particular alcohol use, has also been shown to reduce GCS, and could potentially serve as a confounder in TBI severity.[20] However, rates of alcohol and substance abuse were the same in both ICP and non-ICP monitoring groups, with no statistically significant differences (**Table 2**). To remain in accordance with current BTF guidelines, we used GCS as a primary marker of TBI severity, despite potential issues with this selection criterion. While this study provides ample data from the hospital admission following the inciting incident, there is insufficient data regarding long-term follow up or functional status. This allows us to only report the immediate effects of ICP monitoring, but we are unable to comment on the long-term outcomes of this type of management.

CONCLUSION

Patients ≥ 65 years of age with severe blunt TBI are less likely to be treated with an ICP monitor when compared to younger patients. Age disparities in adherence to Brain Trauma Foundation Guidelines may result in worse outcomes for patients with severe TBI.

AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

REFERENCES

1. Taylor, C.A., Bell, J.M., Breiding, M.J., Xu, L. (2017). Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths – United States, 2007 and 2013. MMWR Surveill Summ 66 (No.SS-9):1-16.
2. Finkelstein, E., Corso, P., Miller, T. and associates. (2006). The Incidence and Economic Burden of Injuries in the United State. New York: Oxford University Press.
3. Becker, D.P., Miller, J.D., Ward, J.D., Greenberg, R.P., Young, H.F., Sakalas, R. (1977). The outcome from severe head injury with early diagnosis and intensive management. J Neurosurg 47(4):491-502.
4. Tang, A., Pandit, V., Fennell, V., Jones, T., Joseph, B., O'Keeffe, T., Friese, R.S., Rhee, P. (2015). Intracranial pressure monitor in patients with traumatic brain injury. J Surg Res 194(2):565-70.
5. Dang, Q., Simon, J., Catino, J., Puente, I., Habib, F., Zucker, L., Bukur, M. (2015). More fateful than fruitful? Intracranial pressure monitoring in elderly patients with traumatic brain injury is associated with worse outcomes. J Surg Res 198(2):482-8.
6. Carney, N., Totten, A.M., O'Reilly, C., Ullman, J.S., Hawryluk, G.W., Bell, M.J., Bratton, S.L., Chesnut, R., Harris, O.A., Kissoon, N., Rubiano, A.M., Shutter, L., Tasker, R.C., Vavilala, M.S., Wilberger, J., Wright, D.W., Ghajar, J. (2017). Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition. Neurosurgery 80(1):6-15.
7. You, W., Feng, J., Tang, Q., Cao, J., Wang, L., Lei, J., Mao, Q., Gao, G, Jiang, J. (2016). Intraventricular intracranial pressure monitoring improves the outcome of older adults with severe traumatic brain injury: an observational, prospective study. BMC Anesthesiol 16(1):35.

8. Bratton, S.L., Chestnut, R.M., Ghajar, J., McConnell Hammond, F.F., Harris, O.A., Hartl, R., Manley, G.T., Nemecek, A., Newell, D.W., Rosenthal, G., Schouten, J., Shutter, L., Timmons, S.D., Ullman, J.S., Videtta, W., Wilberger, J.E., Wright, D.W. (2007). Brain Trauma Foundation and American Association of Neurological Surgeons. Guidelines for the management of severe traumatic brain injury. J Neurotrauma 24: S1–S106.
9. MacLaughlin, B.W., Plurad, D.S., Sheppard, W., Bricker, S., Bongard, F., Neville, A., Smith, J.A., Putnam, B., Kim, D.Y. (2015). The impact of intracranial pressure monitoring on mortality after severe traumatic brain injury. Am J Surg 210(6):1082-6; discussion 1086-7.
10. Agrawal, D., Raghavendran, K., Schaubel, D.E., Mishra, M.C., Rajajee, V. (2016). A Propensity Score Analysis of the Impact of Invasive Intracranial Pressure Monitoring on Outcomes after Severe Traumatic Brain Injury. J Neurotrauma 33(9):853-8.
11. Shafi, S., Diaz-Arrastia, R., Madden, C., Gentilello, L. (2008). Intracranial pressure monitoring in brain-injured patients is associated with worsening of survival. J Trauma. 64(2):335–40.
12. Farahvar, A., Gerber, L.M., Chiu, Y.L., Carney, N., Hartl, R., Ghajar, J. (2012). Increased mortality in patients with severe traumatic brain injury treated without intracranial pressure monitoring. J Neurosurg. 117(4):729–34.
13. Shen, L., Wang, Z., Su, Z., Qiu, S., Xu, J., Zhou, Y., Yan, A., Yin, R., Lu, B., Nie, X., Zhao, S., Yan, R. (2016). Effects of Intracranial Pressure Monitoring on Mortality in Patients with Severe Traumatic Brain Injury: A Meta-Analysis. PLoS One 11(12):e0168901.
14. Han, J., Yang, S., Zhang, C., Zhao, M., Li, A. (2016). Impact of Intracranial Pressure Monitoring on Prognosis of Patients With Severe Traumatic Brain Injury: A PRISMA Systematic Review and Meta-Analysis. Medicine (Baltimore) 95(7):e2827.
15. Lilley, E.J., Scott, J.W., Weissman, J.S., Krasnova, A., Salim, A. Haider, A.H., Cooper, Z.

(2017). End-of-Life Care in Older Patients After Serious or Severe Traumatic Brain Injury in Low-Mortality Hospitals Compared With All Other Hospitals. JAMA Surg 153(1): 44-50.

16. Young, P.J., Bowling, W.M. (2012). Midlevel practitioners can safely place intracranial pressure monitors. J Trauma Acute Care Surg. 73(2):431-4.
17. Sadaka, F., Kasal, J., Lakshmanan, R., Palagiri, A. (2013). Placement of intracranial pressure monitors by neurointensivists: case series and a systematic review. Brain Inj. 27(5):600-4.
18. Ekeh, A.P., Ilyas, S., Saxe, J.M., Whitmill, M., Parikh, P., Schweitzer, J.S., McCarthy, M.C. (2014). Successful placement of intracranial pressure monitors by trauma surgeons. J Trauma Acute Care Surg 76(2):286-90; discussion 290-1.
19. Salottolo, K., Levy, A.S., Slone, D.S., Mains, C.W., Bar-Or, D. (2014). The effect of age on Glasgow Coma Scale score in patients with traumatic brain injury. JAMA Surg 149(7):727-34.
20. Rundhaug NP, Moen KG, Skandsen T, Schirmer-Mikalsen K, Lund SB, et al. Moderate and severe traumatic brain injury: effect of blood alcohol concentration on Glasgow Coma Scale score and relation to computed tomography findings. J Neurosurg. 2015 Jan;122(1):211-8.

Table 1. Demographics of Patients with Isolated Traumatic Brain Injury	
Number of Patients	30,710
Age (years, mean +/- STD)	51.7 +/- 20.9
Sex (Male)	70.7%
ISS (median +/- IQR)	19.5 (14-26)
AIS Head	**Number (%)**
1	131 (0.4)
2	369 (1.2)
3	4,233 (13.8)
4	12,653 (41.2)
5	13,080 (42.6)
Subarachnoid Hemorrhage	14,409 (46.9)
Subdural Hemorrhage	18,119 (59.0)
Epidural Hematoma	2,290 (7.5)
Craniotomy	4,235 (13.8)
Craniectomy	1,511 (4.9)
Mortality	8,493 (27.7)

Table 2. Demographics and Clinical Characteristics (NTDB 2010-2014)							
	ICP monitoring n (%)	No ICP monitoring n (%)	p-value		ICP monitoring n (%)	No ICP monitoring n (%)	p-value
N	4,093	26,617		Alcohol use	1383 (46.6)	7575 (45.4)	p = 0.213
Age (mean)	44.5 +/- 18.4	52.8 +/- 21.1	p < 0.001	Substance use	1175 (56.4)	6607 (54.2)	p = 0.07
Male Sex	3,074 (75.1)	18,632 (70.0)	p < 0.001	AIS Head			
TBI				1	2 (0.0)	129 (0.5)	p=0.0001
Subarachnoid Hemorrhage	2,189 (53.5)	12,220 (45.9)	p < 0.001	2	3 (0.0)	366 (1.4)	p<0.0001
Subdural Hemorrhage	2,743 (67.0)	15,376 (57.8)	p < 0.001	3	225 (5.5)	4,008 (15.1)	p<0.0001
Epidural Hematoma	419 (10.2)	1,871 (7.0)	p < 0.001	4	1,481 (36.2)	11,172 (42.0)	p<0.0001
ISS (median +/- IQR)	22.7 (17-26)	19.0 (13-25)	p < 0.001	5	2,373 (58.0)	10,707 (40.2)	p<0.0001
Hospital days (median +/- IQR)	15 (8-26)	12 (6-21)	p < 0.001	Craniotomy	991 (24.2)	3,244 (12.2)	p < 0.001
ICU stay (median days)	11 (6-17)	4 (2-10)	p < 0.001	Craniectomy	582 (14.2)	929 (3.5)	p < 0.001
Time on ventilator (median days)	9 (4-14)	3 (2-7)	p < 0.001	Overall mortality	1,257 (30.7)	7,236 (27.2)	p < 0.001

Table 3. Insurance Status and Hospital Data (NTDB 2010-2014)

	ICP monitoring n (%)	No ICP monitoring n (%)	p-value
Insurance status			$p < 0.001$
Private/commercial	945 (23.1)	4,615 (17.3)	
Self-pay	625 (15.3)	3,721 (14.0)	
Blue Cross/Blue Shield	258 (6.3)	1,342 (5.0)	
Medicare	664 (16.2)	7,962 (29.9)	
Medicaid	594 (14.5)	2,996 (11.3)	
Other/unknown	384 (9.4)	2,732 (10.3)	
Hospital Status			$p = 0.034$
Community	1,467 (35.8)	9,488 (35.6)	
Non-teaching	405 (9.9)	2,993 (11.2)	
University	2,221 (54.3)	14,136 (53.1)	
Number of Neurosurgeons			$p < 0.001$
0	0 (0.0)	56 (0.2)	
1-2	285 (7.0)	2,280 (8.6)	
3-5	2,008 (49.1)	12,595 (47.3)	
Greater than 5	1,800 (44.0)	11,686 (43.9)	

Table 4. Multivariable Analysis for Predictors of ICP Monitor Placement (NTDB 2010-2014)

	OR (95% CI)	Adjusted OR (95% CI)
Age		
< 65 years	---	---
≥ 65 years	0.39 (0.35-0.42)	0.41 (0.36-0.46)
Male Sex	1.29 (1.20-1.40)	1.10 (1.02-1.19)
Insurance Status		
Medicaid	---	---
Private/commercial	1.03 (0.92-1.16)	1.14 (1.01-1.28)
Self-pay	0.85 (0.75-0.96)	0.89 (0.79-1.01)
Blue Cross/Blue Shield	0.97 (0.83-1.14)	1.02 (0.86-1.20)
Medicare	0.42 (0.37-0.47)	0.72 (0.62-0.83)
Hospital Status		
University	---	---
Community	0.98 (0.92-1.06)	1.00 (0.93-1.08)
Non-teaching	0.86 (0.77-0.96)	0.95 (0.84-1.06)
Number of neurosurgeons		
< 3	---	---
≥ 3	1.29 (1.13-1.46)	1.23 (1.08-1.41)