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Benchmarking the incidence of organ failure after injury at trauma centers and nontrauma centers in the United States

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Abstract

BACKGROUND—Organ failure after injury is a significant cause of morbidity and mortality, yet its true incidence is unknown. We sought to benchmark the incidence of organ failure following injury at trauma centers and nontrauma centers using a nationally representative sample of hospital discharges. We hypothesized that injured patients receiving care at trauma centers would have a lower incidence of organ failure than those at nontrauma centers.

METHODS—We used the 2006 Nationwide Inpatient Sample to identify injured adults (age ≥ 15 years) with organ dysfunction using specific DRG International Classification of Diseases—9th Rev. codes by system. After adjusting for hospital size, geographic region, comorbidities, Injury Severity Score (ISS), age, and sex, a multivariate logistic regression model was created to compare rates of organ dysfunction between trauma centers and nontrauma centers.

RESULTS—We identified 396,276 injured patients, representing the patient care experience of a total of 1,939,473 patients. Among these patients, 6.5% had concurrent organ failure. Injured patients who had acute organ failure were more likely to die than injured patients without organ failure (12.4% vs. 1.7%, $p < 0.001$). Mortality increased with the number of organ system failures. Patients treated at trauma centers had a higher incidence of respiratory and cardiac failure compared with nontrauma centers.

CONCLUSION—We offer the first national benchmark of rates of acute organ failure among injured patients. Postinjury organ failure is uncommon, but incidence increases with injury severity and correlates with mortality. Patients at trauma centers had higher rates of respiratory and cardiac failure, possibly representing differences in referral patterns or resuscitation strategies.

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LEVEL OF EVIDENCE—Prognostic and epidemiologic study, level III.**Keywords**

Organ failure; multiple-organ failure; trauma centers.

The development of multiple-organ failure (MOF) is the leading cause of late death after trauma, accounting for more than 50% of delayed mortality.¹ The true incidence of posttraumatic MOF, however, is unknown and varies from less than 10% to nearly 25%, depending on the series. Nonetheless, developing MOF has been associated with a mortality rate between 11% and 100% and is proportional to the number of organ systems involved.^{1–3} Beyond mortality, MOF has important social and financial implications, as survivors are 3.9 times more likely to require ongoing assistance with activities of daily living compared with trauma survivors without MOF.⁴

Despite its importance, there are significant limitations regarding the current body of literature describing the epidemiology of postinjury MOF. Single-institution case series provide the bulk of the current literature. Unfortunately, these series are not generalizable, are limited by the lack of consensus definitions of organ failure, and fail to distinguish between outcomes for patients treated at a trauma center.⁵ A larger-scale examination of postinjury MOF would help to establish its true incidence and further delineate its importance in the care of trauma patients.

We sought to better characterize the epidemiology of organ failure after injury using a nationally representative sample of US hospital discharges. Given the recognized improvement in survival at trauma centers,⁵ our goal was to determine the incidence and outcome of MOF at trauma centers and nontrauma centers in the United States. We hypothesized that patients cared for at trauma centers would have a lower incidence of postinjury MOF and improved mortality when compared with those treated at nontrauma centers.

PATIENTS AND METHODS

We used the 2006 Nationwide Inpatient Sample (NIS) to perform a population-based cohort study examining the incidence and outcomes for patients with MOF. The NIS is the largest all-payer inpatient care database in the United States and includes data from 38 states and approximately 7 million hospital stays. The NIS was developed as part of the Healthcare Cost and Utilization Project at the Agency for Healthcare Research and Quality (AHRQ). The NIS is a 20% stratified sample of all US hospitals containing patient- and hospital-level data including demographic information, hospital characteristics, in-hospital mortality, and DRG International Classification of Diseases—9th Rev. (ICD-9) diagnostic and injury codes.

We identified injured patients in the NIS using ICD-9 codes (800–904, 910–929, 940–957) as previously described.^{6–9} Consistent with previous literature on the adult trauma population, we limited our analysis to patients 15 years or older.^{10–12} We excluded patients who were transferred from another acute care hospital, from another type of health care

facility, or whose transfer status was unknown. In addition, patients whose in-hospital mortality status was unknown were also excluded.

ICD-9 codes were used to identify organ failure for four organ systems (respiratory, cardiac, hepatic, and renal) based on the Denver postinjury MOF scoring system.^{13,14} To more accurately reflect organ failure specific to trauma patients, we added ICD-9 modifiers (Table 1). For example, organ failure of the respiratory system was defined as the presence of the code for mechanical ventilation (96.7) plus an additional code in the respiratory category. This was done to exclude those patients who may have been mechanically ventilated but without underlying respiratory failure (e.g., intubated for intoxication, altered mental status, or traumatic brain injury). Organ failure of the cardiac system was defined as the code for hypotension (458) plus an additional code in the cardiac category. Our goal was to avoid including patients who might have developed hypotension secondary to hypovolemic/hemorrhagic shock. Organ failure of the renal and hepatic systems was defined by the presence of any ICD-9 codes in their respective categories. In addition, a subset of patients having a renal failure code as well as the code for hemodialysis (39.95) were identified as having “severe” renal failure. Finally, patient records containing the ICD-9 codes for chronic renal failure (585), chronic respiratory failure (518.83), and chronic liver disease (571) were excluded from the analysis.

Patient variables collected included age, sex, and comorbidities. Comorbidities were assigned based on ICD-9 codes as defined by the AHRQ.¹⁵ Hospital variables collected included bed size, geographic region, and American College of Surgeons Trauma Center designation. Injury Severity Scores (ISSs) were calculated using ICDMAP-90.¹⁶

To assess differences in the variables of interest between patients receiving care at Level I or II trauma centers versus other facilities, χ^2 test and Student's *t* test were used as appropriate. Unadjusted and adjusted analyses were performed using logistic regression to adjust for bed size of the hospital (small, medium, and large), region (Northeast, Midwest, South, and West), each of the 29 individual AHRQ comorbidities, ISS, age (15–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, >85 years), and sex while testing the relation between organ dysfunction rate and trauma center status. Results are expressed as odds ratios (ORs) with 95% confidence intervals (CIs). All analyses were performed using SAS-callable SUDAAN statistical software, version 10.0.1 (Research Triangle Institute, Research Triangle Park, NC) to account for weighted frequencies and provide national estimates.

RESULTS

A total of 396,276 injured patients were identified, representing the patient care experience of a total of 1,939,473 patients. Table 2 shows the demographic information for identified patients in trauma and nontrauma centers. Among these patients, the mean and median ages were 60.6 and 64 years, respectively (interquartile range, 42–81). The mean and median number of AHRQ comorbidities was 1.83 and 2, respectively (interquartile range, 0–3).

Patients included in our analysis had an overall rate of organ failure of 6.5%. Among patients with organ failure, single-organ system failure occurred in 92.2%, two-organ system

failure occurred in 6.6%, three-organ system failure occurred in 1.0%, and four-organ system failure occurred in 0.1%. Injured patients with a single-system organ failure had a mortality rate of 12.4%, compared with 1.7% for no organ system failure. The mortality rate for two-organ system failures increased to 39.4%. Patients with greater than three organ system failures had a mortality rate of 59.6% (Fig. 1).

Table 3 demonstrates the prevalence of organ dysfunction stratified by ISS. With the exception of renal failure, the rate of organ dysfunction in all categories increased with increasing ISS. The incidence of respiratory failure had the most significant increase with increasing ISS.

Table 4 demonstrates the prevalence and mortality rate for organ dysfunction stratified by age. With the exception of renal dysfunction, mortality rates associated with organ dysfunction were highest among patients older than 65 years.

Table 5 indicates the prevalence of organ dysfunction in trauma and nontrauma centers using our logistic regression model. Patients cared for at trauma centers had a higher incidence of respiratory and cardiac dysfunction compared with those at nontrauma centers. There was no significant difference observed in the rates of renal or hepatic dysfunction.

DISCUSSION

Posttraumatic MOF is a significant cause of morbidity and mortality, yet its true incidence remains largely unknown. The impact of trauma center care on overall mortality has been demonstrated previously, but its influence on the development of MOF has not been well characterized. Our study attempted to both define the incidence of posttraumatic MOF and characterize the impact of trauma center designation on its development. To our knowledge, this is the first study of its kind to generate national estimates of posttraumatic MOF. Posttraumatic organ failure is uncommon, increases with injury severity, and correlates with mortality. There also seems to be variation in the types of organ failure seen at trauma centers compared with non-trauma centers. In contrast to previous studies, our results highlight an overall low incidence of organ dysfunction following injury (6.5%). Faist et al.¹⁷ presented a series of 433 patients with a rate of organ failure of 11.5%. A more modern series of 1,361 patients by Nast-Kolb et al.³ showed a rate of single-organ failure between 7% and 21%, depending on the period evaluated. Some of the discrepancy seen with our study and previous work may involve the simple definition of organ dysfunction. Although there are several well-known and widely used scoring systems designed to quantify the level of organ dysfunction, including the Sequential Organ Failure Assessment (SOFA) score¹⁸ and Marshall score,¹⁹ we chose to model the Denver postinjury MOF score because it is perhaps the most widely used, well validated, and easily adapted to the use of ICD-9 codes.^{13,14,20}

The results of our study highlight the striking consequences of organ dysfunction after injury. Injured patients experiencing any form of organ dysfunction were significantly more likely to die than those without organ dysfunction. Among specific organ systems, cardiac failure proved to be the most deadly with a 41.5% mortality rate. Renal failure was

associated with a 9.1% mortality but carried a greater than threefold increase in mortality when renal failure progressed to dialysis. Importantly, the mortality rate increased proportionally with an increasing number of organ systems in failure. Our series reports a mortality rate of nearly 60% for patients with three or more separate organ system failures. Previous studies have yielded similar results, with mortality rates ranging from 60% to 100% for these patients.^{2,21,22} Unfortunately, despite more than 30 years since the report of Fry et al., MOF after trauma continues to carry exceptionally high mortality rates.

We found a significantly increased rate of respiratory and cardiac dysfunction among patients cared for at a trauma center compared with those treated at a nontrauma center. The reasons for these differences are unclear, but there are several possibilities. First, they may represent different patient populations as a result of referral patterns. Field triage guidelines from the Center for Disease Control and Prevention suggest initial transport to a trauma center for multiple patient and injury characteristics including signs of shock or significant injuries to the thorax.²³ The presence of shock as well as significant chest injuries have previously been shown to correlate with an increased incidence of MOF.²⁴ Another possibility is that this represents a difference in resuscitation strategies used at trauma and nontrauma centers. Blood transfusion has been previously shown to correlate with the development of organ failure, particularly of the respiratory system.^{25,26} In a previous study by Ang et al.,²⁷ patients treated at trauma centers were more likely to receive high-volume blood transfusion. Although Ang et al. did not demonstrate a difference in MOF, respiratory and cardiac dysfunctions were not specifically examined.

While the strength of our analysis lies in the ability to generate national estimates, there are limitations associated with using nationally representative administrative data. Commonly used organ dysfunction definitions and scores rely on specific laboratory values or the presence of specific therapeutic interventions. Although we can assume that organ dysfunction will be captured by diagnostic codes, this method does not allow any gradation of the severity of dysfunction for most systems. We are also unable to differentiate timing of various organ system failures. This is potentially problematic given the well-established concept that “early” MOF during the resuscitation phase of trauma is an entity different from MOF occurring later in the posttrauma course.²⁸ Furthermore, we are unable to truly differentiate sequential organ system dysfunction and recovery from concurrent organ failure.

In our study, organ system dysfunction in some systems is better characterized by diagnostic codes compared with others. The analysis of cardiac dysfunction in this study is potentially the most problematic. Previous studies and grading systems of organ failure generally depend on the use of vasopressors as at least part of the definition for cardiac dysfunction.^{13,14,18,19}

Since this is not captured by an ICD-9 code, these data are not present in our sample. Our methods identify those patients with hypotension not caused by hemorrhagic shock. While labeling this as cardiac dysfunction may not be entirely accurate, we believe this is a reasonable approximation to the use of vasopressors. It must be noted that there is inherent difficulty in defining cardiac dysfunction even when specific vasopressor data are available.

The requirement of vasopressors to maintain blood pressure may have a variety of causes such as inadequate resuscitation, ongoing hemorrhage, or low systemic vascular resistance. All of these conditions may commonly exist in the trauma patient and lead to vasopressor use, although there is normal cardiac function. Capturing dysfunction in the remaining organ systems is aided by the presence of more specific diagnostic codes.

We describe the epidemiology of organ failure after trauma and offer the first national benchmark of organ failure rates among injured patients. We also demonstrate significant variation between trauma and nontrauma centers. Although uncommon, postinjury organ failure is associated with significantly increased mortality and mortality that increase dramatically with an increasing number of organ system failures. The development of consensus definitions of specific organ failure and diagnostic codes that can specifically identify posttraumatic organ failure would allow national databases to more accurately capture one of the most important consequences of trauma. An improved understanding of the incidence of posttraumatic organ failure would allow for the more nuanced evaluation of changing treatment paradigms and could be used as an important measure of quality for performance improvement.

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FIGURE 1.
Mortality rate by number of organ system failures.

TABLE 1**ICD-9 Diagnostic Codes to Define Organ Dysfunction**

System	ICD-9 Code	Description
Renal	586	Renal failure, unspecified
	584.9	Acute renal failure, unspecified
	593.9	Unspecified disorder of kidney
	585	Chronic renal failure (exclusion)
	39.95	Hemodialysis
Respiratory	518.4	Acute pulmonary edema
	518.5	Pulmonary insufficiency following trauma
	518.7	Transfusion related acute lung injury
	518.81	Acute respiratory failure
	518.82	Acute pulmonary insufficiency
	518.84	Acute-on-chronic respiratory failure
	518.83	Chronic respiratory failure (exclusion)
	96.7	Mechanical ventilation
Hepatic	570	Acute hepatic failure
	782.4	Jaundice, unspecified
	277.4	Hyperbilirubinemia
	571	Chronic liver disease (exclusion)
Cardiac	458	Hypotension
	785.5	Nonhemorrhagic shock
	998.0	Postoperative shock

TABLE 2

Demographics of Sample Population

	Level I/II TC	NTC	Difference
Total patients	136,597 (34.3)	259,679 (65.7)	
Bed size			$p < 0.001$
Small	4,662 (3.2)	44,415 (16.9)	
Medium	29,943 (21.9)	69,925 (27.0)	
Large	101,992 (74.9)	145,339 (56.1)	
Region			$p = 0.75$
Northeast	24,802 (19.3)	45,804 (19.2)	
Midwest	32,241 (25.1)	57,360 (22.8)	
South	48,352 (33.8)	108,430 (19.9)	
West	31,202 (21.8)	48,085 (18.1)	
Sex			$p < 0.001$
Male	79,818 (58.5)	110,922 (42.7)	
Female	56,129 (41.1)	148,244 (57.1)	
Unknown	650 (0.5)	513 (0.2)	
ISS			$p < 0.001$
1–15	116,630 (85.4)	247,884 (95.5)	
16–24	14,398 (10.5)	9,883 (3.8)	
>25	5,569 (4.1)	1,912 (0.7)	
Age, y	Mean, 52.3	Mean, 65.0	
	Median, 50	Median, 72	
	Interquartile range, 31–74	Interquartile range, 49–83	

Unweighted n (weighted %).

NTC, nontrauma center; TC, trauma center.

TABLE 3**Organ Dysfunction Prevalence Stratified by ISS**

	ISS = 1–15, %	ISS = 16–24, %	ISS > 25, %
Renal (overall) (379,420)	4.15	3.11	3.36
TC (132,344)	3.16	2.55	2.97
NTC (247,076)	4.62	3.93	4.50
Severe renal (overall) (379,420)	0.07	0.11	0.22
TC (132,344)	0.07	0.15	0.24
NTC (247,076)	0.07	0.06	0.17
Respiratory (overall) (395,739)	1.65	9.66	26.67
TC (136,472)	2.53	11.86	29.28
NTC (259,267)	1.24	6.47	19.14
Hepatic (overall) (390,796)	0.14	0.18	0.36
TC (134,906)	0.13	0.18	0.34
NTC (255,890)	0.15	0.18	0.44
Cardiac (overall) (396,276)	0.41	0.76	1.59
TC (136,597)	0.46	0.82	1.45
NTC (259,679)	0.38	0.67	1.99

NTC, nontrauma center; TC, trauma center.

TABLE 4

Organ Dysfunction Prevalence Stratified by Age (in Years)

	15–24 y	25–34 y	35–44 y	45–54 y	55–64 y	65–74 y	75–84 y	>85 y
Renal								
Weighted n (unweighted n)	188,899 (38,541)	168,368 (34,535)	180,972 (37,021)	220,503 (45,096)	196,599 (40,225)	214,330 (43,881)	369,116 (75,339)	318,281 (64,782)
Rate (overall), %	0.40	0.76	1.17	1.99	3.40	5.33	6.56	7.77
Rate (TC), %	0.39	0.69	1.01	1.90	3.07	5.53	6.52	8.22
Rate (NTC), %	0.40	0.83	1.30	2.05	3.58	5.25	6.57	7.65
Adjusted OR (95% CI)	0.84 (0.58–1.20)	0.80 (0.60–1.06)	0.79 (0.62–0.99)	1.11 (0.96–1.28)	0.96 (0.84–1.10)	1.09 (0.98–1.22)	1.02 (0.92–1.14)	1.09 (0.98–1.21)
Mortality, %	14.9	9.5	9.1	7.8	7.5	7.6	9.1	10.3
Renal (Dialysis)								
Weighted n (unweighted n)	188,899 (38,541)	168,368 (34,535)	180,972 (37,021)	220,503 (45,096)	196,599 (40,225)	214,330 (43,881)	369,116 (75,339)	318,281 (64,782)
Rate (overall), %	0.02	0.04	0.05	0.08	0.13	0.12	0.10	0.04
Rate (TC), %	0.03	0.05	0.04	0.10	0.20	0.16	0.11	0.04
Rate (NTC), %	0.02	0.03	0.06	0.06	0.10	0.11	0.09	0.04
Adjusted OR (95% CI)	* (1.43–2.83)	* (1.70–3.05)	* (1.31–2.36)	* (1.76–2.58)	2.15 (1.19–3.90)	1.25 (0.69–2.24)	1.04 (0.57–1.87)	* (1.61–2.34)
Mortality, %	30.8	30.5	22.0	16.5	33.4	36.2	38.3	37.6
Respiratory								
Weighted n (unweighted n)	189,021 (38,565)	169,095 (34,685)	183,000 (37,436)	225,253 (46,077)	205,349 (42,025)	228,888 (46,866)	394,708 (80,573)	341,525 (69,512)
Rate (overall), %	3.49	2.95	3.00	3.13	3.26	2.79	2.21	1.39
Rate (TC), %	4.99	4.36	4.57	5.06	5.51	5.19	4.33	2.58
Rate (NTC), %	1.64	1.46	1.62	1.74	2.07	1.90	1.55	1.07
Adjusted OR (95% CI)	2.01 (1.43–2.83)	2.27 (1.70–3.05)	1.76 (1.31–2.36)	2.13 (1.76–2.58)	1.81 (1.51–2.19)	1.96 (1.67–2.31)	2.08 (1.81–2.40)	1.94 (1.61–2.34)
Mortality, %	13.4	11.0	14.6	17.1	23.0	28.5	40.7	47.9
Hepatic								
Weighted n (unweighted n)	188,922 (38,545)	168,174 (34,495)	179,771 (36,775)	217,789 (44,542)	199,646 (40,861)	225,241 (46,122)	392,161 (80,055)	340,993 (69,401)
Rate (overall), %	0.08	0.11	0.13	0.15	0.15	0.18	0.20	0.13

	15–24 y	25–34 y	35–44 y	45–54 y	55–64 y	65–74 y	75–84 y	>85 y
Rate (TC), %	0.09	0.10	0.09	0.14	0.17	0.20	0.18	0.23
Rate (NTC), %	0.07	0.12	0.16	0.16	0.14	0.18	0.20	0.11
Adjusted OR (95% CI)	*	*	0.40 (0.21–0.78)	0.88 (0.53–1.44)	1.18 (0.69–2.03)	1.08 (0.66–1.79)	0.87 (0.58–1.32)	2.07 (1.35–3.19)
Mortality, %	15.3	9.9	16.5	27.0	24.8	25.0	29.5	16.0
Cardiac								
Weighted n (unweighted n)	189,080 (38,577)	169,137 (34,693)	183,058 (37,448)	225,435 (46,113)	205,735 (42,103)	229,502 (46,992)	395,584 (80,753)	341,942 (69,597)
Rate (overall), %	0.11	0.17	0.29	0.41	0.56	0.62	0.60	0.54
Rate (TC), %	0.15	0.20	0.28	0.48	0.77	0.86	0.92	0.87
Rate (NTC), %	0.06	0.13	0.29	0.36	0.45	0.54	0.50	0.45
Adjusted OR (95% CI)	*	1.16 (0.62–2.15)	0.70 (0.42–1.17)	1.28 (0.92–1.77)	1.45 (1.04–2.01)	1.27 (0.94–1.71)	1.54 (1.22–1.95)	1.79 (1.36–2.36)
Mortality, %	40.1	30.5	28.8	28.8	34.8	40.1	47.2	51.4

NTC, nontrauma center; TC, trauma center.

* The adjusted model failed to converge.

TABLE 5**Organ Dysfunction Prevalence and Associated Mortality**

	Renal	Renal (Dialysis)	Respiratory	Hepatic	Cardiac
Rate (TC), %	3.09	0.09	4.60	0.14	0.54
Rate (NTC), %	4.59	0.07	1.58	0.15	0.40
Unadjusted OR (95% CI)	0.66 (0.59–0.75)	1.26 (0.91–1.73)	3.01 (2.53–3.59)	0.96 (0.79–1.17)	1.33 (1.13–1.56)
Adjusted OR (95% CI)	1.02 (0.95–1.10)	1.25 (0.91–1.72)	2.03 (1.75–2.37)	0.97 (0.79–1.19)	1.40 (1.18–1.66)
Mortality, %	9.1	32.5	24.9	22.8	41.5

NTC, nontrauma center; TC, trauma center.