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Complication Rates among Trauma Centers

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Abstract

Background—To examine the association between patient complications and admission to level 1 trauma centers (TC) compared to non-trauma centers (NTC).

Study Design—A retrospective cohort study of data derived from the National Study on the Costs and Outcomes of Trauma (NSCOT). Patients were recruited from 18 level 1 TC and 51 NTC in 15 regions encompassing 14 states. Trained study nurses, using standardized forms, abstracted the medical records of the patients. The overall number of complications per patient was identified as well as the presence or absence of 13 specific complications.

Results—Patients treated in TC were more likely to have any complication compared to NTC with an adjusted relative risk (RR) of 1.34 (95% CI 1.03, 1.74). For individual complications, only urinary tract infection RR 1.94 (95% CI 1.07, 3.17) was significantly higher in TC. TC patients were more likely to have three or more complications, RR 1.83 (95% CI 1.16, 2.90). Treatment variables that are surrogates for markers of injury severity, such as use of pulmonary artery catheters, multiple operations, massive transfusions (> 2,500mL packed red blood cells), and invasive brain catheters, occurred significantly more often in TC.

Conclusions—Trauma centers have a slightly higher incidence rate of complications even after adjusting for patient case mix. Aggressive treatment may account for a significant portion of TC-associated complications. PA catheter use and intubation had the most influence on overall TC

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complication rates. Further study is needed to provide accurate benchmark measures of complication rates and to determine their causes.

Introduction

The American College of Surgeons (ACS) developed criteria for defining trauma centers and for regionalizing trauma care in 1976 [1, 2]. The College then began the evaluation process for designation and verification of trauma centers in 1987 [3]. Currently, 190 centers in the United States have been designated as level 1 trauma centers, of which 89 are ACS verified [1]. The slower than expected adoption of organized trauma systems in the United States was partly due to the lack of evidence to support their effectiveness. However, recent data have shown that designated level 1 trauma centers substantially improve overall survival [2–12], as well as functional outcome for some types of trauma [13–15], compared to NTC. As regionalization of trauma care evolves, careful study is required to provide both statistically sound and applicable benchmarks for potential complications associated with trauma centers and to identify significant risk contributors to trauma center-associated complications.

The current study offers insight into the risk of complications at Level 1 trauma centers. We hypothesized that there would be differences in the prevalence of complications after hospital admission to trauma centers compared with non-trauma centers. We also hypothesized that certain risk factors could be identified that are associated with these complications.

Methods

The National Study on the Costs and Outcomes of Trauma (NSCOT) was a prospective, multicenter cohort study designed to determine the effectiveness of trauma centers in urban and suburban America. Patients were recruited from 18 level 1 trauma centers and 51 non-trauma centers in 15 regions encompassing 14 states [7]. The institutional review boards for each hospital approved the study. The inclusion criteria for study patients were age 18 to 84 years and the presence of at least one injury of Abbreviated Injury Scale (AIS) score of 3 or greater. Details of patient recruitment have previously been described and published [7, 16, 17]. Patient recruitment occurred from July 2001 to November 2002. Trained study nurses used standardized forms to extract data from the medical records of study patients. These medical records were abstracted from the whole chart and data specifically documenting complications were recorded. A standardized manual for definitions of complications was used for reference. Ten percent of the charts were then randomly re-abstracted to check for accuracy.

The overall number of complications per patient was identified as well as the presence or absence of thirteen specific complications listed in table 1. The complications were defined as described below. Arrhythmia was defined as atrial, ventricular, or other types of arrhythmia including bradycardia, exclusive of sinus tachycardia. Pulmonary embolism (PE) was defined as present if one of the following criteria was met: angiographic confirmation, computed tomography evidence, or moderate to high probability on ventilation/perfusion scan. Wound infection or surgical site infection was defined by either superficial, deep or organ space infection. Deep infections were defined as present if aspirates were positive for organisms on gram stain or cultures. Pneumonia was defined by radiologic, clinical, and bacteriologic findings. Radiographically, pneumonia was defined as a new or evolving infiltrate or consolidation on chest radiograph. Clinical criteria required fever or hypothermia in addition to leukocytosis, bandemia, or leukopenia. Bacteriologic criteria required confirmation of at least one of the following: positive blood culture also identified in a respiratory culture, bronhoaveloar lavage (BAL) with greater than 10,000 colony forming units per milliliter, positive sputum gram stain with greater than or equal to 3+ of one type of bacterial, or positive gram stain from BAL fluid. Sepsis included both bacteremia and fungemia. Multiple organ

failure was defined by at least two of the following criteria beginning no earlier than 48 hours from emergency department (ED) arrival: PaO2/FiO2<300, serum creatinine >2.5 mg/dl, total bilirubin >4.0 mg/dl, or need for dopamine or dobutamine support. Acute respiratory distress syndrome and renal failure were criteria that separately met multiorgan failure. Reintubation was defined as intubation within 48 hours after extubation. Unplanned visit to the intensive care unit (ICU) was defined as an unanticipated transfer to the ICU any time during the patient's stay in the hospital. Unplanned visit to the operating room (OR) was defined as an unanticipated operation in the operating room any time during the patient's stay in the hospital. Urinary tract infections were defined as clean voided specimen with >100,000 organisms/ml or catheter urine specimen with >50,000 organisms/ml. Cardiac arrest was defined as the sudden cessation of cardiac activity, including pulseless electrical activity, after ED arrival. Coagulopathy was defined as both uncontrolled diffuse bleeding and coagulation abnormalities after 48 hours following ED arrival. Deep venous thrombosis (DVT) was defined as venous thrombosis in the lower extremity confirmed by autopsy, venogram, duplex scan, or other non-invasive vascular evaluation.

We investigated treatment variables known to be associated with complications and assessed both their frequency of use in TC versus NTC and also their contribution to the association between trauma centers and complications. These treatment variables were pulmonary artery catheter monitoring, use of intracranial pressure monitors, intubation, massive resuscitation defined as packed red blood cell (PRBC) transfusion of greater than 2,500 mL, auto-transfusion, and number of operations per patient. In addition, we examined whether or not the institution was a teaching hospital.

Data Analysis

All data were weighted to account for differential sampling by diagnosis and survival. To adjust for differences in case mix between patients treated in trauma centers (TC) compared to non-trauma centers (NTC), a propensity score for the likelihood of treatment in a TC vs NTC based on pre-hospital and injury characteristics of the patients was calculated as described previously [7]. The variables in the propensity score were: field Glasgow Coma Scale (GCS), prehospital intubation, ED GCS, Injury Severity Score (ISS), coagulopathy, blood transfusion in the first 24 hours, obesity, Charlson score [18], shock in the ED, midline intracranial shift, flail chest, open skull fracture, paralysis, long bone fracture or amputation, maximum AIS, New Injury Severity Score (NISS), age, gender, ethnicity, max AIS thorax, max AIS abdomen, max AIS head, max AIS extremity, and insurance status. Initially, both the type and number of complications were analyzed without propensity score adjustment. Propensity score adjustment was then done to adjust for differences in case mix between trauma centers and non-trauma centers. Poisson regression analysis was used to calculate relative risks. Multiple imputation techniques using 10 datasets were used to impute missing data for some covariates [19]. The percentage of missing data for these covariates ranged between 0.2% and 16.6%. Estimates and standard errors were computed using Rubin's combining rules [20]. Robust standard errors were computed to account for clustering within hospitals. All analyses were performed using data weighted to the population of eligible patients.

Subgroup analysis was performed on treatment variables that were more common in TC. We examined the association between use of pulmonary artery catheters and calculated risks among known associated complications.

Analyses were conducted using SAS (SAS version [9.1] of the SAS System for [Unix]. Copyright © 2006 SAS Institute Inc., Cary, NC, USA.) and STATA (StataCorp. 2005. *Stata Statistical Software: Release 9*. College Station, TX: StataCorp LP.).

Using the mediation of proportion method [21], we determined how much of the effect of the exposure on the outcome was due to the treatment variable. This approach uses structural equation models in which the relative size of the regression coefficients for various relationships measures the effect of the intermediate variable (treatment variable) on the association of interest (trauma center-associated complications) [21].

Results

After the prehospital propensity adjustment was performed, nearly all of the socio-demographic and injury characteristics of the patient mix between TC and NTC were similar (Table 2). Overall, there were 1,999 patients in the study admitted to trauma centers and 3,044 admitted to non-trauma centers, representing 14,477 weighted patients. In TC and NTC, 29.0% and 15.7% of patients, respectively, had at least one of the 13 complications. The average incidence of complications was significantly greater in TC compared to NTC with incidence rate ratio (IRR) 1.34 (95% CI 1.03, 1.74). The number of patients with three or more complications was also significantly greater in TC (Table 1). The most frequent complications were pneumonia, urinary tract infections, multi-organ failure, unplanned ICU visits, and cardiac arrhythmias. One-fourth of all patients had one or more complications, while 6.2% of patients had 3 or more complications (Table 1). Most individual complications were more frequent in TC; however, only urinary tract infection was significantly more common in TC (RR 1.85, 95% CI 1.07, 3.17).

Since the complications with the largest relative risk estimates in TC were DVT and PE, we examined DVT screening, prophylaxis, and treatment practices in TC. TC were more likely to treat patients with both sequential compression devices and low molecular weight heparin prophylaxis when compared to NTC, 42% vs. 15%, RR 2.57 (95% CI 1.90, 3.47). Screening measures, such as ultrasound, for DVT were also more common in TC than NTC, 25.2% vs. 7.9% (RR 2.87, 95% CI 1.47, 5.58). However, the rate of inferior vena cava (IVC) filter use was not significantly different between TC and NTC, 5.3% vs. 10.3%, respectively (RR 0.68, 95% CI 0.27, 1.68).

To examine whether certain treatment variables were associated with the greater risk of complications in TC, we compared the frequency of these variables between TC and NTC. As shown in table 3, pulmonary artery catheters, ICP monitors, massive transfusions, and numbers of operations per patient were significantly more common in TC compared to NTC.

Placement of pulmonary artery catheters was associated with higher risk of arrhythmias, pulmonary embolism, and cardiac arrest among trauma patients regardless of type of center (Table 4).

Multiple operations were associated with wound infection in only NTC (RR 1.50, 95% CI 1.21, 187). There was no significant association between multiple operations and wound infections in TC (RR 1.05, 95% CI 0.83, 1.32).

Using the mediation of proportion method to estimate the contribution of each treatment variable on the overall complication rate, we determined that of all the treatment variables that were more frequent in TC, intubation and pulmonary artery catheters had the largest influence on the overall incidence of TC associated complications. Table 5 illustrates, in a step-wise fashion, the contribution of each treatment variable on the overall complication risk. As each treatment variable is added, the overall relative risk of complications in TC decreases. Thus, the higher frequency of the treatment variables is associated with the higher complication rate in TC compared to NTC.

Discussion

Level 1 trauma centers have been shown to improve survival from serious trauma [2–17]. As a result we expect that, at baseline, TC patients will have a higher risk of complications, because survivors of severe injuries tend to be more critically ill. Some studies have shown that advanced age, decreased mobility, and poor GCS are also risk factors for complications [22]. We compensated for potential risk factors in our analysis by adjusting the crude patient case mix between TC and NTC until socio-demographic and injury characteristics were similar. Despite having similar case-mix of patients, our results show that the overall incidence of complications remains slightly higher in TC.

Complications may arise from differences in either medical practice or patient disease[23]. By adjusting *a priori* for possible differences in patient disease, injury, and socio-demographic characteristics, our results suggest that the higher rate of complications may stem from differences in medical practices. This may be explained by the fact that TC had a significantly higher frequency of more invasive or aggressive procedures (Table 3). These findings are consistent with very recent studies that have suggested that overly aggressive care is associated with poorer outcomes[24, 25].

These treatment variables are associated with known complications regardless of trauma center designation. In addition the positive benefits on outcome of these procedures have been questioned. For example, the efficacy of the pulmonary artery (PA) catheter has been a controversial issue with conflicting data [26–29]. As demonstrated elsewhere, we showed that PA catheter use had a statistically significant association with complications such as arrhythmias [30], cardiac arrests, and pulmonary embolism [31].

Multiple operations, particularly urgent reoperations of the abdomen, have been correlated with increased morbidity and mortality [32–34], but data are scarce concerning the correlation between number of surgeries during a single hospital admission and complications. In our study having two or more operations was associated with increased risk of mortality only in NTC.

Massive transfusion (> 2500 mL PRBC in the first 24 hours) was significantly more common in TC. Known complications associated with massive blood transfusions such as single [35] or multi-organ failure [36] were not significantly higher in TC compared to NTC. The correlation between moderate to massive blood transfusion and outcomes such as sepsis and coagulopathy demonstrated in prior studies was not evident in our study [37].

We weighed the treatment variables' individual influences on the overall complication rate by using the mediation of proportion method. The treatment variables were treated as intermediate variables in the pathway between the exposure of interest (TC versus NTC) and the outcome of interest (overall complication rate). This method revealed that both PA catheter use and intubation had the largest influence on the higher TC associated complication rate. By identifying the significant contributors to TC-specific complications, this analysis provides more useful and specific targets for potential interventions to improve complication rates at trauma centers. Central line complications and ventilator associated pneumonia are well known consequences that occur frequently in all intensive care units. Dedicated central line teams, better decision making on timing of PA catheter placement, and appropriate interpretation and use of PA catheter derived parameters may aid in limiting complications. Expeditious extubation, daily spontaneous breathing trials, and protocol driven weaning and aspiration precautions may help with intubation centered complications.

The significance of UTI in trauma centers warrants further investigation in the use of urinary catheters and their management. While treating UTI may not affect the overall complication rate, this is a complication that is easily correctable. Factors that may be important in preventing

urinary tract infections include location of placement, duration, number of recatheterizations, obstruction, and type of catheter [38, 39]. We did not further study due to lack of adequate denominator data, such as number of catheter days, for comparing TC and NTC.

This study had several limitations. First, we were unable to infer causation among the various associations between treatment variables and complications due to uncertainty about the timing of events. For example, we know that PA catheter use can lead to DVT, which can then lead to pulmonary embolism. Conversely, pulmonary embolism can cause hemodynamic instability which may require PA catheter monitoring. Another limitation is that the higher TC associated complication rates, regardless of *a priori* adjustment, may be due to the epidemiological phenomenon of competing risks. It is possible that the higher rate of complications in TC is due to longer time at risk for complications in TC patients compared with NTC patients. However, time to complication data was not available in this dataset, and thus, we were unable to adjust complication rates for the effect of time at risk. Screening practices and diagnostic methods may bias complications to appear more often in TC. For example, TC were more likely to screen for and detect DVT by means of ultrasound and, perhaps, appear to have higher rates of DVT compared to NTC. This has been suggested in prior research as a potential bias[40].

Furthermore, despite efforts to adjust for patient disease, injury, and socio-demographic characteristics, it is possible that certain markers of injury severity were not accounted for in our model. We used the treatment variables as measures of differences in practice; however these treatment variables may continue to reflect the severity of a patient's illness if the prehospital propensity adjustment failed to capture influential mechanisms of injury severity. In addition, TC patients had a higher risk of developing three or more complications. The higher complications may reflect a worse initial disease state, lending support to the possibility that TC patients may be intrinsically different than NTC.

Conclusion

Trauma centers have a slightly higher incidence rate of complications. These complications are associated with and may be due to more aggressive treatment variables in trauma centers. It is not clear whether these specific treatment variables are actual indicators of severity of illness that cannot be accounted for by conventional adjustment, by intrinsic differences between TC patients and NTC patients, or by true differences between TC and NTC in clinical practice patterns. This study has provided methodology to benchmark complication rates and to examine the contribution of certain variables to exposure specific outcomes. Prospective studies are needed to further investigate and determine the causes of higher complication rates at trauma centers.

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Table 1

Prevalence and Unadjusted / Adjusted Relative Risk of Complications in Trauma Center and Non-Trauma Center Patients

Complications	Total%	TC%	NTC%	Unadjusted RR(95% CI) TC versus NTC	Adjusted* RR(95% CI) TC versus NTC
Pneumonia	10	12.0	4.7	2.55(2.20,2.96)	1.31(0.99,1.72)
>/= 3 of the 13 complications	6.2	7.9	1.9	4.25(3.36,5.37)	1.83(1.16,2.90)
Urinary tract infection	5.5	6.3	3.5	1.81(1.51,2.16)	1.85(1.07,3.17)
Multi-organ failure	4.5	5.5	1.8	3.01(2.37,3.82)	1.46(0.71,3.01)
Unplanned ICU visits	4.3	4.8	3.0	1.62(1.33,1.97)	1.23(0.84,1.82)
Arrhythmias	3.8	4.3	2.5	1.74(1.40,2.15)	1.46(0.91,2.34)
Sepsis	3.7	4.5	1.7	2.60(2.03,3.33)	1.54(0.89,2.66)
Reintubation	3.6	4.6	1.2	3.92(2.91,5.26)	1.14(0.77,1.69)
Wound infection	2.8	3.4	1.2	2.96(2.18,4.01)	0.70(0.39,1.26)
Unplanned operation	2.8	3.3	1.5	2.22(1.69,2.92)	1.03(0.55,1.92)
Cardiac arrest	2.8	3.2	1.7	1.83(1.42,2.37)	0.78(0.51,1.20)
Deep venous thrombus	2.5	3.3	0.6	5.31(3.54,7.95)	2.37(0.69,8.11)
Coagulopathy	1.3	1.5	0.7	2.16(1.44,3.22)	1.29(0.53,3.14)
Pulmonary embolus (not including fat embolus)	0.8	0.9	0.5	1.70(1.07,2.71)	1.84(0.70,4.83)

*Adjusted by propensity score for admission to a trauma center vs. non-trauma center.

NTC, non-trauma center; TC, trauma center.

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Table 2

Sociodemographic and Injury Characteristics of Trauma Center and Non-Trauma Center Patients

	Before adjustment , %		After adjustment, %	
	TC	**NTC**	**TC**	**NTC**
Age, y				
<55	73.6	48.3	67.4	73
55–64	10.6	13.9	11.1	9.7
65–74	8.5	11.2	9.7	8.1
75–84	7.4	26.7	11.9	9.3
Gender				
Male	71.3	56.4	68.4	70.8
Female	28.8	43.6	31.6	29.2
Race				
Hispanic	17.3	11.2	15.7	16.3
Non-Hispanic, Caucasian	57.8	65.6	61	51
Non-Hispanic, non-Caucasian	25	23.3	23.3	32.7
Health insurance before injury				
None	27.9	16	24.5	27.3
Medicare only	10.2	26.9	14.7	12.8
Medicare plus private insurance	9.8	16.1	11.5	7.2
Private insurance	39.6	26.1	37	34.8
Medicaid	9.4	10.1	9	13
Other	3.2	4.9	3.3	5
Charlson comorbidity index score				
0	71.9	46	66.1	72
1	16.4	19.2	18	11.9
2	5	9.6	6.6	4.7
>=3	7.7	25.2	9.3	11.4
Injury mechanism				
Penetrating	16.3	8.7	14.2	20.8
Blunt	83.7	91.3	85.8	79.2
New injury severity score				
<16	10.6	35.8	15.9	12.3
16–24	16.8	15.7	17.9	15.1
25–34	22.8	16.3	21.3	18.3
>34	49.8	32.2	44.9	54.3

NTC, non-trauma center; TC, trauma center.

Table 3

Frequency of different treatment variables in trauma centers and non-trauma centers after propensity adjustment

Treatment variable	n (weighted)	After propensity adjustment		
		NTC, %	TC, %	p Value
ICU status	2999 (7462)	54.5	53.2	0.76
Pulmonary artery catheter	615 (1454)	5.7	11.4	0.001
Invasive brain catheter	448 (1069)	4.6	7.7	0.003
Intubation	1322 (3177)	20.9	23.3	0.56
PRBC units transfused				
<6	4476 (13238)	93.7	90.9	
>=6	568 (1240)	6.3	9.1	
PRBC > 2500cc	322 (677)	2.7	5.0	0.02
Autotransfusion	102 (277)	2.2	1.9	0.69
Residents	3637 (10805)	45.4	86.3	0.07
PRBC cc	5043 (14477)	292.0(2358.3)*	412.0(2450.5)*	0.06
Operations per patient	5043 (14477)	1.7(7.3)*	2.4(8.2)*	0.01

*Values are mean (SD).

Table 4

Complications Associated with Pulmonary Artery Catheter Use

	Trauma Center RR (95% CI)	Non-trauma Center RR (95% CI)
Arrhythmias	4.53 (2.16, 9.51)	7.03 (2.30, 21.42)
Pulmonary Embolus	3.83 (1.5,9.77)	4.51 (0.88, 23)
Cardiac Arrest	5.32 (3.30,8.56)	10.68(6.06,18.83)
Deep Vein Thrombosis	5.79 (3.07,10.93)	NA

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Table 5

Quantifying the Influence of Treatment Variables on Complication Outcomes of Trauma Centers

Population modified by treatment variables	RR (95% CI)
No adjustment	2.35 (1.82,3.04)
Propensity adjustment only	1.35 (1.04,1.75),
Propensity adjustment +ICU patients	1.33 (1.02,1.73),
Propensity adjustment +ICU patients+intubation	1.24 (0.95,1.62),
Propensity adjustment +ICU patients+intubation+pulmonary artery catheters	1.17 (0.89,1.54),
Propensity adjustment + ICU patients+intubation+pulmonary artery catheters +invasive brain catheter	1.17 (0.89,1.54),
Propensity adjustment + ICU patients+intubation+pulmonary artery catheters +invasive brain catheter +residents	1.20 (0.85,1.71),
Propensity adjustment + ICU patients+intubation+pulmonary artery catheters +invasive brain catheter +residents +operation	1.18 (0.84,1.68),
Propensity adjustment + ICU patients+intubation+pulmonary artery catheters +invasive brain catheter +residents +operation + PRBC cc	1.16 (0.82,1.63)
Propensity adjustment + ICU patients+intubation+pulmonary artery catheters +invasive brain catheter +residents +operation + PRBC cc + autotransfusion	1.15 (0.82,1.62),