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Neuro, trauma, or med/surg intensive care unit

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Neuro-, Trauma -, or Med/Surg-ICU: Does it matter where polytrauma patients with TBI are admitted? Secondary analysis of AAST-MITC decompressive craniectomy study

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Abstract

Introduction—Patients with non-traumatic acute intracranial pathology benefit from neurointensivist care. Similarly, trauma patients with and without TBI fare better when treated by a dedicated trauma team. No study has yet evaluated the role of specialized neurocritical (NICU) and trauma intensive care units (TICU) in the management of TBI patients, and it remains unclear which TBI patients are best served in NICU, TICU, or general (Med/Surg) ICU.

Methods—This study is a secondary analysis of The American Association for the Surgery of Trauma Multi-Institutional Trials Committee (AAST-MITC) decompressive craniectomy study. Twelve Level 1 trauma centers provided clinical data and head CT scans of patients with Glasgow

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Coma Scale (GCS) ≤13 and CT evidence of TBI. Non-ICU admissions were excluded. Multivariate logistic regression was performed to measure the association between ICU-type and survival and calculate the probability of death for increasing ISS. Polytrauma patients (ISS > 15) with TBI and isolated TBI patients (other AIS < 3) were analyzed separately.

Results—There were 3641 patients with CT evidence of TBI with 2951 admitted to an ICU. Prior to adjustment, patient demographics, injury severity, and survival differed significantly by unit type. After adjustment, unit-type, age and ISS remained independent predictors of death. Unit-type modified the effect of ISS on mortality. TBI-polytrauma patients admitted to a TICU had improved survival across increasing ISS (Fig1). Survival for isolated TBI patients was similar between TICU and NICU. Med/Surg ICU carried the greatest probability of death.

Conclusion—Polytrauma patients with TBI have lower mortality risk when admitted to a Trauma ICU. This survival benefit increases with increasing injury severity. Isolated TBI patients have similar mortality risk when admitted to a Neuro ICU compared to a Trauma ICU. Med/Surg ICU admission carries the highest mortality risk.

Keywords

ICU; polytrauma; TBI; outcomes

Background

Rates of traumatic brain injury (TBI) are increasing, particularly among high-risk groups such as the elderly.[1] Despite this trend, TBI outcomes have improved significantly in recent years as advances in care and monitoring have reduced the incidence of secondary insults.

Neuro-protective protocols aim to minimize secondary hypoxic injury to vulnerable brain tissue through close monitoring and management of intracranial pressures and oxygen delivery. Studies have shown that adherence to such protocols is associated with reductions in in-hospital mortality, hospital length of stay (HLOS), and total charges.[2, 3] The institutional adoption of protocols designed to embrace these principles and standardize care have resulted in significant improvements in survival after TBI.[4, 5] There is also growing evidence that patients with acute intracranial pathology benefit from neurointensivist care in dedicated neurocritical care units (Neuro ICU).[6, 7] Along these lines, the development of highly specialized and organized neurosurgical intensive care teams has shown similar benefit with regard to survival and functional outcomes.[8]

Similarly, the use of dedicated trauma teams led by a trained trauma surgeon has been associated with improved outcomes and cost savings, particularly for the more severely injured patient.[9, 10] Additionally, implementation of a dedicated trauma care unit and addition of trauma-specific physician assistants have also shown benefit.[11] Studies evaluating the value of the specialized trauma intensive care unit (Trauma ICU), however, are surprisingly few. A retrospective review from a single Level 1 trauma center reported similar outcomes for trauma patients admitted to non-trauma surgical ICUs and Trauma ICUs, despite the later caring for sicker patients.[12] Dedicated Trauma ICUs may also result in reduced HLOS and costs for complex trauma populations.[13]

Despite the growing evidence supporting the value of specialized teams and intensive care units for complex patient populations such as TBI and trauma patients, it remains unclear whether a trauma patient with concomitant TBI should be preferentially admitted to a specialized unit (Neuro or Trauma ICU) or to a general intensive care unit (Med/Surg ICU). We hypothesize that isolated TBI patients will have lower mortality and morbidity when admitted to a Neuro-ICU, and polytrauma patients with TBI derive additional benefit when cared for in a Trauma-ICU.

Methods

Data acquisition

Retrospective data of TBI patients was acquired from 11 Level I US trauma centers as described previously.[14] Inclusion criteria were age 16 years or older, evidence of blunt TBI on admission head CT, and admission Glascow Coma Score (GCS) of 13 or less. Patient demographics, pre-existing comorbidities, clinical and laboratory data, and admission CT scans were collected utilizing an online web-portal data entry system developed in conjunction with the American Association for the Surgery of Trauma (AAST) and Acute Care Surgery (ACS). CT scans were reviewed by the primary research site and graded according to the Marshall Classification scheme.[15] Non-ICU admissions were excluded from analysis after completion of summary statistics. Deaths occurring within the first 24 hours of admission were also excluded from all subsequent analysis.

Outcomes

The primary outcome of interest was in-hospital mortality. Secondary outcomes included complications (ventilator-associated pneumonia [VAP], adult respiratory distress syndrome [ARDS], deep venous thrombosis [DVT], catheter-related blood stream infection [CRBSI], abscess, or meningitis), hospital length of stay (HLOS), and total hospital costs. More than one complication could occur for a single patient, however the presence of any complication was treated as a dichotomous outcome rather than as a count variable. HLOS was calculated from the date of admission until the date of death or discharge. Total hospital charges were reported by the facility, and rounded to the nearest dollar amount.

Demographic, physiologic, and laboratory variables for the final cohort were compared across ICU setting using Pearson’s chi-squared test for categorical variables, two-sample t-test for continuous or interval variables, and Kruskal Wallis for ordinal variables. Unadjusted outcomes data were reported as percentages (incidence) and means with standard deviation.

Regression analysis

Multivariate regression analyses were performed to measure the association between ICU-type and primary and secondary outcomes for increasing age and ISS. We chose to analyze these outcomes across age and ISS because we hypothesized that age and ISS might act as effect modifiers for the relationship between ICU type and outcome. We suspected that outcomes would not be substantially different by ICU type for young, relatively uninjured cohorts but might be more divergent when patients were elderly or more severely injured.

Variables captured patient demographics (age, race, insurance status), clinical presentation and physiology (systolic blood pressure, heart rate, intubation, paralytics), injury severity upon admission (GCS, ISS), initial head CT Marshall score, laboratory values (lactate, hematocrit, INR), transfusion needs, surgical interventions (laparotomy, craniotomy, other surgical procedures), and hospital and critical care unit characteristics (institution, open vs. closed unit, in-house neurosurgeon). A dichotomous variable was generated to identify institutions adhering to Brain Trauma Foundation (BTF) guidelines for placement of ICP monitors in at least 50% of study patients in whom the guidelines would indicate that an ICP monitor should be placed. This variable was then used as proxy during univariate and multivariate analysis to control for institutions that were more likely to adhere to unmeasured BTF guidelines.

All potential confounders were included in the initial full model, which was then refined through backward elimination. Variables known to be associated with survival outcomes in trauma populations were retained regardless of statistical significance. The full regression model included variables that were independently predictive of death (age, ISS, race, insurance status, motor GCS on admission, heart rate [HR], systolic blood pressure [SBP], head AIS, intubation status, product transfusion, lactate, need for craniotomy or other surgical procedure, and whether the site was likely to follow BTF guidelines). Additional variables thought to be relevant and incorporated in the model, but not independently predictive, included presence of on-board paralytic at time of ED arrival, CT classification (Marshall score), and treating facility. Model optimization was achieved through goodness of fit (Hosmer-Lemeshow; c-statistic) and specification testing. The probability of in-hospital mortality for a specific ICU admission type, as predicted by the final model, was then graphed with 95% confidence intervals against age and injury severity score (ISS). Secondary outcomes were analyzed similarly, with regression model (logistic for binary outcomes, linear for continuous outcomes) and variable selection specific to the outcome of interest. Hospital costs considered only patients surviving until discharge, and controlled for HLOS and presence of in-hospital complications in addition to previously mentioned variables. Controlling for these variables attempts to adjust hospital costs for the charges accrued through the use of consults, imaging studies, laboratory tests, and billable procedures performed by the treating unit. Costs were then analyzed without adjusting for HLOS and complications; this assumes that both HLOS and complications are on the causal pathway and permits a comparative assessment of care efficiency by unit type.

Within the TBI population the severity of associated injuries can be highly variable and thus significantly impact patient outcomes. Therefore, subgroup analysis was carried out to identify populations most likely to benefit from admission to a Neuro, Trauma, or Med/Surg ICU. From the final cohort described above, polytrauma (defined as a head injury and Abbreviated Injury Scale (AIS) ≥ 3 in chest, abdomen, pelvis, or long bone) and isolated TBI (defined as head AIS ≥ 2, all other AIS regions < 2) patients were identified for subgroup analysis. Regression modeling, including variable selection and reporting, and model evaluation was performed for these groups in similar fashion as described for the full cohort. All statistical analyses were performed using Stata (version 11.0, StataCorp LP). A p-value of less than 0.05 was considered to be statistically significant.

Results

Cohort description

There were 4284 patient observations, of which 155 were under age 15 years, 488 died within 24 hours of admission, 691 were not admitted to an ICU, 155 suffered penetrating injuries, 318 had incomplete data, and 28 were GCS > 13 on admission. The final dataset contained 2449 observations, including 756 admissions to the Neuro ICU, 1147 to Trauma ICU, and 534 to Med/Surg ICU (Figure 1).

Of the 11 contributing Level 1 trauma centers, 6 reported at least one admission to each type of ICU. Two sites admitted patients to Neuro and Trauma ICUs, one site to Neuro and Med/Surg ICUs, one site to Trauma and Med/Surg ICUs, and one trauma center admitted all eligible patients to a Trauma ICU. Observations by site ranged from 28 to 345 (1.1 to 14.5%), with eight of the 11 centers reporting more than 200 (>8%) admissions that met inclusion and exclusion criteria demonstrating a relatively even distribution of patients across sites.

Patient demographics, physiology, GCS, injury severity, and admission head CT scores differed significantly by unit type (Table 1). Trauma ICU had the highest average ISS (29.9; sd 14.0), followed by Neuro ICU (26.8; sd 11.9) and Med/Surg ICU (24.7; 12.0). Patients admitted to a Neuro ICU were significantly more likely to have isolated TBI (n=309; 40.8%; p-value < 0.001), and had lower mean admission GCS (5.7; sd 3.5) than Trauma (6.3; sd 3.7) or Med/Surg (6.4; sd 4.0) ICUs (p-value 0.006).

Unadjusted outcomes

Age over 65 years was associated with higher rates of in-hospital mortality (35.4 vs. 17.2%, p-value < 0.001), but not complications (30.2 vs. 27.7%, 0.362). Increasing ISS was correlated with higher likelihood of in-hospital death (OR 1.05, p-value < 0.001) and complications (OR 1.03, p-value < 0.001). Highest prevalence of mortality was seen in the Neuro ICU, however this did not differ significantly between groups (Table 2). Complications were significantly more common among patients admitted to Trauma ICU as compared to Neuro or Med/Surg ICUs (< 0.001).

Average HLOS for all comers was 19.5 days (median 13), with a maximum reported stay of 359 days. Patients admitted to a Trauma ICU, on average, had a HLOS that was 2 days longer than Neuro ICU admissions (Table 2), however this did not differ significantly from cohort mean and median stays. Hospital charges were lowest for Med/Surg ICU admissions and highest for Neuro ICUs. Mean charges differed significantly by unit type (p-value <0.001), however nearly one quarter of observations had missing data for this field.

Adjusted outcomes

After multivariate regression modeling, ISS scores and age remained predictive of in-hospital mortality. Among all comers with TBI and increasing ISS score, admission to a specialty ICU was protective as compared to a Med/Surg ICU (Figure 2a). Trauma ICU admission was associated with significantly lower probability of death for the most severely injured patients (ISS > 30). All units had similar mortality outcomes for increasing patient age, after adjusting for ISS and other confounders (Figure 2b).

Improved survival of the polytrauma with TBI patient cohort was similarly associated with specialty ICU admission, however the beneficial effect of the Trauma ICU relative to Neuro ICU at very high ISS scores disappeared (Figure 3a). No significant difference in mortality by unit type was again noted across age groups (Figure 3b).

Patients with isolated TBI trended towards lower rates of in-hospital mortality when admitted to a specialty ICU, with the margin between units increasing with higher ISS, however these differences were not significant (Figure 4a). At low levels of injury (ISS < 9), outcomes across the unit types were comparable for this population. No ICU-specific difference in survival was seen with increasing age (Figure 4b).

Risk of in-hospital complications for all comers with TBI remained higher in Trauma ICUs after adjustment, and showed positive correlation with increasing ISS. At very high levels of injury (ISS > 45), the predicted rate of morbidity for each unit was similar. For all age groups, Trauma ICU admission was associated with significantly higher morbidity. Among patients with isolated TBI, Trauma ICU admission was associated with significantly higher morbidity for both increasing ISS and age.

Hospital charges for all comers with TBI surviving until discharge correlated positively with ISS and HLOS. Age was not predictive of costs. Unit differences in total hospital charges were significant, with the mean per patient Neuro ICU costs significantly higher than Med/Surg ICU. Increasing ISS was associated with rising costs in all units, while advancing age trended towards reduced charges in the Neuro and Med/Surg ICUs. These associations were unchanged after also controlling for HLOS and complications.

Discussion

This study compared mortality, morbidity, and cost outcomes for trauma patients with TBI admitted to Neuro, Trauma, or Med/Surg ICUs at 11 Level 1 trauma centers. After adjusting for potential confounders through multivariate regression modeling, we found admission to specialized ICUs (Neuro and Trauma) to correlate with improved in-hospital survival as compared to a general Med/Surg ICU. This was especially true for more severely injured patients, and less so for trauma patients with isolated TBI. After controlling for injury severity, the effect of age on mortality was similar across all unit types. Interestingly, Trauma ICU admission was associated with the highest rates of in-hospital complications across all age groups, but intermediate total hospital charges. Our work is unique as it highlights the value of specialized critical care units in optimizing outcomes of polytrauma patients with TBI.

Dedicated care teams are able to provide highly specialized and efficient care to unique patient populations, resulting in improved clinical outcomes, reduced HLOS, and cost savings.[6, 8–11] Our results are consistent with prior studies demonstrating benefit in the adoption of dedicated trauma and neurocritical care teams.[8, 10, 11] The difference in predicted survival between the Neuro, Trauma, and the Med/Surg ICUs grew with increasing

ISS, suggesting that the most severely injured patients with TBI should be cared for in a Trauma ICU. This is not surprising as complex polytrauma patients frequently suffer significant injury to multiple body regions. The critical care physician and neurointensivist, along with their respective unit personnel, may be less familiar with the pathophysiology, complications and early management of traumatic injury than the trauma/critical care surgeon. This assertion is supported by the comparable predicted mortalities across a wide age range. Age is known to correlate positively with trauma-related mortality, particularly for patients with TBI. [16–18] That ISS, not age, anticipates differences in predicted unit-specific mortality supports the assertion that variability in the management of sustained injuries is likely influencing our results. Predictably, less severely injured, isolated TBI patients derived non-significant benefit from admission to a Neuro ICU over Trauma ICU; here again demonstrating the value of specialized care teams for specific patient populations.

Interestingly, the survival benefit of the Trauma ICU did not have a similar effect on rates of in-hospital complications. There is limited data supporting the ability of specialized care teams to reduce morbidity to the same extent as mortality, HLOS, and total costs.[9, 11, 19] Additionally, one large prospective, multicenter study found a higher incidence of complications among trauma patients treated at trauma centers as compared to non-trauma centers.[20] Its authors hypothesized that more aggressive (i.e. invasive) treatment strategies – especially the placement of pulmonary artery catheters and intubations – may account for these differences. A retrospective study of trauma patients with severe head injury (GCS ≤8) admitted to 34 academic trauma centers reported that more aggressive management (placement of intracranial pressure monitors is > 50% of patients meeting BTF guidelines) was associated with significant reductions in mortality.[21] Taken together, these studies support the findings reported here and suggest a viable explanation for the seeming discordance of mortality and morbidity for Trauma ICU admissions: improved survival of Trauma ICU patients may be secondary to more aggressive management strategies, which comes at a cost of higher rates of complications.

The initiation of trauma-specific care teams has been associated with cost savings. The improved efficiency results in reduced HLOS and improved billing practices, without any detectable negative impact on patient outcomes.[9, 20] Among neurosurgical patients, however, results have been mix. A large prospective study of TBI patients admitted to 67 ICUs reported that while dedicated Neuro ICUs had higher total charges, their improved outcomes relative to general ICUs made them more cost-effective when measured in terms of quality-adjusted life years (QALYs).[22] Although costs were not specifically considered, a single institution study evaluating the impact of a neurointensivist on outcomes in a Neuro ICU found that a neurointensivist-led team model effected a significant reduction in mortality and HLOS.[7] These conclusions are consistent with our findings that admission to the Neuro ICU is more costly, but associated with better outcomes than Med/Surg ICU.

The analogous assessments of costs and outcomes in Neuro and Trauma ICUs have yet to be completed. Interestingly, a recent report suggests that exclusive management of non-operative TBI by trauma surgeons may be both safe and cost-effective.[23] Among patients presenting with significant TBI (skull fracture or intracranial hemorrhage on CT scan), the need for neurosurgical consult was determined through application of the Brain Injury

Guidelines.[24] Those not requiring neurosurgical consults were managed exclusively by trauma surgeons, resulting in statistically significant cost savings, reduced HLOS, and fewer ICU days without any increase in mortality.[23] While no cost-effectiveness analysis was undertaken for this study, admission to Neuro ICU was associated with higher total hospital charges than admission to either Trauma or Med/Surg ICUs. The absence of a significant mortality benefit for Neuro ICU patients over Trauma ICU admits suggests that trauma surgeons and intensivists are capable of providing high-quality, efficient care for trauma patients with TBI.

This study has several important limitations owing to its non-randomized design and the potential for significant site variability with regards to patient management. As this was an observational study, no established guidelines to direct physicians in the allocation of patients to the various ICUs. This determination was left to the treating physician, and any existing institutional guidelines that may have influenced the decision-making process at that time. Beyond knowledge of the institution providing care, site trauma volume, and staffing practices for neurosurgical residents and trauma surgeons, no additional variables were collected that might better characterize this highly individualized process. The likely substantial but unmeasured heterogeneity of participating ICUs raises concerns for type II error.

The limited data on the specifics of the ICUs and patient care also requires careful consideration. While we did capture open vs. closed ICU management strategies, the training background and degree of oversight by the supervising intensivist as well as the role of resident physicians and midlevel staff in these settings remains undefined. There were no defined criteria for what was considered a Neuro or Trauma ICU, and not all accruing sites had dedicated Neuro, Trauma, and Med/Surg ICUs. The designation of any specialty unit as such was made by researchers at the participating institutions. This raises concern that unit types may not be comparable due to the lack of objective measures for differentiation. However, by convention, a Neuro ICU at a Level I Trauma Center would not be called such without a high volume of neurologically injured patients, and the presence of a dedicated intensivist who frequently cares for the neurologic patient. A name alone does not capture the function and staffing of an ICU, but based upon our results the focused expertise of these specialty ICUs may translate into real differences in outcomes. Additional research will be necessary to better understand this complex relationship. While a Med/Surg ICU may at times be staffed by a trauma surgeon, the variability of staffing expertise and patient populations is the key feature of the non-specialty ICU. As such, we believe that data collected from a mixed population Med/Surg ICU at a facility with a single ICU is relevant in this study even in the absence of a specialty ICU at that same site.

Methodological concerns include the potential for selection bias through exclusion of patients dying within 24 hours of ICU admission. We considered this necessary to avoid immortality time bias. We were also unable to determine if there was a higher tendency to withdraw care in certain unit types, which would influence mortality risk for reasons not related to care delivered. Finally, a major limitation of this study is the inability to assess both functional status and long-term outcomes of this patient population. Researchers and clinicians have become increasingly aware of the value of outcome measures other than mortality, particularly in populations with neurologic insults. GCS score at ICU discharge has been shown to be a good predictor of outcomes at 1-year, however this measure was not captured in this study.[25] Additionally, no measures of functional independence or Glasgow Outcome Scale scores were collected.

Future studies should attempt to address the shortcomings of this initial study evaluating of the impact of specialized vs. general ICU care for trauma patients with TBI. Well-designed prospective studies can more closely examine the relative benefits and financial costs associated with admission to Neuro vs. Trauma ICUs for specific trauma subpopulations. Additionally, thoughtfully selected functional outcome measures and inclusion of ICU-specific variables (e.g. resident staffing practices) may provide meaningful insight into the differences highlighted in this report.

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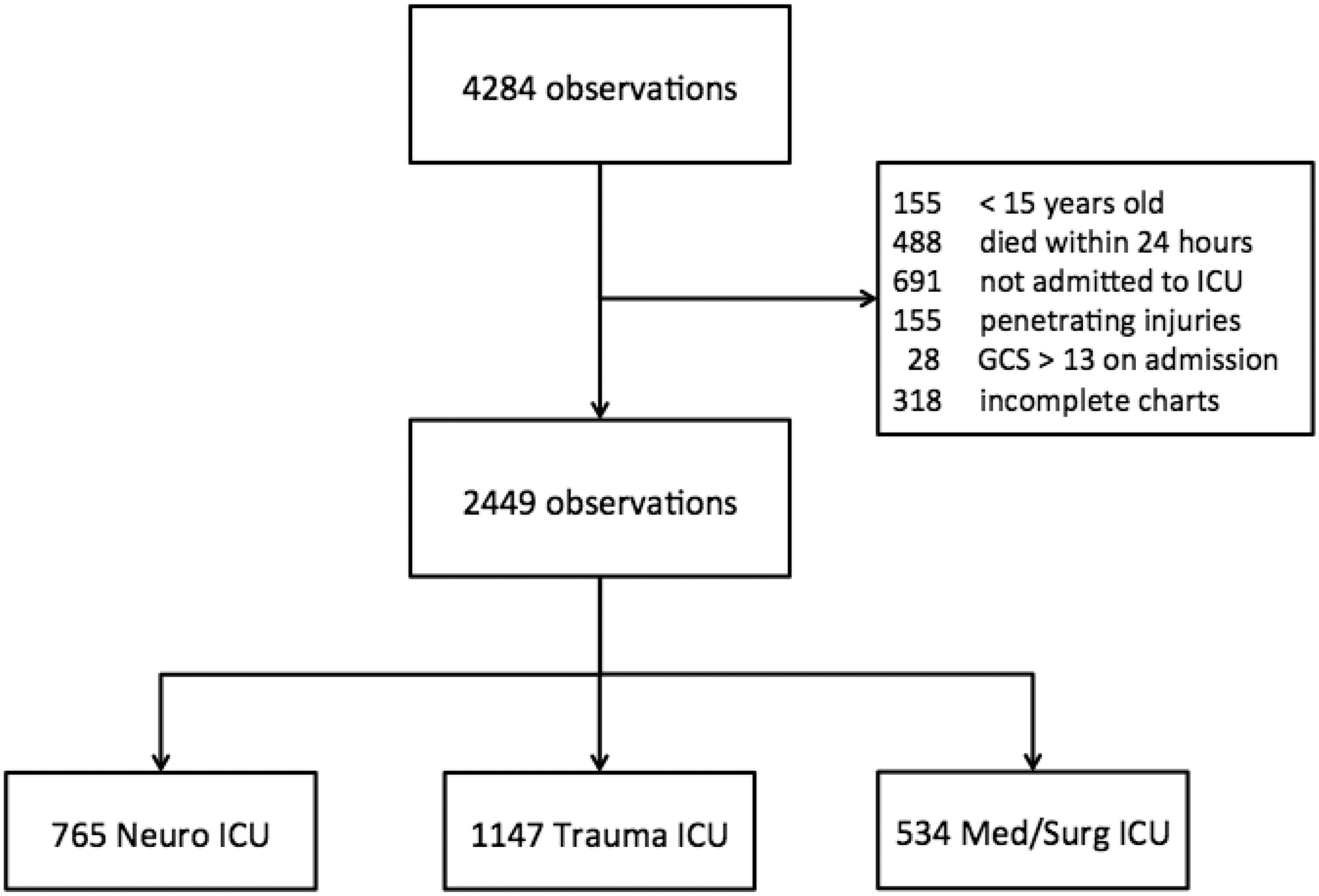

Figure 1.
Observations by unit type and inclusion/exclusion criteria

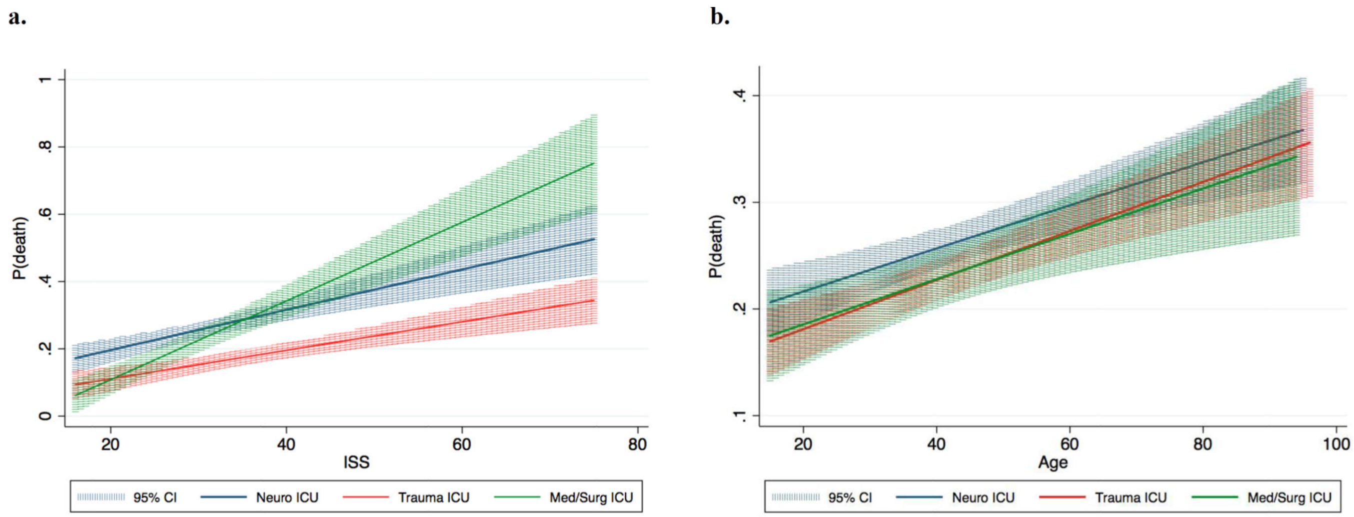

Figure 2.

All comers with TBI, predicted probability of death by unit and ISS (a); and by unit and age (b).

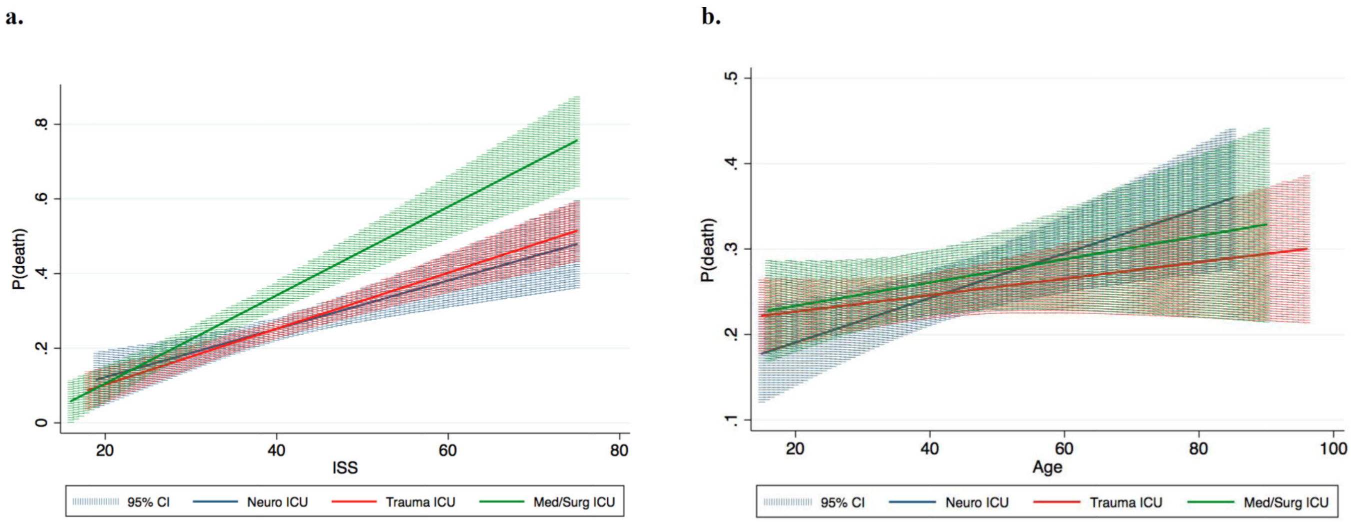

Figure 3.
Polytrauma with TBI, predicted probability of death by unit and ISS (a); and by unit and age (b).

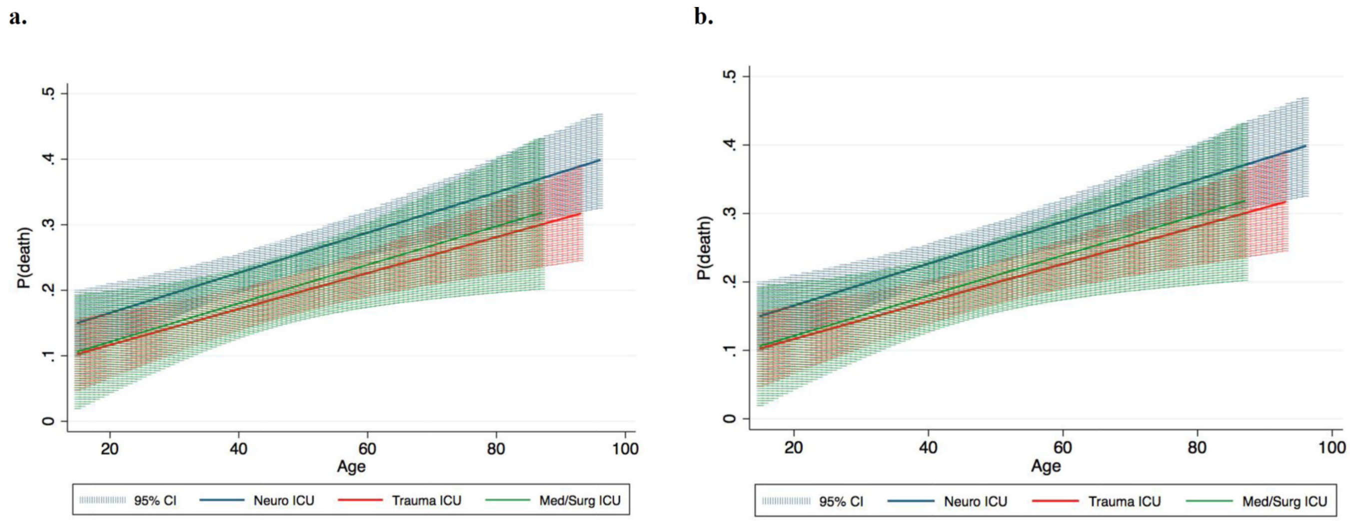

Figure 4.

Isolated TBI, predicted probability of death by unit and ISS (a); and by unit and age (b).

Table 1

Patient characteristics

	Neuro ICU (n=757)	Trauma ICU (n=1158)	Med/Surg ICU (n=534)	p-value
Age, yrs	43.1 ± 19.8	40.6 ± 19.1	40.8 ± 19.6	0.014
Race, %				
White	63.4	56.5	46.1	< 0.001
Hispanic	12.5	21.9	13.2	
African American	8.5	14.1	16.2	
Other	15.8	7.5	24.6	
Male, %	77.2	76.7	74.2	0.417
Any comorbidity, %	19.0	14.5	14.6	0.020
Insurance, %				
Medicare	16.4	15.8	17.0	<0.001
Medicaid	10.1	19.6	4.8	
Private	53.0	34.2	44.3	
Self pay	20.6	30.4	33.9	
Admission SBP < 90, %	4.9	7.3	8.1	0.047
Admission HR > 120, %	14.0	25.0	19.9	<0.001
Admission GCS, %				
>12	6.7	9.5	12.0	0.006
12–9	18.1	18.9	21.4	
<9	75.2	71.6	66.7	
Admission ISS, %				
0–15	14.5	10.1	19.5	<0.001
16–25	29.5	31.4	41.2	
26–40	43.1	36.7	27.3	
>40	13.0	21.8	12.0	
Isolated TBI, %	40.8	30.1	21.4	<0.001
Intubated, %	84.2	74.9	83.7	<0.001
Marshall score (CT), %				
1	0	0.5	0.4	0.020
2	61.5	57.5	63.3	
3	13.9	16.7	15.0	
4	3.4	4.3	6.4	
5	11.6	11.1	8.8	
6	9.7	9.9	6.2	

Table 2

Unadjusted outcomes

	Neuro ICU (n=756)	Trauma ICU (n=1147)	Med/Surg ICU (n=534)	p-value
Mortality, %	21.8	18.8	18.4	0.196
Morbidity, %	25.9	35.2	24.0	<0.001
VAP	17.9	14.5	15.7	
ARDS	2.8	7.3	6.7	
DVT	6.0	4.3	3.9	
CRBSI	3.2	3.3	3.4	
Other	2.5	11.1	0.6	
Hospital LOS, days	17.9 (19.2)	20.7 (22.0)	19.1 (30.4)	0.039
Hospital charges, $1000s	289 (164)	242 (241)	144 (152)	<0.001