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Readmissions after Non-operative Trauma: Increased Mortality and Costs with Delayed Intervention

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Abstract

Background: We sought to examine patterns of readmission after non-operative trauma, including rates of delayed operative intervention and mortality.

Methods: The Nationwide Readmissions Database (2013–2014) was queried for all adult trauma admissions and 30-day readmissions. Index admissions were classified as operative (OI) or non-operative (NOI), and readmissions examined for major operative intervention (MOR). Multivariable regression modeling was used to evaluate risk for readmission requiring MOR and in-hospital mortality.

Results: Of 2,244,570 trauma admissions, there were 59,573 readmissions: 66% after NOI, and 35% after OI. Readmission rate was higher after NOI compared to OI (3.6% vs 1.7% $p<0.001$). Readmitted NOI patients were older, with a higher proportion of ISS ≥ 15 and were readmitted earlier (NOI median 8 days vs OI 11 days). 31% of readmitted NOI patients required MOR and experienced higher overall mortality compared to OI patients with operative readmission (NOI 2.9% vs OI 2%, $p=0.02$). Intracranial hemorrhage was an independent risk factor for NOI readmission requiring MOR in both the overall (HR 1.11 [95% CI 1.01–1.22]) and ISS ≥ 15 cohorts (HR 1.46 [1.24–1.7]), with a predominance of non-spine neurosurgical procedures (20.3% and 55.1%, respectively). Operative readmission after NOI cost a median of \$17,364 [IQR: \$11,481, \$27,816], and carried a total annual cost of \$147M (95% CI \$141M–\$154M).

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Author Contribution

MLM contributed to literature search, study design, data collection, data analysis, data interpretation, writing and critical revision

CZ and AP contributed to study design, data analysis and interpretation and critical revision

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Conflicts of Interest

The authors have no conflicts of interest to report

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Conclusions: Non-operative trauma patients have a higher readmission rate than operative index patients, and nearly one-third require operative intervention during readmission. Operative readmission carries a higher overall mortality rate in NOI patients, and together accounts for nearly \$150M in annual costs.

Keywords

trauma; non-operative; readmission; quality

Introduction

Management of traumatic injury has undergone a distinct paradigm shift over the past 50 years, from aggressive operative intervention to selective non-operative management for many blunt and penetrating injuries.(1–3) Advances in diagnostic imaging, invasive monitoring and non-operative intervention techniques have made it possible to minimize the morbidity and cost associated with nontherapeutic operative explorations.(4) Trauma patients are consequently a heterogeneous population of patients who have undergone surgical intervention and those who have not - with nearly half of all admissions managed non-operatively.

Attention to readmission rates has grown since the inception of the Hospital Readmission Reduction Program (HRRP) in 2012, which penalizes hospitals with higher-than-expected readmission rates for certain medical conditions and surgical procedures. The use of readmission as a quality metric has been justified for surgical conditions, as readmissions within 30 days of discharge are often due to complications from the initial procedure.(5, 6) To date, studies of readmission after traumatic injury largely have examined this population as a homogeneous group, despite significant differences between the operative and non-operative populations.(7, 8) While non-operative trauma patients have not been exposed to the risks inherent to surgical intervention, they are at risk for non-operative management failure and may suffer injury progression, and therefore represent a unique surgical population.

There is a paucity of knowledge surrounding outcomes after non-operative trauma, including rates of readmission, and need for unplanned operative intervention after initial discharge. As approximately 30% of trauma patients are readmitted to non-index hospitals, single-center studies likely underestimate the total proportion of patients readmitted after initial conservative management of injury, as well as those who ultimately require surgical intervention.(7, 9, 10) Given the knowledge gap related to trauma readmissions and outcomes as well as the potential, but yet undetermined, relevance of unplanned trauma readmissions to quality, we sought to answer three questions using national, all-payer data. First, what is the burden of readmission after non-operative trauma, including the rate of *unplanned* operative intervention during that readmission? Secondly, what are the primary indications for readmission after non-operative trauma, and are there risk factors for unplanned operative intervention? And finally, since delayed management of injury is associated with worse clinical outcomes, how does readmission after non-operative trauma affect both mortality and total cost of care?

Methods

Data source:

The Nationwide Readmissions Database (NRD), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality is an all-ages, all-payer database drawn from 22 HCUP State Inpatient Databases.(11) Together it contains 15 million unweighted discharges which are then weighted to give a nationally representative sample of 35 million discharges. The dataset contains unique patient identifiers that permit longitudinal tracking of patients' readmissions over the course of one calendar year.

Population:

We queried the 2013 and 2014 NRD for all admissions 18 years of age with a primary diagnosis of trauma, identified using the *International Classification of Diseases, Ninth Revision Clinical Modifier (ICD-9 CM)* diagnosis codes (800–904, 910–929, and 950–959). (7–9) Eligible index admissions were identified, and the database was searched for all non-elective readmission within 30-days of discharge of the index trauma admission. A single index trauma admission could therefore have >1 readmission if each occurred within 30 days of discharge from the index admission. Exclusion criteria for index trauma admissions included elective admission, admission during the month of December (as this would preclude a full 30-days of follow-up), death during that admission, missing discharge disposition or transfer to a short-term hospital (which would imply the existence of two separate records for a single admission and could result in misclassification of readmission). Readmissions were excluded if they were coded as elective.

Injury Severity Score (ISS) and mechanism of injury were calculated for each patient using the validated ICD Programs for Injury Categorization (ICDPIC) version 3.0 software package in Stata.(12) To classify the primary indication for readmission and major operating room procedures, we used the HCUP Clinical Classifications Software (CCS) for ICD-9-CM.(13) The CCS is a diagnosis and procedure categorization scheme, whereby the over 14,000 diagnosis codes and 3,900 procedure codes are collapsed into a smaller number of meaningful categories. As there is still clinical overlap between many of the CCS categories, we manually reviewed all 670 single-level CCS diagnosis and 231 single-level CCS procedure categories, and grouped these into clinically relevant categories, as has been done previously in other studies examining readmission diagnoses, (Supplemental Table S1).(14, 15)

Variables of interest:

Patient sex, ISS, mechanism of injury, insurance status, income quartile and discharge disposition were utilized as categorical variables. Age was included as a continuous variable in all regression models. Number of chronic comorbid conditions was categorized as 0, 1, 2, and 3. Complications during index hospitalization were identified using ICD-9 codes and included intracranial hemorrhage, cardiorespiratory arrest, red blood cell (RBC) transfusion, cardiogenic shock, acute deep vein thrombosis (DVT), acute pulmonary embolus (PE), pneumonia, wound complication, sepsis and urinary tract infection and were selected due to their previously identified association with readmission after relevant operative procedures

or traumatic injury.(16–20) The NRD includes a variable identifying presence of a major operating room procedure during the admission, which we used to differentiate “operative index admissions” (OI) from “non-operative index admissions” (NOI). To identify the primary operative procedure, we searched the listed ICD-9-CM procedure codes for the first operative procedure using the CCS procedure classification as detailed above. 30-day readmission was calculated from the day of discharge. Cost of admission was calculated using the reported charge, multiplied by the HCUP cost-to-charge ratio. This ratio is calculated annually for each hospital and is based on CMS accounting reports and published by HCUP.(21)

Statistical analysis methods

All analyses utilized stratified cluster sampling methods, including sample weights and hospital clusters to achieve estimates of standard error appropriate for the survey design of the NRD, as detailed in NRD documentation.(22) We report weighted national estimates for all variables.

Characteristics of patients at their index and readmission visits, costs, and mortality were summarized and compared with operative status at the index admission in the full cohort of patients, and within the subgroup of severely injured (defined as ISS ≥ 15). Categorical variables were summarized as count and percent, and compared using survey-weighted chi-squared tests. Continuous variables are reported as medians [interquartile range], and compared using survey-weighted Wilcoxon rank-sum tests. All descriptive summaries and tests were survey design adjusted, accounting for post-stratification weights, clustering by hospitals and hospital strata using the survey package in R.(23)

To identify significant predictors of 30-day readmission (ie “readmission”) requiring operative intervention, and in-hospital mortality we first performed univariable regression for all predictors of interest. Multivariable cox regression models (predictors of readmission) and logistic regression (predictors of in-hospital mortality) were then constructed using age, sex, mechanism, ISS, and all variables achieving $p < 0.2$ in univariable analysis. Multicollinearity among predictors was checked using the variance decomposition method, where a condition index greater than 30 suggested potential multicollinearity.(24)

Readmission was studied for the full cohort and separately for non-operative and operative index visits, and the ISS ≥ 15 subset. Readmission was also analyzed among the subset of index visits that had a readmission requiring major operative intervention, for both NOI and OI. Mortality during readmission was assessed for NOI and OI, and separately for the subset of patients requiring operative intervention during readmission. For readmission analyses, we used sampling weights from the index admission. For analysis of mortality during readmission, sampling weights from the readmission visit were used. Hazard ratios (HRs) and odds ratios (ORs) were reported from the readmission and mortality models respectively, along with 95% confidence intervals (CIs) and p-values. All analyses were conducted with statistical significance set at $p < 0.05$, using R version 3.5.(25)

The study was reviewed by the University of Utah Institutional Review Board and exempt from formal review and informed consent as all patient information is de-identified. All

research activities followed regulations within the HCUP and Agency of Healthcare Research and Quality data use agreements.

Results

Patient and Index Hospitalization Characteristics

A total of 1,306,394 trauma admissions were identified in 2013–2014, of which 1,014,786 met inclusion criteria, corresponding to 2,244,570 weighted admissions. 1,055,259 (47%) of patients were managed without major operative intervention during the index admission. Of all index admissions, a total of 58,495 patients had non-elective readmissions (2.61%) (Figure S1 and S2). Non-operative index trauma admissions (NOI) had a higher overall readmission rate compared to operative index (OI) admissions (3.62% vs 1.70%, $p<0.001$). Patients readmitted after NOI admissions were also older (median age 71 [54, 84] vs 69 [49–83]), with higher proportion of severely injury (ISS 15 23.4% vs 17.7%), and a higher proportion of patients using public insurance (Medicare and Medicaid total 74.4% vs 66.5%) (Table 1a).

The proportion of readmitted patients with 3 medical comorbidities was similar in the readmitted OI (53.8%) and NOI (52.1%) populations. These groups demonstrated clinically similar rates of diabetes, chronic pulmonary disease, congestive heart failure and liver disease. NOI patients had slightly higher rates of baseline hypertension (NOI 59% vs OI 56.3%) and alcohol use (NOI 13.9% vs OI 10.4%). Both groups had similar rates of depression/psychiatric illness (NOI 21.1% vs OI 21.4%) and substance abuse (NOI 5.9% vs OI 6.9%).

Patients readmitted after NOI had higher rates of initial discharge to home (42.6% vs OI 28.6%) and discharge against medical advice (4.3% vs 1.3%) compared to OI patients, who had higher rates of transfer to other health facilities (OI 55.2% vs NOI 36.6%) (Table 1b).

Readmission Hospitalization

Two-thirds of all readmissions took place in the first 14 days after discharge (median 9 days [IQR 4 – 18]). Readmissions after NOI occurred earlier than after OI (NOI median days post-discharge 8 [4–16] vs OI 11 [5–19], $p<0.001$), with 47% of NOI readmissions occurring in the first week, compared to 36.1% of OI readmissions, $p<0.001$ (Table 2). NOI patients were readmitted to non-index hospitals more often than OI patients (30.7% vs 22.1%, $p<0.001$). Overall, a predominance of patients was readmitted from the emergency department (81.7%), with a higher proportion of NOI patients compared to OI (83.7% vs 78.1%, $p<0.001$) (Table 3). Length of stay was shorter for readmission after NOI compared to after OI (4 days [3–8] vs 5 days [3–9], $p<0.001$).

Operative Intervention during Readmission

Overall, 36.9% of readmitted patients required a major operating room procedure (MOR during readmission. OI patients had a higher rate of operative intervention during readmission (OI 47.7% vs NOI 31.2%, $p<0.001$); however, when limited to major trauma (ISS 15), there was no significant difference between the two groups (OI 38.4% vs NOI

36.5%, $p=0.24$). Patients requiring a major operative procedure when readmitted after NOI presented earlier (NOI median 9 [4–16], vs 13[6–20], $p<0.001$), with 44% of MOR NOI patients readmitted in the first week after discharge vs 29.7% of MOR OI, $p<0.001$ (Table 2).

Multivariable cox regression modelling was used to identify risk factors independently associated with readmission requiring MOR after non-operative index admission, controlling for patient factors, clinical factors during initial admission, and hospital clustering (Table 4). Among all NOI patients, the following independent risk factors were identified: female sex (adjusted hazard ratio [aHR] 0.91 [95% CI: 0.85–1.00]), ISS (ISS 15–24 aHR 2.07 [1.88–2.26]); ISS ≥ 25 aHR 1.59 [1.22–2.07]), three or more medical comorbidities (aHR 1.14 [1.03–1.26]), length of stay (aHR 0.98 [0.98–0.99]), intracranial hemorrhage (aHR 1.13 [1.03–1.23]), acute pulmonary embolus (aHR 1.90 [1.21–2.99]), RBC transfusion (aHR 1.19 [1.04–1.36]) and non-home discharge (against medical advice: aHR 2.60 [2.25–3.02], home health: aHR 1.32 [1.19–1.46], and transfer to SNF/LTAC aHR 1.20 [1.10–1.31]). In the ISS ≥ 15 cohort, female sex (aHR 0.85 [0.73–0.99]), intracranial hemorrhage (aHR 1.47 [1.25–1.73]) and discharge AMA (aHR 1.66 [1.07–2.57]) remained significant for readmission requiring MOR.

Primary Procedures

Of all readmitted patients, non-spine neurosurgical procedures (14.4%) and hip/femur procedures (12.8%) predominated operative procedures. The most common indications for operative intervention differed between the NOI and OI cohorts (Table 5). In the non-operative index cohort, the most common procedural categories during readmission were non-spine nervous-system procedures (20.5%), and peripheral vascular procedures (11.5%). In the operative index cohort, hip/femur (17.6%) and other lower extremity (14%) procedures dominated. Among the severely injured (ISS ≥ 15) cohort, non-spine neurosurgical procedures dominated both NOI and OI groups (55.1% and 28.8% respectively), followed by peripheral vascular procedures (NOI 13.4% and OI 17.7%). Examination of CCS codes for primary diagnosis during readmission showed appropriate correlation with the above patterns of procedures, with a predominance of orthopedic trauma diagnosis in the overall OI and NOI cohorts, and intracranial injury in the OI and NOI among the severely injured cohort (Supplemental Table S2).

Mortality

Among all readmitted patients, unadjusted mortality rates after NOI and OI were similar (NOI 3.8% vs OI 3.8%, $p=0.92$). However, among patients with ISS ≥ 15 , mortality during readmission after NOI was significantly higher than after OI (NOI mortality 5.1% vs OI 3.6%, $p=0.05$). Mortality in patients requiring a major operating room procedure during readmission was higher in the NOI patients, with 2.9% mortality, compared to 2% in the OI cohort, $p=0.02$. (Figure 1). This difference was more pronounced after major trauma (ISS ≥ 15) with mortality in NOI patients of 4.8%, compared to 2.4% after OI though this did not reach statistical significance ($p=0.12$). Readmission with MOR after NOI was associated with a significantly higher odds of mortality in an unadjusted analysis (OR=1.45 [1.06,1.99]), but not in a multivariable analysis adjusting for age, sex, ISS, mechanism,

insurance, and number of comorbidities (aOR= 1.15 [95% CI 0.82–1.59]) (Supplemental Table S3). In the multivariable analysis, age (aOR 1.04 [1.03–1.06], ISS 15–24 (aOR 1.75 [1.21–2.52]), ISS 25 (aOR 3.35 [1.47–7.64]) and 3 comorbidities (aOR 4.63 [1.94–11.08]) were all independently associated with increased mortality.

Total Cost

Overall, the median cost of readmission was higher for patients who underwent operative intervention during index admission: OI \$12,053 [6,630 – 20,968] vs NOI \$9,497 [5,290 – 17,332], $p<0.001$. However, amongst patients who required major operative intervention during readmission, total cost of readmission was similar between the two groups: OI \$17,260 [11,537 – 27,313] vs NOI \$17,364 [11,481 – 27,816], $p=0.71$. The total annual cost of readmission for NOI trauma patients who subsequently required major operative intervention during readmission was \$147.82 M (95% CI 141.32M – 154.39M). For OI trauma patients requiring operative intervention on readmission, the total annual cost was \$68.15M (95% CI 63.59M – 72.72M).

Discussion

The growth of advanced imaging, intensive monitoring and interventional radiology procedures over the past fifty years has led to an increase in the proportion of patients who are now managed without major operative intervention. In this national analysis of trauma patients, we confirm that nearly half of all patients admitted due to injury are managed non-operatively, and constitute a clinically important subset of the trauma population. Compared to patients who require operative intervention during their initial admission, non-operative patients experience a higher rate of readmission and nearly one-third require a major operative intervention during readmission. Readmission requiring operative intervention was associated with a higher overall mortality rate in non-operative index patients, though this appeared mainly driven by severity of injury. These unplanned operative readmissions represent a substantial economic burden, totaling nearly \$150 million in potentially avoidable costs annually in the United States.

To our knowledge, this is the first study to consider non-operative trauma patients separately from those who undergo operative intervention during their initial admission. Non-operative trauma patients represent a unique population, often having sustained multi-system injury – and remain at risk for failure of planned non-operative management after discharge from hospital. As indications for selective non-operative management of injuries have expanded this subgroup of trauma patients now constitutes nearly half of all trauma admissions.(1, 26–28) Failure of overall non-operative management in the trauma patient – whether requiring readmission for progression of injury, management of missed injury, or management of comorbid medical illnesses affected by injury – is poorly understood and may contribute to overall outcomes in this patient population.

As successful non-operative management by definition should not be followed by unplanned early readmission requiring operative intervention, we considered such operative procedures to represent “delayed intervention” – whether due to progression of existing injury or missed injury during initial admission. While non-operative management of various injuries will

always have a measurable failure rate, these failures ought to be identified during index admission. Per current national quality metrics, early unplanned operative readmissions therefore represent “potentially preventable” events. While it is important to note that the vast majority of non-operative patients are successfully managed and certainly benefit from avoiding major surgery, failure of such management post-discharge may have serious consequences. Identifying patients at high-risk for failure prior to initial discharge could mitigate this risk.

Our analysis was significant for the higher overall readmission rate for non-operative index patients compared to those who underwent initial operative management (3.62% vs 1.70%), a disparity that was also present in the severely injured population (5.74% vs 3.21%). Even more surprising was the high rate of major operative intervention in this population that was initially managed non-operatively. Previous studies that have evaluated the rate of operative intervention during readmission of all trauma patients report similar rates to ours. Rosenthal *et al*, in their single-center study of readmissions at a Level-I safety-net hospital, found 35% of patients required a procedure or operation during readmission.(29) Wheeler *et al*, found a similar rate of intervention during readmission in the pediatric population, with 39% of patients requiring a major operating room procedure.(30) Our study builds upon this literature by specifically examining non-operative trauma patients and found a high rate of delayed intervention occurring during early, unplanned readmissions in both the overall (31%) and severely injured (37%) populations. This unexpectedly high rate raises concern for failure of planned non-operative management, progression of known injury, or missed injuries.

Readmission after traumatic injury has been shown to be associated with increased mortality.(29, 31) In our analysis of trauma patients who required major surgery during readmission, non-operative index patients with traumatic brain injury appear to at increased risk of poor outcomes: intracranial hemorrhage was an independent risk factor for operative readmission in the severely injured cohort, and neurosurgical procedures dominated operations after NOI in both the overall and severely injured cohorts. The clinical burden of traumatic brain injury has grown substantially over the past two decades, yet the literature on rates of readmission and surgical intervention after initial conservative management is limited.(32, 33) Franko *et al*, examined the impact of surgical intervention on 30-day readmission after management of subdural hematoma and found that non-operative management during index admission was associated with 5-fold greater odds of unexpected readmission, and that 33% of those readmitted required surgical intervention.(34) While it might be unreasonable and uneconomical to keep such patients in the hospital for longer observation, it is clear that some patients suffer from failure to recognize the need for surgical intervention during their index admission. The high proportion of neurosurgical readmission and operative intervention in our study of readmitted non-operative trauma patients underscores the need for further research to delineate specific risk factors for readmission after non-operative TBI.

While attention to long-term outcomes after trauma is growing, few studies to date have examined post-discharge sequelae after non-operative management of specific injury patterns. Recent work evaluating outcomes after non-operative management of isolated

splenic trauma highlight the need for a focused and rigorous approach in this regard. Freitas and colleagues examined complications within 30-days of discharge after initial non-operative management of blunt splenic injury and found nearly one fifth of readmitted patients required an unplanned operative intervention during readmission.(35) Their patient population included multi-trauma patients, was not limited to isolated splenic injuries or splenectomy during readmission, and did not clearly differentiate between splenectomy and other operative interventions. Subsequently, Rosenberg and colleagues examined isolated splenic injuries using the NRD and considered 6-month post-discharge outcomes and found that while the 6-month readmission rate approximated 20%, the rate of delayed splenectomy was only 1.2%.(36) Our study, in its broad consideration of non-operative trauma patients management demonstrated a similarly high overall rate of unplanned operative intervention during readmission as Freitas *et al*, and that splenectomy made up only a small proportion of the primary operative procedures. As we cannot discern from administrative data alone if operative interventions during readmission were due to initial judgement errors, or progression of known disease, additional work on contributors to failed non-operative management is warranted. This will require a granular approach with regard to patient injury patterns, clinical characteristics, and specific procedures performed on readmission in order to meaningfully inform changes in management practices.

Targeted transitional care programs have shown promise in reducing readmissions after trauma by focusing on highly vulnerable patients and those with high-risk injury patterns. Hall *et al*. report a significant reduction in 30-day readmission for high-risk trauma patients with the implementation of a Trauma Transitional Care Program (TTCP) consisting of telephone followup within 72 hours of discharge, medication reconciliation and coordination of post-discharge medical care. (37) In our analysis, we identify multiple risk factors for failure of non-operative management and delayed intervention, including ISS 15, complex medical comorbidities, non-home discharge, intracranial hemorrhage and acute pulmonary embolism – all of which were included in Hall and colleagues' TTCP program. In addition to transitional care support, simple interventions during the index trauma admission may also prove valuable. In particular, involvement of internal medicine or geriatric consultants for patients with multiple comorbid illnesses and improvement of inpatient systems to promote communication and coordination of management across surgical specialties ought to be considered. There is currently a paucity of formal cost-effectiveness analysis for such interventions, and economic analysis is another avenue for research moving forward.

Our analysis is limited by factors inherent to the use of large administrative databases, and specifically the NRD. Administrative data is subject to errors in coding, including misrepresentation of the primary indication for readmission, primary procedure or non-elective status.(37) To address this, we used the AHRQ CCS classification, and found a high degree of correlation between the CCS grouping of the primary diagnosis code and the first coded major operating room procedure, which lends strength to our categorization of readmission. The NRD is specifically designed for the evaluation of non-elective readmissions. We followed the dataset guidelines to identify these appropriately and found our overall readmission rate to be in-line with other estimates from single-center and national analyses.(29, 31, 38) Furthermore, 82% of all patients had emergency department services billed during their readmission, suggesting these were indeed unplanned

readmissions. To address the clinical redundancy in ICD-9 and CCS codes for primary diagnoses and procedures and obtain accurate estimates of the indication for readmission and operative interventions, we grouped these codes into relevant clinical categories, as others have done.(14, 15) Nevertheless, this results in a loss of granularity as to the specific injury patterns and procedures patients underwent during readmission. Further focused analysis of specific subgroups, such as intracranial injury and neurosurgical procedures, is therefore warranted.

A further limitation is that in order to examine the effect of delayed intervention on outcomes, we had to condition our models on the intermediate outcome of readmission with a major operative procedure. It is known that analyses in these situations can result in biased and even paradoxical findings.(39) The high degree of correlation between primary diagnoses and primary operative procedures does suggest that the outcome observed was driven by the patient's injuries. Nevertheless, there may still be underlying bias as we were unable to account for out-of-hospital deaths or patient readmissions in another state using the NRD. Finally, the use of administrative data to evaluate clinical outcomes after trauma is particularly challenging, due to the heterogeneity of patient injuries. While we used standard risk adjustment practices, we were restricted in our ability to account for physiologic differences or unmeasured patient characteristics, including social factors. Confounding by indication for surgery due to polytrauma and effect of multiple organ system injuries is also difficult to accurately adjust for in this dataset.

Conclusions

Non-operative trauma accounts for nearly half of all trauma admissions and represents a unique patient population with a heterogeneous constellation of disease. This patient population experiences a higher overall readmission rate compared to patients requiring operative intervention for their injuries, and these readmissions occur earlier, with nearly half in the first week following discharge. The risk associated with failure of non-operative management is substantial: non-operative trauma patients who subsequently require unplanned readmission with operative intervention experience higher overall rates of mortality and contribute nearly \$150 million annually in potentially avoidable costs in the United States. This study highlights the need for further research to identify patients at risk for readmission after non-operative management.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
30-day Mortality During Readmission with Operative Intervention

Table 1a.

Index admission patient and hospital characteristics

	All Index Admissions		Index Admissions with 30-day Readmissions	
	Operative index (N=1,189,311)	Non-Operative index (N=1,055,259)	Operative index (N=20,260)	Non-Operative index (N=38,235)
Age (years)				
18–35	185,056 (15.6%)	163,040 (15.5%)	2,857 (14.1%)	3,649 (9.5%)
36–64	347,752 (29.2%)	316,957 (30%)	6,126 (30.2%)	11,813 (30.9%)
65–80	299,626 (25.2%)	249,972 (23.7%)	5,244 (25.9%)	10,174 (26.6%)
81	356,877 (30%)	325,290 (30.8%)	6,033 (29.8%)	12,598 (32.9%)
Female	653,900 (55%)	532,448 (50.5%)	9,829 (48.5%)	18,649 (48.8%)
ISS				
<15	1,073,908 (90.5%)	893,115 (84.9%)	16,609 (82.4%)	29,211 (76.5%)
15–24	83,559 (7%)	147,965 (14.1%)	2,640 (13.1%)	8,487 (22.2%)
25	29,446 (2.5%)	11,405 (1.1%)	918 (4.6%)	472 (1.2%)
Mechanism				
Non-Penetrating	1,136,466 (95.6%)	1,019,351 (96.6%)	19,258 (95.1%)	37,287 (97.5%)
Penetrating	52,845 (4.4%)	35,908 (3.4%)	1,002 (4.9%)	949 (2.5%)
Primary Expected Payer				
Private	259,844 (21.9%)	228,321 (21.7%)	3,666 (18.1%)	5,705 (14.9%)
Medicare	657,811 (55.4%)	576,201 (54.7%)	11,737 (58%)	24,011 (62.9%)
Medicaid	100,861 (8.5%)	101,077 (9.6%)	2,167 (10.7%)	4,384 (11.5%)
Self-pay	78,408 (6.6%)	80,220 (7.6%)	1,238 (6.1%)	2,230 (5.8%)
No charge	9,775 (0.8%)	8,652 (0.8%)	175 (0.9%)	347 (0.9%)
Other	80,416 (6.8%)	59,022 (5.6%)	1,241 (6.1%)	1,517 (4%)
Median Income Quartile				
1	322,017 (27.5%)	278,733 (26.9%)	5,834 (29.4%)	10,561 (28.1%)
2	324,460 (27.7%)	277,332 (26.7%)	5,452 (27.4%)	9,988 (26.5%)
3	281,507 (24.1%)	247,210 (23.8%)	4,757 (23.9%)	8,654 (23%)
4	241,953 (20.7%)	234,046 (22.6%)	3,826 (19.3%)	8,417 (22.4%)
Number of Comorbidities				
0	218,225 (18.3%)	191,070 (18.1%)	2,445 (12.1%)	4,233 (11.1%)

	All Index Admissions		Index Admissions with 30-day Readmissions	
	Operative index (N=1,189,311)	Non-Operative index (N=1,055,259)	Operative index (N=20,260)	Non-Operative index (N=38,235)
1	216,842 (18.2%)	214,648 (20.3%)	3,084 (15.2%)	6,390 (16.7%)
2	226,541 (19%)	213,201 (20.2%)	3,822 (18.9%)	7,693 (20.1%)
3	527,703 (44.4%)	436,340 (41.3%)	10,909 (53.8%)	19,919 (52.1%)
Hospital Bed size				
Small	131,290 (11%)	123,746 (11.7%)	1,954 (9.6%)	4,413 (11.5%)
Medium	288,482 (24.3%)	249,773 (23.7%)	4,670 (23.1%)	9,146 (23.9%)
Large	769,539 (64.7%)	681,740 (64.6%)	13,636 (67.3%)	24,676 (64.5%)
Teaching Hospital	711,095 (59.8%)	647,816 (61.4%)	12,839 (63.4%)	23,723 (62%)
Hospital Ownership				
Not-for-profit	850,269 (71.5%)	742,474 (70.4%)	13,728 (67.8%)	26,399 (69%)
Private, investor-owned	170,384 (14.3%)	161,726 (15.3%)	3,330 (16.4%)	6,421 (16.8%)
Government, nonfederal	168,658 (14.2%)	151,059 (14.3%)	3,202 (15.8%)	5,415 (14.2%)

Index admission clinical events

Table 1b.

	All Index Admissions		Index Admissions with 30-day Readmissions	
	Operative index (N=1,189,311)	Non-Operative index (N=1,055,259)	Operative index (N=20,260)	Non-Operative index (N=38,235)
Clinical Events				
Intracranial hemorrhage	43,573 (3.7%)	142,397 (13.5%)	1,774 (8.8%)	8,032 (21%)
Cardiorespiratory arrest	3,397 (0.3%)	1,520 (0.1%)	108 (0.5%)	53 (0.1%)
RBC Transfusion	229,008 (19.3%)	45,429 (4.3%)	4,554 (22.5%)	2,373 (6.2%)
Cardiogenic shock	1,145 (0.1%)	363 (0%)	18 (0.1%)	10 (0%)
Acute DVT	15,955 (1.3%)	6,500 (0.6%)	564 (2.8%)	291 (0.8%)
Acute PE	8,189 (0.7%)	3,370 (0.3%)	244 (1.2%)	153 (0.4%)
Pneumonia	38,482 (3.2%)	31,176 (3%)	872 (4.3%)	1,248 (3.3%)
Wound complication	14,048 (1.2%)	2,376 (0.2%)	363 (1.8%)	108 (0.3%)
Sepsis	20,066 (1.7%)	15,145 (1.4%)	586 (2.9%)	599 (1.6%)
Urinary tract infection	4,594 (0.4%)	3,986 (0.4%)	89 (0.4%)	131 (0.3%)
Advanced Resource Utilization				
Intubation and mechanical ventilation	21,470 (1.8%)	22,663 (2.1%)	626 (3.1%)	684 (1.8%)
Hemodialysis	7,058 (0.6%)	10,376 (1%)	214 (1.1%)	738 (1.9%)
Angiogram with or without embolization	5,486 (0.5%)	3,792 (0.4%)	173 (0.9%)	147 (0.4%)
Disposition				
Home	426,675 (35.9%)	548,210 (52%)	5,785 (28.6%)	16,282 (42.6%)
Home health care	172,190 (14.5%)	134,777 (12.8%)	3,018 (14.9%)	6,324 (16.5%)
Transfer to SNF/LTAC	586,501 (49.3%)	354,371 (33.6%)	11,185 (55.2%)	13,983 (36.6%)
Against medical advice	3,944 (0.3%)	17,901 (1.7%)	272 (1.3%)	1,646 (4.3%)
Length of stay (index admission) (median [IQR])		3 [2,5]	6 [4,10]	3 [2,6]
Cost of index admission (median [IQR])	15,417 [10821,23735]	6,574 [4191,10524]	17,963 [12245,29907]	7,017 [4358,11581]

Table 2.

Timing of readmissions after operative and non-operative index admissions

Days from Index Discharge	Readmission after Operative Index Admission (N=20,553)			Readmission after Non-Operative Index Admission (N=39,020)			p-value comparing readmission with OI vs. NOI
	Operative readmission (N=9,814)	Non-operative readmission (N=10,739)	Total	Operative readmission (N=12,168)	Non-operative readmission (N=26,852)	Total	
0-7	2,913 (29.7%)	4,511 (42%)	7,424 (36.1%)	5,359 (44%)	12,986 (48.4%)	18,345 (47%)	<0.001
8-14	2,657 (27.1%)	2,498 (23.3%)	5,155 (25.1%)	3,263 (26.8%)	5,911 (22%)	9,175 (23.5%)	-
15-30	4,244 (43.2%)	3,730 (34.7%)	7,975 (38.8%)	3,546 (29.1%)	7,955 (29.6%)	11,500 (29.5%)	-

OI=Operative index admission, NOI=Non-operative index admission

Table 3.

Readmission hospitalization characteristics

	Operative Index Admission (N=20553)	Non-Operative Index Admission (N=39020)	p-value
Non-Index Hospital	4536 (22.1%)	11995 (30.7%)	<0.001
Major OR Procedure	9780 (47.6%)	12095 (31%)	<0.001
ED Services Billed	16054 (78.1%)	32645 (83.7%)	<0.001
Disposition			
Home	5749 (28%)	13971 (35.8%)	<0.001
Home health care	3331 (16.2%)	5642 (14.5%)	-
Transfer to short term hospital	277 (1.3%)	422 (1.1%)	-
Transfer to SNF/LTAC	10205 (49.7%)	16588 (42.5%)	-
Against medical advice	196 (1%)	856 (2.2%)	-
Died in hospital	773 (3.8%)	1478 (3.8%)	0.92
Length of Stay (median [IQR])	5 [3,9]	4 [3,8]	<0.001
Cost	12053 [6630,20968]	9497 [5290,17332]	<0.001

Predictors of readmission requiring major operative intervention after non-operative index admission

Table 4.

Predictor	Univariable		Multivariable	
	HR	p-value	HR	p-value
Age	1.00 (1.00,1.01)	<0.001	1.00 (1.00,1.00)	0.33
Female	0.95 (0.89,1.01)	0.08	0.91 (0.85,0.98)	0.011
ISS (<i>ref <15</i>)				
ISS 15–24	2.22 (2.05,2.41)	<0.001	2.07 (1.88,2.26)	<0.001
ISS 25	1.49 (1.15,1.93)	0.002	1.59 (1.22,2.07)	<0.001
Penetrating Mechanism	0.77 (0.62,0.96)	0.020	0.97 (0.78,1.22)	0.82
Primary Expected Payer (<i>ref Private</i>)				
Medicare	1.33 (1.22,1.45)	<0.001	1.26 (1.13,1.41)	<0.001
Medicaid	1.23 (1.10,1.38)	<0.001	1.21 (1.08,1.36)	0.001
Self-pay	0.93 (0.81,1.07)	0.29	0.91 (0.79,1.05)	0.18
Other	1.09 (0.96,1.25)	0.18	1.09 (0.96,1.25)	0.18
Number of Comorbidities (<i>ref 0</i>)				
1	1.09 (0.99,1.21)	0.09	1.00 (0.90,1.12)	0.95
2	1.21 (1.09,1.34)	<0.001	1.08 (0.97,1.20)	0.15
3	1.29 (1.18,1.42)	<0.001	1.14 (1.03,1.26)	0.015
Median Income Quartile (<i>ref 1</i>)				
2nd	0.95 (0.87,1.03)	0.18	--	--
3rd	0.96 (0.88,1.05)	0.37	--	--
4th	0.99 (0.91,1.08)	0.84	--	--
Length of Stay	1.00 (0.99,1.00)	0.12	0.98 (0.98,0.99)	<0.001
Intracranial hemorrhage	1.97 (1.81,2.13)	<0.001	1.13 (1.03,1.23)	0.007
Cardiorespiratory arrest	0.50 (0.20,1.23)	0.13	0.49 (0.20,1.21)	0.12
Acute DVT	1.03 (0.65,1.65)	0.89		
Acute PE	1.71 (1.09,2.68)	0.020	1.90 (1.21,2.99)	0.005
Sepsis	0.82 (0.63,1.06)	0.13	0.85 (0.66,1.10)	0.22
Pneumonia	0.82 (0.66,1.01)	0.06	0.84 (0.68,1.04)	0.10
Wound complication	1.34 (0.82,2.21)	0.24	--	--

Predictor	Univariable		Multivariable	
	HR	p-value	HR	p-value
Urinary tract infection	0.80 (0.49,1.30)	0.37	--	--
RBC Transfusion	1.18 (1.03,1.35)	0.016	1.19 (1.04,1.36)	0.014
Disposition (ref Home)				
Transfer to SNF/LTAC	1.24 (1.16,1.33)	<0.001	1.20 (1.10,1.31)	<0.001
Home health care	1.39 (1.27,1.52)	<0.001	1.32 (1.19,1.46)	<0.001
Against medical advice	2.62 (2.27,3.02)	<0.001	2.60 (2.25,3.02)	<0.001
Teaching Hospital (ref Metropolitan Non-teaching)				
Metropolitan teaching	1.05 (0.98,1.12)	0.21	1.01 (0.95,1.09)	0.69
Non metropolitan	0.73 (0.64,0.84)	<0.001	0.79 (0.69,0.90)	<0.001

Table 5.
Most common primary operating room procedures during readmission hospitalization

All Patients			Severe Trauma: ISS 15	
Operative Index Admission (N=9,814)	Non-Operative Index Admission (N=12,168)	Operative Index Admission (N=1,396)	Non-Operative Index Admission (N=3,343)	
Hip/Femur fracture (17.6%)	Nervous system (20.5%)	Nervous system (28.8%)	Nervous system (55.1%)	
Other Lower Extremity fracture (14%)	Peripheral vascular (11.5%)	Peripheral vascular (17.7%)	Peripheral vascular (13.4%)	
Joint (10.6%)	Other Orthopedic procedure (10.1%)	Other Orthopedic procedure (6.1%)	Thoracentesis (4.0%)	
Peripheral vascular (10.2%)	Hip/Femur fracture (8.9%)	Wound debridement (5.4%)	Other Orthopedic procedure (3.4%)	
Other Orthopedic procedure (10.1%)	Other Lower Extremity fracture (7.9%)	Muscle/Tendon procedure (4.6%)	Hip/Femur fracture (2.0%)	