CE 1.5 ANCC Contact Hours

Complications and Mortality Among Correctly Triaged and Undertriaged Severely Injured Older Adults With Traumatic Brain Injuries

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ABSTRACT

Determining differences in clinical outcomes of older adults treated at trauma centers (TCs) and nontrauma centers (NTCs) is imperative considering their persistent undertriage and the projected costs of fixing the problem. This study compared the incidence and predictors of complications and mortality among brain-injured older adults treated at TCs and NTCs. This secondary analysis of New York inpatient data included patients aged 55+ years, primary brain injury diagnosis, and acute care hospital admission. Interfacility transfers and nontraumatic brain injuries were excluded. *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis codes identified complications and mortality. Injury severity was determined by mapping ICD-9-CM diagnoses to Abbreviated Injury Scale 2005 Revision 2008 dictionary scores. A subgroup analysis of 1,594 patients with New Injury Severity Scores greater than 15 was performed to examine complications and mortality. This study included 7,138 patients who met inclusion criteria. Predictors of subgroup complications included chronic renal failure, odds ratio (OR) = 2.251 (confidence interval [CI] = 1.470-3.447), $p < .001$; major operating room procedure, OR = 2.349 (CI = 1.679-3.285), $p < .001$; number of diagnoses, OR = 1.201 (CI = 1.158-1.245), $p < .001$; and number of procedures, OR = 1.119 (CI = 1.077-1.162), p £ .001. Mortality predictors included age, OR = 1.031 (CI = 1.017-1.045), $p < .001$; preexisting coagulopathy, OR = 1.753 (C = 1.130-2.719), $p = .012$; number of procedures, OR = 1.122 (CI = 1.081-1.166), $p < .001$; acute renal failure, OR = 3.114 (CI = 1.672-5.797), $p < .001$; systemic inflammatory response syndrome, OR = 4.058 (CI = 1.463-11.258), $p = .007$; adult respiratory distress syndrome, OR = 3.179 (CI = 1.673-6.041), $p < .001$; and subarachnoid bleed, OR = 2.667 (CI = 1.415-5.029), $p = .002$. Nearly 23% of the severely/critically injured patients experienced 1 or more complications. Incidence of complications was low and comparable for TCs and NTCs. The proportion of deaths was slightly higher at TCs but not significant. The most prevalent complications carry a high mortality risk.

Key Words

Brain injury, Complications, Elderly, Mortality, Trauma

Trauma center (TC) care is the gold standard for treatment of life-threatening injuries for all patients. Unfortunately, undertriage of older adults to nontrauma center (NTC) hospitals is a problem that has been well documented for several decades (Chang, Bass, Cornwell, & Mackenzie, 2008; Davis et al., 2012; Ma, MacKenzie, Alcorta, & Kelen, 1999; Scheetz, 2004; Vassar, Holcroft, Knudson, & Kizer, 2003). Despite periodic evidence-based revisions of a national trauma triage algorithm (Sasser et al., 2012), a considerable degree of undertriage persists among older adults (Kodadek, Selvarajah, Velopulos, Haut, & Haider, 2015). In addition, a study of injury patterns among older adults revealed a high incidence and substantial undertriage of traumatic brain injuries (TBIs; Scheetz, 2012).

The persistence of undertriage necessitates a comparative analysis of TC and NTC outcomes for older adults with TBIs to determine whether treatment of these patients at NTCs is associated with worse outcomes. Outcomes that are relevant include mortality, cost, and complications. Studies of mortality in older adults revealed contradictory findings (MacKenzie et al., 2006; Pracht, Langland-Orban, & Flint, 2011; Scheetz, 2015; Staudenmayer, Hsia, Mann, Spain, & Newgard, 2013) and a recent cost-effectiveness study provided startling projections of increased health care costs if the undertriage problem were to be fixed (Newgard et al., 2016). However, few studies have focused on the types and frequency of postinjury complications that arise during the initial hospitalization. This information is relevant because the presence of postinjury complications has been associated with increased mortality, especially among older

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patients (Richmond, Kauder, Strumpf, & Meredith, 2002). Earlier studies reported singular complications from various injuries (Hendrickson et al., 2016; Sperry et al., 2007; Wu et al., 2008), but only one study was found that compared a wide range (n = 13) of complications among older adults treated at TCs and NTCs (Ang et al., 2009). That study revealed the relative risk of complications to be 34% higher among TC patients.

Considering the persistent undertriage of older adults and the likely unsustainable costs of fixing the problem, it is important to compare clinical outcomes of TC and NTC patients to determine what, if any, differences exist. Doing so affords the trauma community opportunities to implement mitigation strategies to improve clinical outcomes. Therefore, the purpose of this study was to conduct a comparative analysis of complications among severely brain-injured older adults treated at TCs and NTCs. Because of previous conflicting findings regarding mortality, this study also compared TC versus NTC mortality for this population.

METHODS

This secondary analysis used data files extracted from the Healthcare Cost and Utilization Project (HCUP) New York State Inpatient Discharge (SID) data for 2014 (HCUP Databases, 2009). This database is a partnership between the Agency for Healthcare Research and Quality (AHRQ) and New York State. Inclusion criteria were age 55 years and older, primary diagnosis of brain injury, and initial admission to an acute care hospital (TC or NTC). Patients who were subsequently transferred to another hospital and patients whose brain injury was due to nontraumatic conditions were excluded. All patients who met the inclusion and exclusion criteria were included in the study. Records with missing data were excluded from analysis. This study was granted an exemption by the City University of New York Integrated Institutional Review Board.

Brain injuries included skull fracture with and without intracranial injury, brain contusion and laceration, concussion, subdural hemorrhage, epidural hemorrhage, subarachnoid hemorrhage, and other nonspecified intracranial bleeding. These were identified by *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis codes. Brain injury severity and New Injury Severity Scores (NISSs) were determined by mapping *ICD-9-CM* diagnoses to Abbreviated Injury Scale (AIS) 2005 Revision 2008 dictionary scores, using procedures described in a recent mapping validation study (Zonfrillo, Weaver, Gillich, Price, & Stitzel, 2015). The NISS is calculated by adding the squares of the three highest AIS scores (of *any* body region) and differs from the injury severity score (ISS), which is derived from the summed squares of the three highest AIS scores in *different* body regions (Kodadek et al., 2015). Correct triage, undertriage, and overtriage were determined by an NISS cut point of 15. The NISSs greater than 15 and admission to a TC and NISSs of 15 or less and admission to a NTC were considered correct triage. The NISSs greater than 15 and admission to a NTC were considered undertriage and NISSs less than 15 and admission to a TC were considered overtriage. This analysis focused on patients whose NISSs were greater than 15 and correctly triaged to a TC or undertriaged.

Categorical variables were created for complications using *ICD-9-CM* codes (Table 1). The selection of complications for analysis was culled from relevant literature (Ang et al., 2009; Hendrickson et al., 2016; Lenz, Franklin, & Cheadle, 2007); those generally known to occur following surgery, diagnostic, and therapeutic procedures; and government websites, including the Centers for Medicare & Medicaid Services (Centers for Medicare & Medicaid Services, 2015) and the Office of Inspector General (Office of Inspector General, 2010). Mortality was defined as inhospital death.

Data files were prepared and validated according to protocol specified by the AHRQ for the HCUP SID files (HCUP Databases, 2009). Data were then filtered by inclusion and exclusion criteria. The resulting data set was examined for distribution of variables of interest and missing data. Each patient record allowed for the inclusion of 25 diagnoses, all of which were examined for injuries and complications. A maximum of 29 AHRQ-designated comorbid (preexisting) conditions, unrelated to the primary diagnosis or reason for admission, are included for each patient record. These are a separate designation from diagnoses and complications.

A subgroup analysis of patients with NISSs greater than 15 was performed to examine complications, mortality, overall injury severity, and triage destination. Descriptive statistics, χ^2 analysis, independent-samples t tests, and univariate and multivariate logistic regression analyses were performed using IBM SPSS, version 25 (IBM Corporation, 2017). Two regression models were developed to identify predictors of complications and to determine the association of complications with mortality. Univariate logistic regression was performed to determine which plausible variables should be included in the multivariate logistic regression models. An α value of .1 or less was used for identifying variables for the regression model. The level of significance for all other analyses was α value of less than .05. Predictor variables for the multivariate logistic regression analyses were entered into the model using backward stepwise likelihood ratio method. Model fit was determined by the Hosmer–Lemeshow test.

RESULTS

A total of 7,138 patient records met inclusion criteria. The undertriage rate was 23.8% and the overtriage rate was

TABLE 1 Complications and Defining *ICD-9* Diagnosis Codes[a]

Complication	*ICD-9* Diagnosis Codes
Acute renal failure	584.5-584.9
Adult respiratory distress syndrome	518.51, 518.53, 518.82 cross-referenced with ventilator support
Aspiration pneumonitis	507.0, 507.1, 507.8
Catheter-associated urinary tract infection	996.64
Clostridium difficile infection	008.45
Central line–associated bloodstream infection	999.32
Methicillin-resistant staphylococcus aureus	041.12
Poor glycemic control (includes diabetic ketoacidosis Types 1 and 2, hyperosmolarity Types 1 and 2, and diabetic mellitus Types 1 and 2 with coma)	250.10-250.13, 250.20-250.23, 251.0, 249.10-249.11, 249.20-249.21
Postoperative—postprocedure complications (includes shock, hemorrhage, hematoma, accidental puncture or laceration, wound disruption, transfusion reaction, foreign body left during procedure, persistent postoperative fistula, surgical emphysema, other unspecified complications, nonhealing surgical wound, *not* wound infection)	998.00-998.99 (excludes 998.59)
Postoperative wound infection	998.59
Pressure ulcer, Stages III and IV	707.23, 707.24
Sepsis	995.91
Septicemia	038.00-038.99
Systemic inflammatory response syndrome	995.90-995.94
Thrombophlebitis and thromboembolism	451.00-451.99
Ventilator-associated pneumonia	997.31

Note. ICD-9, = *International Classification of Diseases, Ninth Revision.*
[a]*Not present on admission.*

65.0%. Seven hundred seven patients (9.9%) died during hospitalization. Within this population, 1,737 patients had NISSs greater than 15, with 1,594 admitted to NTCs and 143 admitted to TCs (Table 2). The subgroup analysis to examine complications focused on this group of severely and critically injured patients.

Patients With NISSs Greater Than 15

The median NISS for patients admitted to NTCs was 25 (interquartile range [IQR] = 18–27) compared with 22 (IQR = 18–27) for patients admitted to TCs, $p < .001$.

TABLE 2 Triage Status (*N* = 7115)

	NISS ≤15	NISS >15	Total
TC admit	266	143	409
NTC admit	5,112	1,594	6,706
Total	5,378	1,737	7,115

Note. NISS = *New Injury Severity Score; NTC* = *nontrauma center; TC* = *trauma center.*

Males outnumbered females ($n = 961$, 55.3% vs. $n = 776$, 44.7%). The NTC patients were older, with a mean age of 76.1 ($SD = 11.3$) years versus 70.9 ($SD = 11.5$) years (t [167.5] = 5.23, $p \leq .001$).

Nearly one-quarter of the patients experienced complications (22.9%), with 398 patients experiencing 693 complications (Table 3). Most complications were so infrequent that a comparative analysis of TC and NTC patients was not performed. For the two complications in which a statistically significant difference was found between TCs and NTCs (*Clostridium difficile* and aspiration pneumonitis), the effect size was negligible to small.

The most frequent complications were acute renal failure, adult respiratory distress syndrome (ARDS), aspiration pneumonitis, sepsis, septicemia, and systemic inflammatory response syndrome (SIRS). Multiple regression analysis, adjusted for covariates, revealed four variables predictive of complications: chronic renal failure, major operating room procedure, number of diagnoses, and number of procedures (Table 4). The strongest predictor was having undergone a major operative procedure.

TABLE 3 Incidence of Complications in Severely Injured Patients With Traumatic Brain Injuries (N = 1,737)[a]

Complications	Complications Frequency	Number (%) Treated at a NTC (n = 1,594)	Number (%) Treated at a TC (n = 143)	p	Effect Size (Phi and Cramer's V)
Acute renal failure	161	145 (9.1)	16 (11.2)	NS	–
ARDS	138	108 (6.8)	30 (21.0)	<.001	0.146
Aspiration pneumonitis	71	67 (4.2)	<10 (2.8)	NS	–
CAUTI[b]	<10	<10 (<0.01)	<10 (<1.0)	–	–
C-diff	23	18 (1.1)	<10 (3.5)	.044	0.018
CLABSI[b]	<10	<10 (<0.01)	<10 (<1.0)	–	–
MRSA[b]	<10	<10 (<0.01)	<10 (<1.0)	–	–
Poor glycemic control[b,c]	<10	<10 (<0.01)	<10 (<1.0)	–	–
Postoperative—postprocedure complications[b,d]	<10	<10 (<0.01)	<10 (1.4)	–	–
Postoperative wound infection[b]	<10	<10 (<0.01)	<10 (0.0)	–	–
Pressure ulcer, Stages III and IV[b]	<10	<10 (<0.01)	<10 (<1.0)	–	–
Sepsis	73	64 (4.0)	<10 (6.3)	NS	–
Septicemia	33	29 (1.8)	<10 (2.8)	NS	–
SIRS	93	82 (5.1)	11 (7.7)	NS	–
Thrombophlebitis and thromboembolism	37	31 (1.9)	<10 (4.2)	NS	–
VAP	20	18 (1.1)	<10 (1.4)	NS	–

Note. *ARDS = adult respiratory distress syndrome; CAUTI = catheter-associated urinary tract infection; C-diff =* Clostridium difficile *infection; CLABSI = central line–associated bloodstream infections; MRSA = methicillin-resistant staphylococcus aureus; NS = statistically nonsignificant; NTC = nontrauma center; SIRS = systemic inflammatory response syndrome; TC = trauma center; VAP = ventilator-associated pneumonia.*

[a] *Frequencies less than 10 are not reported.*

[b] *Cell counts too small to determine significance.*

[c] *Includes diabetic ketoacidosis Types 1 and 2, hyperosmolarity Types 1 and 2, and diabetic mellitus Types 1 and 2 with coma.*

[d] *Includes shock, hemorrhage, hematoma, accidental puncture or laceration, wound disruption, transfusion reaction, foreign body left during procedure, persistent postoperative fistula, surgical emphysema, other unspecified complications, nonhealing surgical wound,* excludes *wound infection.*

In this study, 73 patients developed sepsis and 93 developed SIRS. Among the patients who developed ARDS, 18 developed sepsis, 21 developed SIRS, and 5 died. Among patients who developed acute renal failure, 10 developed sepsis and 9 died. Thirteen acute renal failure patients also developed SIRS and 13 died.

Mortality among severely injured patients was 15.0%. Although nearly all of these deaths occurred among patients treated at NTCs, the largest proportion of deaths by level of care occurred in TCs (n = 29/143, 20.3%) compared with NTCs (n = 232/1,594, 14.6%), an insignificant difference (χ^2 [1, N = 1,594] =3.119, p = .077). Seven covariates predicted inhospital mortality: age, preexisting coagulopathy, number of procedures, acute renal failure, SIRS, ARDS, and subarachnoid hemorrhage. Patients with preexisting depression and hypertension and those who sustained subdural hematomas were less likely to die during hospitalization than patients without these conditions (Table 5).

TABLE 4 Logistic Regression Model Predicting Complications

	B	*SE*	Wald	*df*	Significance	Exp (*B*)	95% CI for Exp (*B*)	
							Lower CI	Upper CI
Preexisting chronic renal failure[a]	0.811	0.217	13.943	1	.000	2.251	1.470	3.447
Preexisting chronic pulmonary disease[a]	−0.514	0.215	5.692	1	.017	0.598	0.392	0.912
Number of chronic conditions	−0.155	0.035	19.303	1	.000	0.857	0.800	0.918
Number of diagnoses	0.183	0.018	99.845	1	.000	1.201	1.158	1.245
Number of procedures	0.113	0.019	33.681	1	.000	1.119	1.077	1.162
Major operating room procedure (yes)[a]	0.854	0.171	24.894	1	.000	2.349	1.679	3.285

Note. *CI = confidence interval.*

[a]The reference is the absence of the condition.

DISCUSSION

Nearly one-quarter of the severely and critically injured patients experienced one or more complications. In many cases, cell counts were too small to test for statistical significance of the difference in TC versus NTC. The number of patients who developed catheter-associated urinary tract infection, central line–associated bloodstream infections, *C. difficile* (C-diff), and ventilator-associated pneumonia (also known as VAE) were very small, likely owing to the widespread use of evidence-based care bundles to prevent these infections. The incidence of poor glycemic control was also very low and was not associated with

TABLE 5 Logistic Regression Model Predicting Inhospital Mortality

	B	*SE*	Wald	*df*	Significance	Exp (*B*)	95% CI for Exp (*B*)	
							Lower CI	Upper CI
Age in years at admission	0.030	0.007	19.515	1	.000	1.031	1.017	1.045
Preexisting coagulopathy (yes)[a]	0.561	0.224	6.280	1	.012	1.753	1.130	2.719
Preexisting depression (yes)[a]	−0.984	0.346	8.113	1	.004	0.374	0.190	0.736
Preexisting hypertension (yes)[a]	−0.285	0.151	3.572	1	.059	0.752	0.560	1.011
Maximum head injury			21.861	4	.000			
Max AIS 2 (moderate)	−0.982	1.166	0.708	1	.400	0.375	0.038	3.685
Max AIS 3 (serious)	0.244	1.115	0.048	1	.827	1.276	0.144	11.341
Max AIS 4 (severe)	1.402	1.163	1.453	1	.228	4.064	0.416	39.721
Max AIS 5 (critical)	0.306	1.115	0.075	1	.784	1.357	0.153	12.079
Number of procedures	0.116	0.019	35.966	1	.000	1.122	1.081	1.166
Complications (number per patient)	−0.654	0.227	8.290	1	.004	0.520	0.333	0.811
Acute renal failure (yes)[a]	1.136	0.317	12.826	1	.000	3.114	1.672	5.798
SIRS (yes)[a]	1.401	0.521	7.238	1	.007	4.058	1.463	11.258
ARDS (yes)[a]	1.157	0.328	12.474	1	.000	3.179	1.673	6.041
Subarachnoid bleed (yes)[a]	0.981	0.323	9.198	1	.002	2.667	1.415	5.029
Subdural bleed (yes)[a]	−1.187	0.338	12.303	1	.000	0.305	0.157	0.592
Constant	−4.705	1.249	14.182	1	.000	0.009		

Note. *ARDS = adult respiratory distress syndrome; CI = confidence interval; Max AIS = maximum abbreviated injury score (highest single injury severity score); SIRS = systemic inflammatory response syndrome.*

[a]The reference is the absence of the condition.

preexisting diabetes mellitus or postoperative infections. Methicillin-resistant staphylococcus aureus, postoperative wound infections, other postoperative complications, pressure injury, and thromboembolism were present in less than 1% of the population.

The most frequent complication was renal failure, which was not surprising. Renal function declines with aging because of hemodynamic and structural changes in the kidney (Scheetz, 2011). Added to this is the treatment, often aggressive, to manage injuries. Drugs and fluids administered during the acute injury phase add stress to already declining renal function and may also affect respiratory function (Hendrickson et al., 2016). The second most frequent complication was ARDS. Anatomic and functional changes associated with aging occur in the respiratory system, predisposing the older injured adult to ARDS (Scheetz, 2011). Previous research in severely brain-injured patients demonstrated that ARDS was more prevalent among males (Hendrickson et al., 2016). That held true in this study, too. Of the 138 patients who developed ARDS, 98 were male.

Undertriage remains an important concern and, as this study demonstrated, only 8.2% of severely and critically injured patients were treated at a TC. Given the persistence of undertriage of injured older adults and concerns about the costs of correcting the problem (if that is even possible), undertriaged patients do not appear to be at an increased risk of developing complications during the acute injury period. Continued strategies to implement evidence-based patient care bundles should be maintained. Continued use of evidence-based sepsis protocols should be maintained where they have already been implemented. Hospitals that have low adherence to these protocols must identify and strengthen weaknesses in early detection and prompt goal-directed treatment of sepsis to minimize the risk of progression to SIRS and multiple organ failure.

As expected, mortality was considerably higher among patients with severe and critical injuries. Consistent with previous research (Miller et al., 2017), aging was (weakly) associated with a higher likelihood of dying (3% more likely with each advancing year of age). Patients with preexisting coagulopathy had a 75% greater chance of dying than those without the condition. Many older adults take anticoagulant and antiplatelet drugs to manage various medical conditions and, therefore, may have therapeutically high international normalized ratio. However, the elevated international normalized ratio caused by these drugs have been associated with an increased risk of death in brain-injured patients (Pieracci, Eachempati, Shou, Hydo, & Barie, 2007; Smith & Weeks, 2013). Neither the overall injury severity score (NISS) nor any of the three highest single injury scores predicted mortality. However, the presence of subarachnoid hemorrhage was a strong predictor of mortality. Patients with a subarachnoid bleed were more than two and one-half times as likely to die during hospitalization than those who did not have this type of injury. Patients who had acute renal failure or ARDS were more than three times as likely to die and those with SIRS were more than four times as likely to die.

Limitations

This study has several limitations. The use of *ICD-9-CM* diagnoses to identify complications may have underestimated their presence. Also, the *ICD-9-CM* clinical manual does not code diffuse axonal injury, a potentially devastating injury. The mapping program to derive NISS scores from *ICD-9-CM* diagnoses is relatively new and would benefit from further validity testing. However, this is the best method available to calculate the NISS and the ISS as previous software to convert *ICD-9-CM* diagnoses is outdated. Generalizability of the findings is limited as New York is not representative of the United States. The data used in this study were collected from all acute care non-government hospitals in the state. New York is large and geographically diverse, and patients are transported from urban, suburban, and rural/remote areas for injury care. Finally, the sample size of the subgroup (NISS ≥16) was too small to detect statistically significant differences in the incidence of complications in TC and NTC patients, given the low incidence of many complications.

CONCLUSION

The incidence of complications in this older adult brain-injured population was modest. However, the complications that were most prevalent carry a large morbidity burden and high mortality risk. Brain injuries are common among older adults. Clinicians must maintain vigilance for signs of evolving brain injury, especially in patients admitted to NTCs. Strategies for early identification and prompt treatment of sepsis and SIRS are needed in this population. Future studies should focus on a geographically diverse population. In addition, studies are needed that compare short- and long-term functional capacity and examination of the Brain Injury Guidelines (Joseph et al., 2014) for brain-injured older adults admitted to NTCs.

KEY POINTS

- More than 10 times as many severely and critically injured patients were treated at nontrauma center hospitals than trauma centers.
- The incidence of complications was modest and comparable for nontrauma center hospitals and trauma centers; however, the most prevalent complications have high mortality.
- Mortality was slightly higher among trauma center patients, but the difference was not statistically significant.

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