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Risk Factors for Unplanned ICU Readmission Among Trauma Patients: Age Matters

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OBJECTIVES: To determine the frequency of unplanned ICU readmission (UIR) among adult (18–64) and elderly (65+) trauma patients and to compare the risk factors for UIR and its clinical impact between age groups.

DESIGN: Retrospective cohort study using clinical data from a statewide trauma registry.

SETTING: All accredited trauma centers in Pennsylvania.

PATIENTS: Consecutive adult and elderly trauma patients requiring admission from the emergency department to the ICU between 2012 and 2017.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Among the 48,340 included in the analysis, 49.5% were elderly and 3.8% experienced UIR. UIR was 1.7 times more likely among elderly patients and was associated with increased hospital length of stay in both age groups. UIR was associated with an absolute increased risk of hospital mortality of 6.1% among adult patients and 16.9% among elderly patients experiencing UIR. In addition to overall injury severity and burden of preexisting medical conditions, specific risk factors for UIR were identified in each age group. In adult but not elderly patients, UIR was significantly associated with history of stroke, peptic ulcer disease, cirrhosis, diabetes, and malignancy. In elderly but not adult patients, UIR was also significantly associated with chronic kidney disease.

CONCLUSIONS: UIR is associated with worse clinical outcomes in both adult and elderly trauma patients, but risk factors and the magnitude of impact differ between age groups. Interventions to mitigate the risk of UIR that take into account patients' age group and specific risk factors may improve outcomes.

KEY WORDS: elderly; intensive care unit; quality improvement; trauma; unplanned intensive care unit readmission

The American population is aging, with the elderly (≥65 yr) constituting 16% of the population, with a 34% increase in the past 10 years (1). Concurrently, the incidence of injury among the elderly has been rising (2). Elderly trauma patients, and especially those with preexisting medical conditions and severe anatomic injuries are at increased risk of adverse outcomes (3). Monitoring and resuscitation in an ICU has been shown to improve survival in elderly trauma patients (4). Nevertheless, elderly patients remain an underserved population in trauma care, with both disparities in access and provider treatment bias (5, 6).

Unplanned ICU readmissions (UIR) are associated with increased hospital length of stay (LOS) and mortality rates among hospitalized patients in general (7, 8) and trauma patients in particular (9, 10). As a result, UIR has been recognized as an important indicator of ICU quality of care, adopted by both the Society of Critical Care Medicine (11) and the American College of Surgeons Trauma Quality Improvement Program (ACS TQIP) (12). A number

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KEY POINTS

- **Question:** Are the incidence, clinical significance, and risk factors of UIR different between adult (18-64) and elderly (65+) trauma patients?
- **Findings:** UIR was 1.7x more common among elderly patients. Mortality was 8.6x higher among patients who experienced UIR, with rates of 19.8% among elderly and 6.7% among adult patients who experienced UIR. Associations between pre-existing medical conditions and UIR differed markedly between adult and elderly patients.
- **Meanings:** UIR is more common among elderly trauma patients and is associated with significant mortality. Averting UIR is an important trauma quality improvement target, and strategies should differ by age group.

of risk factors for UIR have been identified among trauma patients, including age, injury severity, traumatic brain injury, and chronic cardiac and renal disease (13). Although increased age is recognized as a risk factor for UIR, there is a paucity of published data about how risk factors for and clinical significance of UIR differ between elderly and adult trauma patients.

To address this knowledge gap, we sought to determine the occurrence rate of UIR among adult (18–64 yr) and elderly (≥65 yr) trauma patients, to compare the prevalence and clinical significance of potential risk factors for UIR between age groups, and to compare the impact of UIR on the clinical outcomes between age groups. Identifying age-specific risk factors for UIR and better understanding its clinical significance may inform improved targeted monitoring and management strategies to prevent adverse outcomes. This study is unique among analyses of UIR because it uses a relatively large patient sample from a statewide trauma registry to compare risk factors for UIR and its clinical significance between adult and elderly age groups. Using statewide data allows us to achieve greater generalizability than prior institution-level analyses.

MATERIALS AND METHODS

This retrospective cohort analysis was performed using data from the Pennsylvania Trauma Outcomes Study (PTOS) database, which compiles deidentified clinical data on all trauma admissions at accredited trauma centers statewide and thereby provides a representative case mix of trauma patients (14). Inclusion and exclusion criteria of the PTOS database, as well as its definitions of preexisting medical conditions, are available online (15).

Data were extracted for all trauma patients greater than or equal to 18 years old included in the PTOS database who presented between January 1, 2012, and December 31, 2017. For this analysis, we included all patients who were initially admitted to an ICU and then downgraded to a lower level of care in the hospital. Extracted data elements included age, gender, preexisting medical conditions, injury mechanism, triage vital signs, anatomic injury severity quantified as Abbreviated Injury Scores (AIS) for each body region and Injury Severity Score (ISS), disposition from the emergency department (ED), occurrence rate of unplanned ICU admission, hospital mortality, and hospital LOS. Preexisting medical conditions were used to calculate Charlson Comorbidity Index (CCI), a reliable and well-validated predictor of mortality in inpatients and the critically ill that is associated with increased risk of mortality in trauma patients (16, 17). Connective tissue disease and hemiplegia, which are included in CCI, are not captured in the PTOS database and so were omitted from this analysis. We determined this sample size to be adequate to allow for detection of a 20% difference in UIR rates between age groups with an anticipated occurrence rate of 3%, with $\alpha = 0.05$ and $\beta = 0.80$, and to allow for subgroup comparisons based on preexisting medical conditions.

All data were stored in a spreadsheet using Microsoft Excel (Microsoft, Redmond, WA) and analyzed using Stata 13.1 (StataCorp, College Station, TX). AIS was dichotomized as severe (≥3) and not severe (≤2) for analysis. Categorical variables were described with counts and percentages. The continuous variables ISS, Trauma and Injury Severity Score (TRISS), and CCI were not normally distributed, and so were described with medians and interquartile ranges. Bivariable tests of association with elderly age group and UIR were performed with χ^2 tests for categorical variables and Wilcoxon rank-sum tests for continuous variables with statistical significance defined when $p < 0.05$. The relative risk (RR) of UIR associated with each potential risk factor was calculated for adult and elderly patients and compared using 95% CIs. Multivariable logistic regression models were used with a backward stepwise elimination strategy to identify risk factors independently associated with UIR in the cohorts of adult and elderly patients. Models initially incorporated all of the preexisting conditions included in CCI and severe injuries to each body region. With each iteration, the least significant variable was removed until only those with $p < 0.20$ remained. The final multivariable logistic regression models for adult and elderly patients were compared descriptively.

The study protocol (831641—Unplanned ICU Admissions among Trauma Patients: Age-Related Risk Factors and Associated Poor Outcomes) was reviewed by the University of Pennsylvania Institutional Review Board (IRB) 7 on September 12, 2018, and determined to meet eligibility criteria for IRB review exemption, and a waiver of the Health Insurance Portability and Accountability Act authorization requirement was granted. Study procedures were followed in accordance with the ethical standards of the responsible IRB and with the Helsinki Declaration of 1975.

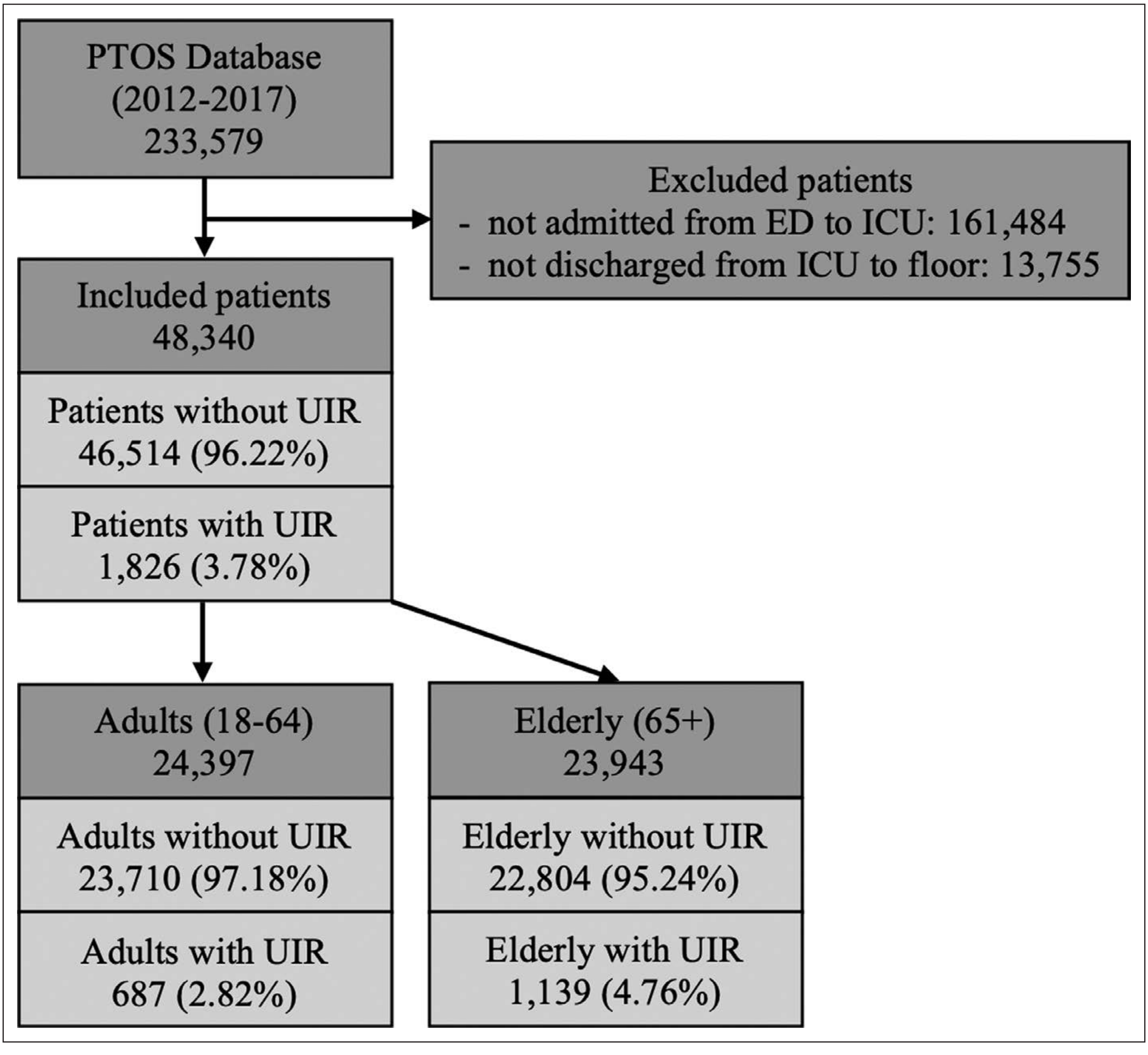

Figure 1. Patient inclusion/exclusion flowchart. Flowchart of patient inclusions and exclusions used to derive the final *n* of 48,340 adult and elderly trauma patients admitted primarily to an ICU. ED = emergency department, PTOS = Pennsylvania Trauma Outcomes Study, UIR = unplanned ICU readmission.

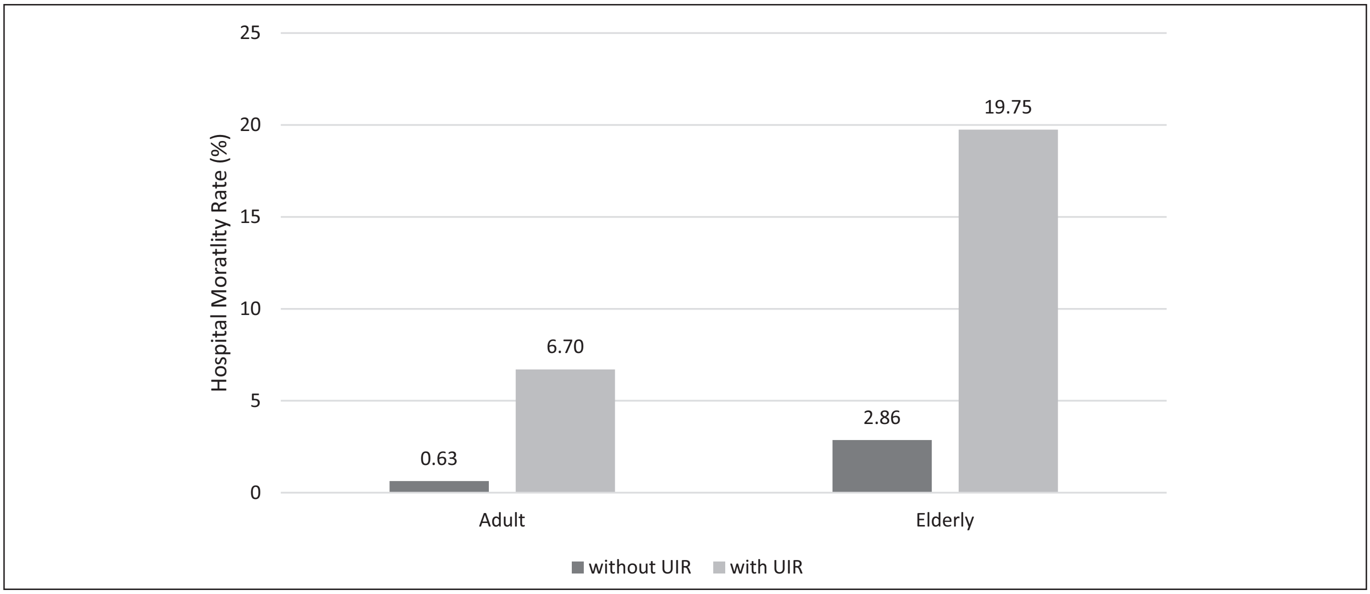

Figure 2. Hospital mortality rates among adult (18–64 yr) and elderly (≥65 yr) trauma patients with and without unplanned ICU readmission. UIR = unplanned ICU readmission.

RESULTS

Over the 6-year study period, 223,579 patients over 18 years old were registered in the PTOS database (**Fig. 1**). Of those, 161,484 were excluded because they were not directly admitted from the ED to the ICU, and 13,755 were excluded because they were not transferred from the ICU to a lower level of care. The remaining 48,340 patients were included in this analysis. Of those, 24,397 were adult (50.47%), and 23,943 were elderly (49.53%). UIR occurred in 3.78% of patients; elderly patients were

TABLE 1.
Clinical Features and Outcomes of Adult and Elderly Trauma Patients Initially Admitted to an ICU

Characteristics	Total (*n* = 48,340)	Adult (*n* = 24,397)	Elderly (*n* = 23,943)	*p*
Demographic characteristics				
Female sex, *n* (%)	19,334 (40.00)	6,824 (27.97)	12,510 (52.25)	< 0.001
Charlson Comorbidity Index, median (IQR)	3 (0–5)	0 (0–2)	4 (4–5)	< 0.001
Injury mechanism				
Blunt, *n* (%)	46,564 (96.33)	22,746 (93.23)	23,818 (99.48)	< 0.001
Penetrating, *n* (%)	1,606 (3.32)	1,524 (6.25)	82 (0.34)	< 0.001
Burn, *n* (%)	170 (0.35)	127 (0.52)	43 (0.18)	< 0.001
Injury severity				
Injury Severity Score, median (IQR)	12 (9,17)	14 (9,19)	10 (9,17)	< 0.001
Trauma and Injury Severity Score, median (IQR)	0.965 (0.939–0.983)	0.983 (0.952–0.993)	0.959 (0.934–0.968)	< 0.001
Clinical outcomes				
Unplanned ICU readmission, *n* (%)	1,826 (3.78)	687 (2.82)	1,139 (4.76)	< 0.001
Hospital mortality, *n* (%)	1,073 (2.22)	196 (0.80)	877 (3.66)	< 0.001
Hospital length of stay among survivors, median (IQR)	5 (3–9)	5 (3–10)	5 (3–8)	< 0.001

IQR = interquartile range.

TABLE 2.
Prevalence of Potential Risk Factors for Unplanned ICU Readmission Among Adult and Elderly Trauma Patients

Potential Risk Factor	All, *n* (%)	Adult, *n* (%)	Elderly, *n* (%)	Relative Risk (95% CI)	*p*
Preexisting medical conditions					
Myocardial infarction	1,637 (3.39)	377 (1.55)	1,260 (5.26)	3.41 (3.04–3.82)	< 0.001
Congestive heart failure	3,325 (6.88)	412 (1.69)	2,913 (12.17)	7.20 (6.51–7.97)	< 0.001
Peripheral vascular disease	976 (2.02)	139 (0.57)	837 (3.50)	6.14 (5.13–7.34)	< 0.001
Stroke	3,303 (6.83)	566 (2.32)	2,737 (11.43)	4.93 (4.51–5.38)	< 0.001
Dementia	4,418 (9.14)	123 (0.50)	4,295 (17.94)	35.58 (29.77–42.53)	< 0.001
Chronic obstructive pulmonary disease	6,501 (13.45)	2,608 (10.69)	3,893 (16.26)	1.52 (1.45–1.59)	< 0.001
Peptic ulcer disease	427 (0.88)	133 (0.55)	294 (1.23)	2.25 (1.84–2.76)	< 0.001
Cirrhosis	902 (1.87)	543 (2.23)	359 (1.50)	0.67 (0.59–0.77)	< 0.001
Diabetes mellitus	9,305 (19.25)	2,682 (10.99)	6,623 (27.66)	2.52 (2.41–2.62)	< 0.001
Chronic kidney disease	1,327 (2.75)	370 (1.52)	957 (4.00)	2.64 (2.34–2.97)	< 0.001
Malignancy	980 (2.03)	201 (0.82)	779 (3.25)	3.95 (3.39–4.61)	< 0.001
AIDS	273 (0.56)	248 (1.02)	25 (0.10)	0.10 (0.07–0.15)	< 0.001
Severely injured body regions					
Head	20,411 (42.22)	9,278 (38.03)	11,133 (46.50)	1.22 (1.20–1.25)	< 0.001
Face	255 (0.53)	205 (0.84)	50 (0.21)	0.25 (0.18–0.34)	< 0.001
Neck	456 (0.74)	281 (1.15)	75 (0.31)	0.27 (0.21–0.35)	< 0.001
Chest	11,635 (24.07)	6,786 (27.81)	4,849 (20.25)	0.73 (0.70–0.75)	< 0.001
Abdomen	2,246 (4.65)	1,890 (7.75)	356 (1.49)	0.19 (0.17–0.21)	< 0.001
Spine	3,881 (8.03)	1,836 (7.53)	2,045 (8.54)	1.13 (1.07–1.21)	< 0.001
Upper extremity	211 (0.44)	181 (0.74)	30 (0.13)	0.17 (0.11–0.25)	< 0.001
Lower extremity	3,228 (6.68)	1,996 (8.18)	1,232 (5.15)	0.63 (0.59–0.67)	< 0.001

significantly more likely than adult patients to experience UIR (4.76% vs 2.82%; RR, 1.69; 95% CI, 1.54–1.85).

Median hospital LOS was 5 days, which was similar for adult and elderly patients. Patients experiencing UIR had significantly longer hospital LOS than those who did not (median 15 vs 5 d; $p < 0.001$). Adult patients experiencing UIR had significantly longer hospital LOS than elderly patients (median, 17 vs 14 d; $p < 0.001$). The overall hospital mortality rate was 2.22%, which was significantly higher among elderly patients than adult patients (3.66% vs 0.80%; RR, 4.56; $p < 0.001$). The hospital mortality rate was significantly higher among patients experiencing UIR than those who did not experience UIR (14.84% vs 1.72%; RR, 8.61; $p < 0.001$) (**Fig. 2**). The RR of hospital mortality associated with UIR was 10.58 among adult patients and 6.91 among elderly patient. Notably, the absolute risk of hospital mortality was 6.06% among adult patients and 16.90% among elderly patients experiencing UIR compared with their others in their age group.

The clinical profiles and injury characteristics of adult and elderly patients differed significantly (**Table 1**). Elderly patients were more likely to be female and, on average, had a higher burden of preexisting medical conditions quantified by CCI. Elderly patients were less likely to have penetrating or burn injury mechanisms and on average had lower injury severity by ISS (which only includes anatomic data) but higher injury severity by TRISS (which also includes age, injury mechanism, and physiologic data). Elderly patients were more likely to have severe injuries to the head and spine, but less likely to have severe injuries to the neck, chest, abdomen, and upper and lower extremities. Elderly patients were significantly more likely to have

TABLE 3.

Unadjusted Analysis Comparing Relative Risk of Unplanned ICU Readmission Associated With Potential Risk Factors in Cohorts of Adult and Elderly Patients

Potential Risk Factor	RR of UIR Among All Patients	RR of UIR Among Adult Patients	RR of UIR Among Elderly Patients
Preexisting medical condition			
Myocardial infarction	**1.29 (1.04–1.61)**	*1.23 (0.72–2.11)*	*1.11 (0.87–1.41)*
Congestive heart failure	**1.61 (1.39–1.86)**	**2.11 (1.42–3.13)**	**1.27 (1.08–1.48)**
Peripheral vascular disease	**1.99 (1.59–2.50)**	**2.58 (1.31–4.71)**	**1.59 (1.24–2.03)**
Stroke	**1.27 (1.09–1.50)**	*1.46 (0.97–2.19)*	*1.02 (0.86–1.22)*
Dementia	*0.99 (0.85–1.16)*	*1.45 (0.61–3.42)*	*0.75 (0.64–0.89)*
Chronic obstructive pulmonary disease	**1.52 (1.35–1.70)**	**1.28 (1.03–1.58)**	**1.50 (1.31–1.72)**
Peptic ulcer disease	*1.31 (0.86–1.99)*	**2.15 (1.09–4.23)**	*0.93 (0.54–1.58)*
Cirrhosis	**1.79 (1.39–2.29)**	**2.43 (1.76–3.36)**	*1.41 (0.96–2.09)*
Diabetes mellitus	**1.36 (1.23–1.51)**	**1.40 (1.13–1.72)**	**1.14 (1.01–1.29)**
Chronic kidney disease	**2.18 (1.81–2.64)**	**1.75 (1.11–2.76)**	**2.01 (1.63–2.48)**
Malignancy	*1.22 (0.91–1.63)*	1.96 (1.10–3.50)	*0.91 (0.66–1.28)*
AIDS	*0.87 (0.46–1.66)*	*1.15 (0.58–2.28)*	*0.84 (0.12–5.74)*
Severely injured body region			
Head	*1.04 (0.95–1.14)*	*1.16 (0.99–1.34)*	*0.91 (0.81–1.02)*
Face	*1.25 (0.72–2.17)*	*1.39 (0.70–2.75)*	*1.68 (0.66–4.32)*
Neck	*0.59 (0.30–1.18)*	*0.50 (0.19–1.33)*	*1.12 (0.43–2.92)*
Chest	**1.61 (1.46–1.77)**	**1.96 (1.69–2.28)**	**1.54 (1.36–1.74)**
Abdomen	*1,19 (0.98–1.45)*	**1.31 (1.02–1.67)**	**1.92 (1.37–2.68)**
Spine	**1.25 (1.07–1.45)**	**1.48 (1.17–1.88)**	*1.09 (0.89–1.32)*
Upper extremity	*1.00 (0.51–1.98)*	*1.18 (0.53–2.60)*	*1.40 (0.37–5.36)*
Lower extremity	**1.33 (1.14–1.56)**	**1.46 (1.16–1.84)**	**1.39 (1.12–1.74)**

RR = relative risk, UIR = unplanned ICU readmission.
Results in bold have 95% CIs that do not 1, and thus are considered to represent statistically significant associations.

all of the preexisting medical conditions included in the CCI except for cirrhosis and AIDS, which were significantly more prevalent in adult patients (**Table 2**).

In a multivariable logistic regression model including injury severity quantified by TRISS and burden of preexisting medical conditions quantified by CCI, both TRISS (odds ratio [OR], 0.25; 95% CI, 0.18–0.35) and CCI (OR, 1.14; 95% CI, 1.12–1.16) were positively associated with increased odds of UIR.

In bivariable analyses, the clinical significance of individual preexisting medical conditions and severely injured body regions in predicting UIR differed between adult and elderly patients (**Table 3**). In multivariable logistic regression models, both the clinical and statistical significance of preexisting conditions and severely injured body regions differed markedly between adult and elderly patients (**Table 4**). In both age groups, UIR was significantly associated with congestive heart failure (CHF), peripheral vascular disease (PVD), and chronic obstructive pulmonary disease (COPD), as well as severe injuries to the head, chest, abdomen and lower extremity. In adult but not elderly patients, UIR was significantly associated with history of stroke, peptic ulcer disease (PUD), cirrhosis, diabetes and malignancy, and negatively associated with severe injuries to the neck. In elderly but not adult patients, UIR was significantly associated with chronic kidney disease (CKD) and negatively associated with dementia.

TABLE 4.
Final Multivariable Logistic Regression Models of Risk Factors Associated With Unplanned ICU Readmission Among Adult and Elderly Trauma Patients

Risk Factor	Parameter Estimate (95% CI)	OR (95% CI)	$p > z$
Adult trauma patients (18–64 yr), pseudo $R^2 = 0.027$			
Preexisting medical conditions			
CHF	0.567 (0.123–1.011)	1.76 (1.13–2.75)	0.012
PVD	0.683 (0.012–1.354)	1.98 (1.01–3.87)	0.046
Stroke	0.326 (–0.111 to 0.762)	1.38 (0.89–2.14)	0.144
COPD	0.157 (–0.073 to 0.388)	1.17 (0.93–1.47)	0.181
Peptic ulcer disease	0.633 (–0.103 to 1.368)	1.88 (0.90–3.93)	0.092
Cirrhosis	0.853 (0.500–1.209)	2.35 (1.65–3.35)	< 0.001
Diabetes mellitus	0.237 (0.012–0.463)	1.27 (1.01–1.59)	0.039
Malignancy	0.620 (0.001–1.238)	1.86 (1.00–3.45)	0.050
Severely injured body regions			
Head	0.348 (0.188–0.509)	1.42 (1.21–1.66)	< 0.001
Neck	–0.776 (–1.770 to 0.219)	0.46 (0.17–1.24)	0.126
Chest	0.754 (0.595–0.913)	2.12 (1.81–2.49)	< 0.001
Abdomen	0.263 (0.000–0.526)	1.30 (1.00–1.69)	0.050
Spine	0.587 (0.336–0.838)	1.80 (1.40–2.31)	< 0.001
Lower extremity	0.392 (0.148–0.635)	1.48 (1.16–1.89)	0.002
Intercept	–4.170 (–4.318 to –4.022)	0.02 (0.01–0.02)	< 0.001
Elderly trauma patients (≥ 65 yr), pseudo $R^2 = 0.016$			
Preexisting medical conditions			
CHF	0.139 (–0.035 to 0.312)	1.15 (0.97–1.37)	0.117
PVD	0.376 (0.106–0.646)	1.46 (1.11–1.91)	0.006
Dementia	–0.243 (–0.414 to –0.071)	0.78 (0.66–0.93)	0.005
COPD	0.381 (0.235–0.527)	1.46 (1.26–1.69)	< 0.001
Chronic kidney disease	0.679 (0.446–0.912)	1.97 (1.56–2.49)	< 0.001
Severely injured body regions			
Head	0.110 (–0.022–0.242)	1.12 (0.98–1.27)	0.103
Chest	0.479 (0.335–0.622)	1.61 (1.40–1.86)	< 0.001
Abdomen	0.620 (0.246–0.993)	1.86 (1.28–2.70)	0.001
Spine	0.200 (–0.013 to 0.412)	1.22 (0.99–1.51)	0.065
Lower extremity	0.346 (0.108–0.583)	1.41 (1.11–1.79)	0.004
Intercept	–3.318 (–3.439 to –3.197)	0.04 (0.03–0.04)	< 0.001

CHF = congestive heart failure, COPD = chronic obstructive pulmonary disease, OR = odds ratio, PVD = peripheral vascular disease. Risk factors in bold are those for which there was a significant association with unplanned ICU readmission in one age group but not the other after adjusting for covariables. Of note, even when a significant association between a risk factor and unplanned ICU readmission existed in both age groups, the magnitude of that association often differed notably between the age groups.

DISCUSSION

This analysis adds to a growing body of literature about UIR and mortality among trauma patients. Several previous analyses have reported a significant increase in mortality associated with UIR among trauma patients (9, 10). As such, the ACS TQIP recognizes UIR as an important quality benchmark, and a clear understanding of risk factors for UIR is crucial to improving clinical outcomes in trauma patients (13, 18).

Numerous studies have documented that elderly patients have an increased risk of overall complications and death after injury (3, 19, 20). This increased risk for poor outcomes makes the elderly trauma population an important target for quality improvement and risk mitigation efforts. The increased risk for poor outcomes in elderly trauma patients is generally attributed to a combination of decreased physiologic reserve and an increased burden of preexisting medical conditions (19). In particular, Min et al (21) demonstrated that increased age and the presence of cirrhosis, coagulopathy, COPD, ischemic heart disease, and diabetes cumulatively increased the risk of death in trauma patients. More recently, researchers have identified other risk factors for poor outcomes in elderly patients such as frailty (22), malnutrition (23), and cognitive impairment (24), which may be missed without proactive screening. In addition, because vital sign abnormalities are not sensitive for severe injury in elderly trauma patients, undertriage has historically contributed to increased mortality in that population (20). It is likely that the same phenomenon results in harmful delays in recognition of complications and clinical deterioration.

In this cohort of adult and elderly trauma patients, UIR occurred in 3.8% of patients and was associated with longer hospital LOS and increased risk of hospital mortality in both age groups. Hospital mortality among those who experienced UIR was 6.7% for adult patients and 19.8% for elderly patients, suggesting a high rate of failure to rescue among elderly trauma patients. In addition to overall injury severity and burden of preexisting medical conditions, individual preexisting medical conditions and severely injured body regions were significantly associated with increased odds of UIR in multivariable logistic regression models. However, the prevalence and clinical significance of these risk factors differed markedly between adult and elderly trauma patients. History of stroke, cirrhosis, diabetes, PUD, and malignancy were strongly associated with UIR in adult but not elderly patients, whereas CKD was strongly associated with UIR in elderly but not adult patients. History of dementia was associated with decreased risk of UIR in elderly but not adult patients, which suggests that elderly patients with dementia may be more careful monitored following ICU downgrade. CHF, PVD, and COPD were associated with UIR in both age groups, although the strength of association was much higher for CHF and PVD among adult patients.

These findings are consistent with several previous analyses of UIR among medical and surgical patients, which identified increased age, illness severity, overall number of preexisting medical conditions, and specific preexisting medical conditions including cardiovascular, gastrointestinal, and renal diseases as independent predictors of UIR (25–28). However, these analyses were not specific to the trauma population and did not compare risk factors for UIR between younger and older patients. A previous study in the trauma population demonstrated that elderly trauma patients had particularly high risk of poor clinical outcomes following UIR despite relatively low injury severity, although that analysis was underpowered for a detailed exploration of risk factors for UIR (29). Several studies have reported that the most commonly reasons for UIR among trauma and surgical patients were respiratory, cardiovascular, and bleeding events (9, 25, 29).

A number of strategies have been proposed to decrease the rate of UIR including extending ICU LOS, aggressive respiratory therapy for patients transferred out of the ICU, improving handoff tools, and implementing critical care transition and outreach teams (13). However, data about the effectiveness of these interventions are conflicting, suggesting that further refinement may be necessary to ensure benefit (30, 31). The differences between adult and elderly trauma patients who experience UIR identified here may help to target age-specific UIR prevention strategies, such as special attention to patients with worsening renal function and avoiding centrally acting medications that may accumulate metabolites in patients with impaired hepatic and renal function. When available, consultation with a geriatrician has also been associated with reduced risk of UIR among elderly trauma patients (32, 33). Routine consultation with a geriatrician when available upon transfer from the ICU should be considered for high-risk elderly patients to assist in mitigating the risk of UIR.

The optimal metric to quantify the burden of preexisting medical conditions among trauma patients is a topic of ongoing research and debate, and the limitations of CCI in trauma patients are well described

(34–36). This analysis demonstrated that several preexisting medical conditions included in CCI were not associated with risk of UIR in either the adult or elderly patient cohorts. In particular, AIDS, which is heavily weighted in CCI, was not associated with risk of UIR in either age group. However, at this time, there is not a well-validated alternative available.

As a retrospective analysis of statewide trauma registry data, this study has several important strengths and limitations. Compared with prior studies of UIR among trauma patients, this study is novel in providing insights into how the risk factors for UIR and its clinical significance differ between adult and elderly trauma patients. Because we used data from over 48,000 trauma patients care for across the state of Pennsylvania over 5 years, we were able to explore numerous associations that smaller cohorts would be underpowered to detect. By using statewide data, we were also able to incorporate a diverse patient population from both urban and rural trauma centers, providing greater generalizability than previous institutional studies on the topic that could be biased by local practice patterns and resource availability. However, we were limited by the data elements captured by the PTOS database. In particular, we were unable to determine the specific reasons for UIR or causes of death, or to differentiate between processes of care during the initial ICU admission and the UIR. In the future, we would recommend inclusion of reasons for UIR in trauma registries for quality improvement purposes. Furthermore, we were unable to account for current practice patterns regarding risk stratification for UIR. For example, the finding that dementia appears protective against UIR in elderly patients appears counterintuitive—this may be because some providers have a lower threshold to admit patients with dementia and relatively mild injuries to ICUs, or because those patients are more likely to be more closely monitored on ICU downgrade. Finally, despite our large study population, some potential risk factors for UIR had low prevalence, and reported differences in clinical significance may reflect a lack of statistical power or random variation.

CONCLUSIONS

UIR is associated with significantly increased risk of hospital mortality and increased hospital LOS among both adult and elderly trauma patients, with an especially high risk of hospital mortality among elderly patients who experience UIR. In addition to overall injury severity and burden of preexisting medical conditions, a number of specific preexisting medical conditions and severely injured body regions are associated with increased risk of UIR, although the clinical significance of these risk factors differs between age groups. Interventions to mitigate the risk of UIR that take into account patients' age group and specific risk factors may improve outcomes.

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REFERENCES

1. United States Census Bureau: National Population by Characteristics: 2010-2019. 2020. Available at: https://www.census.gov/data/datasets/time-series/demo/popest/2010s-national-detail.html. Accessed September 21, 2020
2. Ciesla DJ, Pracht EE, Tepas JJ 3rd, et al: The injured elderly: A rising tide. *Surgery* 2013; 154:291–298
3. Calland JF, Ingraham AM, Martin N, et al; Eastern Association for the Surgery of Trauma: Evaluation and management of geriatric trauma: An Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg* 2012; 73:S345–S350
4. Demetriades D, Karaiskakis M, Velmahos G, et al: Effect on outcome of early intensive management of geriatric trauma patients. *Br J Surg* 2002; 89:1319–1322
5. Mackersie RC: For the care of the underserved. *J Trauma Acute Care Surg* 2014; 77:653–659
6. Kozar RA, Arbabi S, Stein DM, et al: Injury in the aged: Geriatric trauma care at the crossroads. *J Trauma Acute Care Surg* 2015; 78:1197–1209
7. Rosenberg AL, Hofer TP, Hayward RA, et al: Who bounces back? Physiologic and other predictors of intensive care unit readmission. *Crit Care Med* 2001; 29:511–518
8. Kramer AA, Higgins TL, Zimmerman JE: The association between ICU readmission rate and patient outcomes. *Crit Care Med* 2013; 41:24–33
9. Fakhry SM, Leon S, Derderian C, et al: Intensive care unit bounce back in trauma patients: An analysis of unplanned returns

to the intensive care unit. *J Trauma Acute Care Surg* 2013; 74:1528–1533

10. Christmas AB, Freeman E, Chisolm A, et al: Trauma intensive care unit 'bouncebacks': Identifying risk factors for unexpected return admission to the intensive care unit. *Am Surg* 2014; 80:778–782
11. Duke G, Santamaria J, Shann F, et al: Outcome-based clinical indicators for intensive care medicine. *Anaesth Intensive Care* 2005; 33:303–310
12. American College of Surgeons: Trauma Quality Programs (TQP) Participant Use File (PUF) User Manual. 2019. Available at: https://www.facs.org/quality-programs/trauma/quality/national-trauma-data-bank/datasets/. Accessed June 6, 2022
13. Morgan M, Vernon T, Bradburn EH, et al: A comprehensive review of the outcome for patients readmitted to the ICU following trauma and strategies to decrease readmission rates. *J Intensive Care Med* 2020; 35:936–942
14. Glance LG, Osler TM, Mukamel DB, et al: Outcomes of adult trauma patients admitted to trauma centers in Pennsylvania, 2000-2009. *Arch Surg* 2012; 147:732–737
15. Pennsylvania Trauma Systems Foundation: Operational Manual for the Data Base Collection System. 2018. Available at: https://www.ptsf.org/wp-content/uploads/2020/10/7-25-18_FINAL_2018_PTOS_Manual.pdf. Accessed May 6, 2021
16. Gabbe BJ, Magtengaard K, Hannaford AP, et al: Is the Charlson Comorbidity Index useful for predicting trauma outcomes? *Acad Emerg Med* 2005; 12:318–321
17. Charlson ME, Pompei P, Ales KL, et al: A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *J Chronic Dis* 1987; 40:373–383
18. American College of Surgeons: Trauma Quality Improvement Program—Measures of Process of Care. 2017. Available at: https://www.facs.org/~/media/files/quality%20programs/trauma/tqip/tqiphospitalinfoppt.ashx. Accessed February 9, 2022
19. The Committee on Trauma: Advanced Trauma Life Support Student Course Manual. 10th Edition. Chicago, IL, American College of Surgeons, 2018
20. Adams SD, Holcomb JB: Geriatric trauma. *Curr Opin Crit Care* 2015; 21:520–526
21. Min L, Burruss S, Morley E, et al: A simple clinical risk nomogram to predict mortality-associated geriatric complications in severely injured geriatric patients. *J Trauma Acute Care Surg* 2013; 74:1125–1132
22. Joseph B, Pandit V, Zangbar B, et al: Validating trauma-specific frailty index for geriatric trauma patients: A prospective analysis. *J Am Coll Surg* 2014; 219:10–17.e1
23. Kregel HR, Murphy PB, Attia M, et al: The geriatric nutritional risk index as a predictor of complications in geriatric trauma patients. *J Trauma Acute Care Surg* 2022; 93:195–199
24. Selvakumar S, Das S, Newsome K, et al: Preoperative and postoperative cognitive assessment in geriatric patients following acute traumatic injuries: Towards improving geriatric trauma outcomes. *J Surg Res* 2022; 277:352–364
25. Kaben A, Corrêa F, Reinhart K, et al: Readmission to a surgical intensive care unit: Incidence, outcome and risk factors. *Crit Care* 2008; 12:R123
26. Kramer AA, Higgins TL, Zimmerman JE: Intensive care unit readmissions in U.S. hospitals: Patient characteristics, risk factors, and outcomes. *Crit Care Med* 2012; 40:3–10
27. Timmers TK, Verhofstad MH, Moons KG, et al: Patients' characteristics associated with readmission to a surgical intensive care unit. *Am J Crit Care* 2012; 21:e120–e128
28. Martin LA, Kilpatrick JA, Al-Dulaimi R, et al: Predicting ICU readmission among surgical ICU patients: Development and validation of a clinical nomogram. *Surgery* 2019; 165: 373–380
29. Mulvey HE, Haslam RD, Laytin AD, et al: Unplanned ICU admission is associated with worse clinical outcomes in geriatric trauma patients. *J Surg Res* 2020; 245:13–21
30. Stelfox HT, Bastos J, Niven DJ, et al: Critical care transition programs and the risk of readmission or death after discharge from ICU. *Intensive Care Med* 2016; 42:401–410
31. Al-Rajhi A, Mardini L, Jayaraman D: The impact of implementation of an ICU consult service on hospital-wide outcomes and ICU-specific outcomes. *J Intensive Care Med* 2016; 31:478–484
32. Tessler RA, Rangel MM, Rosser ML, et al: Complications in low-risk older adult trauma patients: A case-control study. *J Trauma Acute Care Surg* 2019; 86:858–863
33. Olufajo OA, Tulebaev S, Javedan H, et al: Integrating geriatric consults into routine care of older trauma patients: One-year experience of a level I trauma center. *J Am Coll Surg* 2016; 222:1029–1035
34. Gabbe BJ, Harrison JE, Lyons RA, et al: Comparison of measures of comorbidity for predicting disability 12-months post-injury. *BMC Health Serv Res* 2013; 13
35. Thompson HJ, Rivara FP, Nathens A, et al: Development and validation of the mortality risk for trauma comorbidity index. *Ann Surg* 2010; 252:370–375
36. Fernando DT, Berecki-Gisolf J, Newstead S, et al: The Australian Injury Comorbidity Indices (AICIs) to predict in-hospital complications: A population-based data linkage study. *PLoS One* 2020; 15:e0238182