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Intracranial pressure monitoring in patients with geriatric trauma may not improve outcome but is associated with increases in resource utilization

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ABSTRACT

Background Intracranial pressure (ICP) monitoring (ICPM) is currently recommended for severe traumatic brain injury (TBI). The hypothesis was that ICPM does not change mortality in the geriatric patient population.

Methods The Trauma Quality Improvement Program (TQIP) database (2017–2021) was queried to identify intubated geriatric patients (≥65 years of age) with isolated blunt TBI (non-Head Abbreviated Injury Scale (AIS) score <3), with admission Glasgow Coma Scale (GCS) scores of 3–8. Patients with death on arrival or with hospital length of stay <24 hours and patients who underwent craniotomy before ICPM placement were excluded. Favorable discharge disposition was defined as home with or without assistance, and rehabilitation. Propensity score matching (PSM) was performed between ICPM and non-ICPM patients and outcomes were compared. The primary outcome was defined as in-hospital mortality. Secondary outcomes were defined as discharge disposition, hospital length of stay, intensive care unit (ICU) length of stay and ventilator days.

Results A total of 19 416 patients met criteria for analysis. ICPM was placed in only 12.1% (n=2363) patients. The Injury Severity Score, GCS and head AIS were similar between the patients with and without monitors. After PSM, we were able to match 2148 patients and there was no difference in mortality between the two groups (52.4% vs 52.1%, p=0.874); however, patients treated with ICPM had significantly longer hospital length of stay (10 (5–17) vs 7 (3–15) days, p<0.001), ICU length of stay (8 (4–14) vs 6 (3–10), p<0.001) and ventilator days (6 (3–11) vs 4 (2–7), p<0.001). Discharge disposition was trending towards unfavorable with increasing age but was similar between the ICPM and No-ICPM groups (p=0.115).

Conclusion The usefulness of ICPM in geriatric patients has not yet been shown and would benefit from prospective clinical studies. Minimizing ICPM in geriatric patients may reduce resource burdening without affecting outcome.

Level of evidence Level III retrospective study.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ In patients with primary traumatic brain injury (TBI), the expansion of the initial hemorrhage, brain swelling and tissue hypoxia results in a secondary insult to the brain which intensifies the initial physical injury and causes an elevated intracranial pressure (ICP). ICP monitoring (ICPM) is recommended in all patients with TBI with a Glasgow Coma Scale (GCS) score of ≤8 with an abnormal head CT, or a normal head CT scan with either systolic blood pressure ≤90 mm Hg, posturing or age ≥40 years.

WHAT THIS STUDY ADDS

⇒ This study aimed to evaluate outcomes in patients with geriatric TBI treated with ICPM, compared with those who did not receive such ICPM.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ ICPM in patients with geriatric trauma may not improve mortality outcomes, prompting a re-evaluation of its necessity in this population. Reducing its use could lead to significant resource savings without compromising patient care, influencing both clinical practice and healthcare policies.

INTRODUCTION

According to the Center for Disease Control and Prevention data, traumatic brain injury (TBI) accounts for 2.5 million emergency department visits annually. Although the majority of these patients are treated and discharged from the emergency department, TBI-related hospitalization is frequent among adults 75 and older among all age groups.[1 2] With the aging population, the proportion of older people with severe TBI is expected to increase significantly in the USA and other developed countries.[3] Although it is known that older adults tend to have poorer outcomes and slower recovery after TBI,[3 4] current treatment guidelines for TBI do not consider age-specific differences in recommendations for treatment.[5 6]

In patients with primary TBI, the expansion of the initial hemorrhage, brain swelling and tissue hypoxia results in a secondary insult to the brain which intensifies the initial physical injury and causes an elevated intracranial pressure (ICP).[7–9] Whereas elevated ICP is known to be associated with unfavorable outcomes in patients with TBI, management of the elevated ICP is highly variable in clinical practice, and its usefulness has not yet been verified.[6 10–15]

According to the fourth edition of Brain Trauma Foundation (BTF) guidelines, ICP monitoring (ICPM) is recommended in all patients with TBI with a Glasgow Coma Scale (GCS) score of ≤8 with

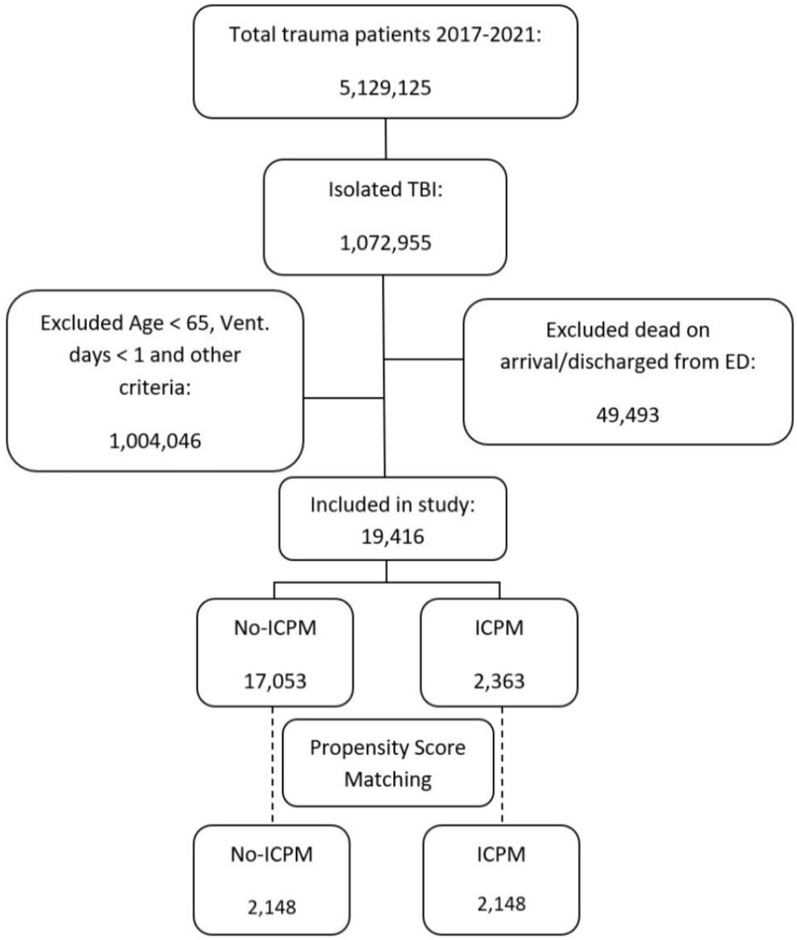

Figure 1 Flow chart of the study population. ED, emergency department; ICPM, intracranial pressure monitoring; TBI, traumatic brain injury; Vent, ventilator.

an abnormal head CT, or a normal head CT scan with either systolic blood pressure (SBP) ≤90 mm Hg, posturing, or age ≥40 years.[5] Following these guidelines, a vast majority of patients with severe TBI are recommended to have ICPM. However, variability among institutional guidelines usually allows for only a subset of hospitalized patients with TBI to receive ICPM. Among these patients are the growing population of frail patients with geriatric TBI with increasingly poor outcomes.[16 17] A recent randomized controlled trial demonstrated no difference in outcomes in patients managed with ICPM versus no ICPM among patients older than 13 years of age.[10] However, there is a paucity of data evaluating outcomes in geriatric patients with severe TBI.

The aim of this study was to evaluate outcomes in geriatric TBI patients treated with ICPM, compared with those who did not receive such ICPM. Our null hypothesis was that utilization of ICPM did not improve outcome in geriatric patients with severe isolated TBI.

METHODS

We used the Trauma Quality Improvement Program (TQIP) database. The study protocol was assessed by the Institutional Review Board (IRB) of our institute and was exempt due to the use of secondary deidentified data. We performed a 5-year (2017–2021) retrospective analysis of all intubated geriatric patients with isolated blunt TBI with admission GCS scores of 3–8. Geriatric patients were defined as patients aged 65 years and older. Patients with isolated blunt TBI were defined as patients with any Head-Abbreviated Injury Scale (AIS) and non-Head AIS score <3. AIS scores were derived from TQIP database variables which were uniformly available for the years studied.

We excluded patients who underwent craniotomy before ICPM placement, hospital length of stay <24 hours and patients who arrived with no signs of life. We collected the following data: demographic data including age, sex, race, ethnicity, mechanism of injury, vitals on presentation which included GCS score, motor component of GCS score, SBP, heart rate, respiratory rate, temperature, status of ICPM placement, Head-AIS, Injury Severity Score (ISS), types of intracranial hemorrhage (ICH), undergoing craniotomy after ICPM placement and undergoing tracheostomy. ICPM was defined based on the following ICD-10 procedure codes: 4A100BZ, 4A103BD, 4A107BD, 4A108BD. ICH types were categorized as epidural hemorrhage (EDH), subarachnoid hemorrhage, subdural hemorrhage, and intraparenchymal hemorrhage based on ICD-10 diagnosis codes. Craniotomy was considered based on ICD-10 procedure codes, including 0N50–0N57. Tracheostomy placement was identified by ICD-10 procedure codes of 0B110F4, 0B110Z4, 0B113F4, 0B113Z4, 0B114F4 and 0B114Z4.

The primary outcome was defined as in-hospital mortality. Secondary outcomes were defined as discharge disposition, hospital length of stay, intensive care unit (ICU) length of stay, and ventilator days. Favorable discharge disposition was defined as home with or without assistance, and rehabilitation. Unfavorable discharge disposition is defined as hospice or skilled nursing facility.[18 19] We should note that mortality was not included as part of the unfavorable discharge disposition, as it was analyzed separately as the primary outcome of this study.

Initially, patients were categorized into two groups: patients with ICPM and patients without an ICPM. We then compared the demographics and outcomes between the two groups prior to matching. Furthermore, we performed a multivariable logistic regression to assess the association between ICPM placement and odds of mortality in the study population. The regression model was adjusted for demographic data, SBP, motor component of GCS, head AIS, ISS, type of ICH and trauma center levels. A 1 to 1 propensity score matching (PSM) was then performed between ICPM and No-ICPM patients using age, gender, race, SBP, motor component of GCS, head AIS, ISS, type of ICH and trauma center levels with a tolerance of 0.001 and exact method resulting in 2148 patients in each post-match group (ICPM and No-ICPM). A post-match comparison of the demographics and outcomes between the two groups was done to affirm comparability and to assess the outcomes.

In a subanalysis, we compared the primary outcome and discharge disposition in different age groups within the study population in both ICPM and No-ICPM groups and performed a Jonckheere-Terpstra trend analysis. Furthermore, we also divided the patients into two groups based on initial GCS ($3\leq GCS\leq 5$ and $6\leq GCS\leq 8$) and compared mortality and discharge disposition based on undergoing ICPM.

We reported the data as mean+SD for continuous descriptive variables, median (IQR) for not normally distributed variables, and as proportions for categorical variables. The Median and Mann-Whitney U test were performed to explore differences in the two groups (ICPM and No-ICPM) for continuous or non-parametric variables. We used the χ^2 test to identify differences in outcomes between the two groups for categorical variables.

All statistical analyses were performed using the Statistical Package for Social Sciences (IBM SPSS Statistics for Macintosh, V.23.0. Armonk, New York: IBM Corp). Missing data were not imputed and were left as missing. P value <0.05 was determined as the significance threshold. We report our results in accordance with The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (online supplemental data 1).

RESULTS

A total of 1 072 955 patients were identified within the TQIP database with an isolated TBI diagnosis, of which 19 416 were included based on our criteria. Figure 1 demonstrates the details of the study population. A total of 1 053 539 patients were excluded based on our criteria to achieve a population with similar injury pattern. We should also note that 11 patients were excluded due to receiving ICPM after undergoing craniotomy. ICPM was placed in only 12.1% (n=2363) of our study population.

We used propensity scores matching among the two groups of our study. We compared the prematch and postmatch demographics of ICPM versus No-ICPM patients in table 1. Prior to matching, there were significant differences between the two groups. Patients who received ICPM had higher ISS and higher rates of ICH types (p<0.001 for both). However, we achieved a balanced population after matching as demographics and injury characteristics of our postmatch groups were equipoise (p>0.05 for all).

Results of prematch logistic regression showed no significant association between ICPM placement and odds of mortality in the study population (OR=1.039, p value=0.177).

Prematch and postmatch outcomes were compared in table 2. There was no difference in mortality between the two groups (52.4% vs 52.1%, p=0.874). However, patients treated with ICPM had significantly longer hospital length of stay (43% increase, p<0.001), ICU length of stay (60% increase, p<0.001), and ventilator days (40% increase, p<0.001).

In a subanalysis of our postmatch data, we graphed the mortality stratified by age in patients with ICPM and without

Table 1 Prematch and postmatch demographics and other variables

Variables		Prematch ICPM (n=2363)	Prematch No-ICPM (n=17 053)	Prematch P value	Postmatch ICPM (n=2148)	Postmatch No-ICPM (n=2148)	Postmatch P value
Age		73 (68–78)	76 (80–72)	<0.001	73 (68–78)	73 (68–78)	0.633
Gender (male)		65.8%	59.4%	<0.001	65.2%	65.5%	0.866
Race (White)		78.8%	82%	<0.001	81.4%	81.0%	0.713
Trauma center level	I	73.8%	78.1%	<0.001	74.2%	75.5%	0.519
	II	17.9%	12.3%		17.3%	16.8%	
	UD	8.3%	9.6%		8.5%	7.7%	
SBP		152 (130–178)	148 (124–174)	<0.001	152 (130–178)	151 (128–176)	0.081
GCS		3 (3–6)	3 (3–6)	<0.001	3 (3–6)	3 (3–6)	0.379
Head AIS		4 (3–5)	4 (3–6)	<0.001	4 (3–5)	4 (3–5)	0.255
ISS		25 (21–26)	25 (16–26)	<0.001	25 (21–26)	25 (21–26)	0.202
ICH	Isolated EDH	1.1%	0.9%	<0.001	1.2%	1.2%	0.119
	Isolated SAH	3.5%	3.9%		3.4%	3.2%	
	Isolated SDH	43.6%	45.9%		43.6%	43.6%	
	Isolated IPH	0.9%	1.5%		0.9%	0.9%	
	Having ≥2 concomitant types of ICHs	48.9%	46.7%		48.8%	49.0%	

AIS, Abbreviated Injury Scale; EDH, epidural hemorrhage; GCS, Glasgow Coma Score; ICH, intracranial hemorrhage; ICPM, intracranial pressure monitoring; IPH, intraparenchymal hemorrhage; ISS, Injury Severity Score; No-ICPM, no intracranial pressure monitoring; SAH, subarachnoid hemorrhage; SBP, systolic blood pressure; SDH, subdural hemorrhage; UD, undesignated.

Table 2 Prematch and postmatch outcome variables

Variables	Prematch ICPM (n=2374)	Prematch No-ICPM (n=17053)	Prematch P value	Postmatch ICPM (n=2148)	Postmatch No-ICPM (n=2148)	Postmatch P value
ICU length of stay	8 (4–14)	4 (2–8)	<0.001	8 (4–14)	6 (3–10)	<0.001
Ventilator days	6 (3–11)	4 (2–6)	<0.001	6 (3–11)	4 (2–7)	<0.001
Hospital length of stay	10 (5–17)	5 (2–14)	<0.001	10 (5–17)	7 (3–15)	<0.001
Mortality	52.2%	49.7%	0.02	52.4%	52.1%	0.874
Unfavorable discharge disposition	19.6%	19.3%	0.718	19.8%	18%	0.115
Tracheostomy	36.1%	31.7%	<0.001	36.8%	35.6%	0.391
Craniotomy	1.2%	0.7%	<0.001	1.2%	0.8%	0.138

ICPM, intracranial pressure monitoring; ICU, intensive care unit; No-ICPM, no intracranial pressure monitoring.

ICPM which showed an increasing trend of mortality with increasing age in each group (p<0.001) (figure 2). By evaluating the survived patients, we observed a significant increase in unfavorable discharge disposition (p<0.001) (figure 3). Furthermore, the study population was divided into two groups based on initial admission GCS. Data showed that 69.6% of patients had 3≤GCS≤5 and 30.4% had 6≤GCS≤8. There was no significant difference between these two groups in terms of undergoing ICPM (p=0.366). Analysis of outcomes showed that patients with 3≤GCS≤5 who underwent ICPM had significantly higher hospital and ICU length of stay compared with non-ICPM group (p<0.001 for both), but had similar rates of mortality and unfavorable discharge disposition (p>0.05 for both). Data showed that among patients with 6≤GCS ≤ 8, there were no significant differences regarding mortality and unfavorable discharge disposition between the ICPM and non-ICPM group (p>0.05 for both); however, patients with ICPM had longer hospital and ICU length of stay (p<0.001 for both) (table 3). Comparison of patients based on their initial GCS showed significantly higher mortality (56.1% in low GCS group vs 44.2% in high GCS group, p<0.001) and unfavorable discharge disposition (21.7% in low GCS group vs 17.6% in high GCS group, p<0.001) in patients with 3≤GCS≤5.

DISCUSSION

Data obtained by means of ICPM are used to guide the management of patients with severe TBI. However, the effect on the outcomes of geriatric patient remains unclear. In our matched cohort of geriatric patients with severe TBI from the TQIP database, patients with ICPM had a longer hospital and ICU length of stay as well as more days requiring mechanical ventilation, whereas no survival or favorable discharge benefits were identified. This study adds to the body of evidence questioning the

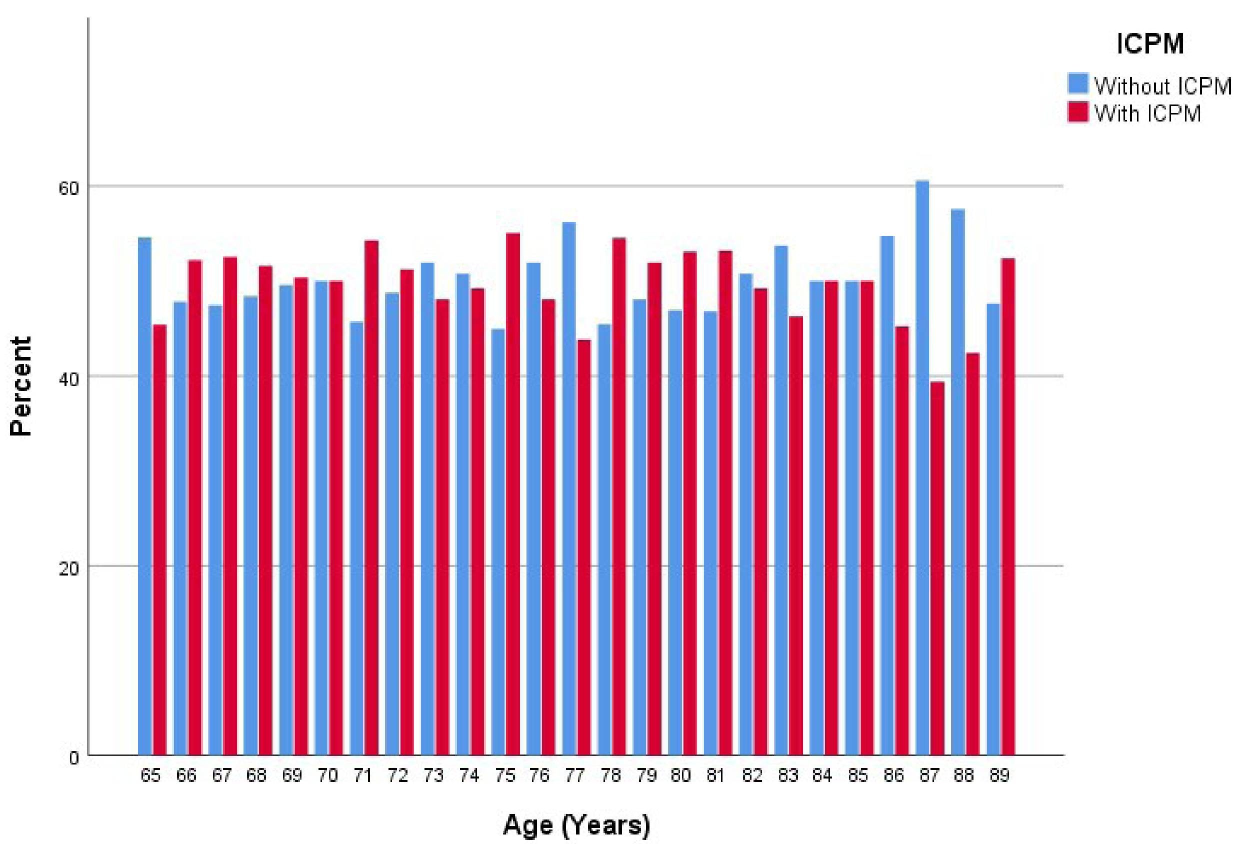

Figure 2 Mortality rates stratified by age among patients with and without ICPM. ICPM, intracranial pressure monitoring.

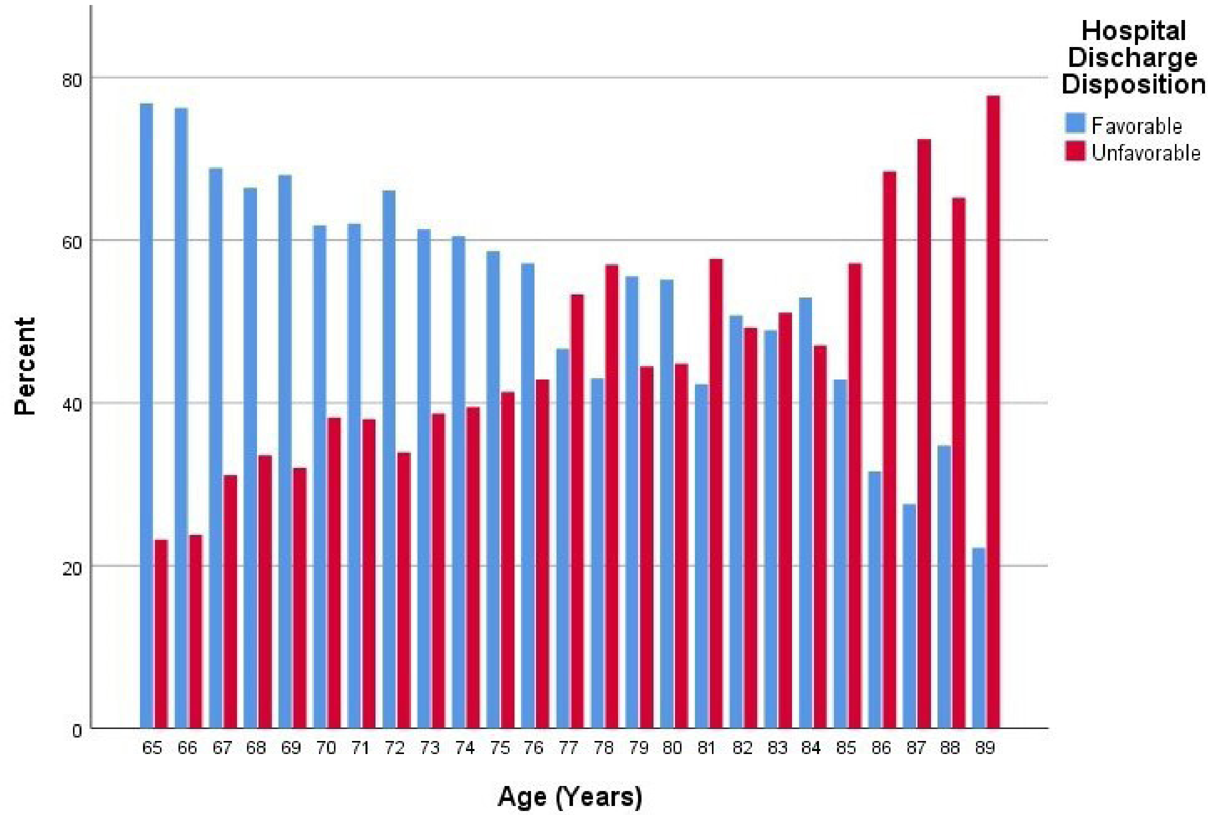

Figure 3 Unfavorable discharge disposition stratified by age among survived patients. The figure contains data of survived patients (47.8% of total population).

role of ICPM in patients (particularly the elderly) with severe TBI.

Although multiple studies have supported the use of ICPM in patients with severe TBI due to the potential survival benefit, routine use of ICPM has led to a lack of equipoise for non-monitored groups of patients.[5] In a retrospective review, Lane *et al* support the use of ICPM and show a potential survival benefit.[14] The authors conclude that the information gained from ICPM guided management decisions, thus resulting in better survival. However, as the authors also acknowledged, there is a potential measurement error, as ICPM may serve as a surrogate for the overall aggressiveness of care, and not necessarily individually responsible for better outcomes. You *et al* in a single-center observational study showed an in-hospital survival advantage for geriatric patients with severe TBI treated with ICPM (51.2% vs 33.8%).[20] This study had a small sample size, and treatment used for increased ICP was mannitol, which can lead to other unmeasured complications potentially affecting survival rates. Similarly, in a prospective study of severe blunt TBI in patients with GCS≤8, Talving *et al* demonstrated significantly higher in-hospital survival rate in patients who underwent ICPM compared with those who did not (53.9% vs 32.7%), but this study does not provide a comparison in the geriatric subgroup.[12]

In contrast, Chesnut *et al* in a multicenter randomized controlled clinical trial of 324 patients with severe TBI found no

Table 3 Comparison of outcomes among patients based on initial GCS

	3≤GCS≤5 n = 13 513			6≤GCS≤8 n = 5903		
Variable	ICPM n=1187	No-ICPM n=12 326	P value	ICPM n=1176	No-ICPM n=4727	P value
ICU length of stay	7 (3–12)	4 (2–6)	<0.001	8 (5–14)	5 (3–9)	<0.001
Ventilator days	6 (2–8)	4 (2–7)	<0.001	7 (3–12)	5 (3–8)	<0.001
Hospital length of stay	12 (6–16)	6 (3–12)	<0.001	9 (5–18)	5 (2–16)	<0.001
Mortality	51.7%	50.2%	0.34	52.5%	49.5%	0.067
Unfavorable discharge disposition	19.5%	18.9%	0.225	19.8%	19.2%	0.176
Tracheostomy	37.5%	31.9%	<0.001	35.9%	31.2%	<0.001
Craniotomy	1.1%	0.6%	<0.001	1.2%	0.7%	<0.001

GCS, Glasgow Coma Scale; ICPM, intracranial pressure monitoring; ICU, intensive care unit.

difference in mortality rate in patients managed with ICPM and patients managed without ICPM.[10] Furthermore, the functional and neuropsychological status at 6 months were similar between the two groups. Dang *et al* in a retrospective study from the National Trauma Database (NTDB) demonstrated that patients without ICPM were 1.21 times more likely to survive compared with that of patients with ICPM.[21] Similarly, Tang *et al* showed that patients without ICPM were 1.2 times more likely to survive compared with patients with ICPM.[22] Our study demonstrates that in geriatric patients with TBI, ICPM has no effect on mortality or discharge disposition. Furthermore, we show that they have a trend towards poor outcomes with increasing age regardless of ICPM use. The data on favorable and unfavorable discharge disposition should be useful as we advise and aid the patients and family members in making decisions regarding management and for prognostication. The results of our study are in line with other studies showing no advantage for ICPM and question the potential survival benefit of using ICPM in the management of severe TBI in geriatric patients. Our results show that using ICPM does not change the increasing mortality rate or functional outcomes with increasing age groups.

The strength of our study is mainly in using a national database and the unique methodology using PSM. In retrospective studies, PSM is considered an analogue to randomized controlled trials.[23] This method uses regression analysis to calculate a propensity score based on the likelihood of receiving the treatment by subjects in groups. Then subjects with similar scores are matched based on predefined criteria, and the outcome comparison can be done. In our study, patients with ICPM had longer hospital and ICU length of stay as well as more mechanical ventilation days with no clear survival advantage. Talving *et al* similarly showed longer hospital length of stay in patients with ICPM compared with patients without ICPM.[12] In another recent study by Liveris and colleagues, they analyzed data of 23 652 patients with severe TBI and reported that ICPM could be associated with survival benefits in younger patients but does not improve survival for patients with TBI above 55 years of age.[24] Increased ICU and overall length of stay in patients with ICPM, as well as mechanical ventilation days, are likely due to following specific treatment bundles once the ICPM is placed; however, this cannot be concluded from our data alone. Still, this increased utilization is further limiting the scarce resources available in hospitals, though not providing a potential survival benefit.

We identified 19 416 patients who potentially met the criteria set forward by BTF, whereas only 12.1% of these patients received ICPM. Previous studies have shown that overall, about 50% of the patients eligible to receive ICPM underwent the procedure and among whom only 76% of them achieved the cerebral perfusion pressure goals defined by BTF.[6] A more recent retrospective study demonstrated that the rate of utilization of ICPM is 6%–17% with the elderly population less likely to be treated with ICPM.[25] In 2021, Ghneim and colleagues assessed data of 2303 patients from the American Association for the Surgery of Trauma Geriatric TBI Study. They reported that of all patients who met the BTF guidelines, only 18% received ICPM.[26] We did not have means to measure the compliance with BTF among subjects of our study; however, our crude numbers demonstrate that adherence to BTF guidelines is likely to be lower than previously shown.

Our study does not challenge the overall value of knowing the precise ICP, nor the value of aggressive treatment based on such information. However, our data suggest that currently the eligibility criteria to receive ICPM do not necessarily identify the population that might benefit most. Geriatric patients, particularly, seem not to benefit from ICPM. Subanalysis of our data shows no difference in unfavorable discharge disposition in both groups; however, patients with a lower initial GCS had worse outcomes regardless of receiving ICPM. Elderly patients regardless of ICPM have worse outcomes as they age and become frailer.[17] We did not measure the frailty in our patient population. We should note that the TQIP database does not include frailty assessments, which could be a critical factor in evaluating patient's complications. Emerging evidence suggests that frailty may be a more important predictor of adverse outcomes than age alone, potentially playing a larger role in this population. Our study also showed that there were no significant differences between patients with and without ICPM regarding undergoing craniotomy. Meaning, ICPM did not increase rates of this intervention.

Several studies have highlighted institutional variability in the implementation of the BTF guidelines in patients with severe TBI.[6,15] One of the limitations of our study is that we are unable to account for these differences in a national database. Identifying the subset of patients who truly benefit from ICPM is vital in order to support the performance of this invasive and potentially harmful procedure. Furthermore, we included trauma center levels in the PSM to reduce variability in ICPM practices; however, differences may still exist between centers of the same level.

Recent studies have suggested that the utilization of ICPM is down trending over years in the elderly,[25] and although some might hesitate in adopting this strategy, we believe this body of evidence will continue to grow. Our study comes with inherent limitations of a retrospective cohort, and although we used an advanced statistical methodology, there may exist unmeasured bias that is not apparent from a retrospective perspective. There may be uncaptured subtle factors that make a difference in selecting a patient for receiving treatment which cannot be addressed in a retrospective study. Future well-designed prospective trials may help us identify these factors in order to further delineate indications for ICPM. Additionally, the TQIP database lacks specific information on the individual centers, limiting our ability to fully control for center-specific variations in practice. Another potential limitation of our study is that we did not know the type and dose of the treatments received, as the treatments for intracranial hypertension to a certain degree may in itself be harmful. The specifications of intracranial injuries, as well as details of admission anticoagulation and antiplatelet status, are lacking in this database. The selection bias inherent to this type of study is difficult to avoid. Even though propensity matching helps, it does not completely exclude selection bias. There may be selection bias towards the use of ICPM only on the very severely injured or even towards only survivable patients. In the geriatric population, it is more likely that patients have advance directives or surrogates decide against such measures as ICPM placement specially in severe traumatic injuries. These unknowns can only be controlled with prospective studies. We did not assess for differences in the long-term outcomes among patients in the study population. Despite these limitations, our study adds to the literature challenging the indications of ICPM in geriatric patients with severe TBI. To date, conclusive evidence demonstrating the benefits of ICPM use is still lacking.

CONCLUSION

In geriatric patients who are intubated with severe isolated blunt TBI, ICPM leads to increased utilization of resources without improving survival or favorable discharge disposition. Favorable discharge disposition decreased with increasing age. The usefulness of ICPM in geriatric patient has not yet been shown and would benefit from prospective clinical studies. Minimizing ICPM in geriatric patients may reduce resource burdening without affecting outcome. Future revisions of guidelines on when and on whom to use ICPM may need to change.

Contributors BZ: data curation, validation, formal analysis, methodology, writing–original draft, writing–review and editing. AR: data curation, methodology, writing–review and editing, resources, validation, visualization. KP: methodology, project administration, data curation, validation, writing– original draft. JK: formal analysis, methodology, data curation, validation, writing–original draft. MB: methodology, validation, data curation, software, writing–original draft, writing–review and editing. IS: software, formal analysis, data curation, validation, writing–review and editing. CG: methodology, writing–review and editing, data curation, validation. PR: investigation, methodology, supervision, data curation, validation, visualization, writing–review and editing.

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