Prevention of Complications and Successful Rescue of Patients With Serious Complications: Characteristics of High-Performing Trauma Centers

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Background: "Failure to rescue" patients with complications is a factor contributing to high mortality rates after elective surgery. In trauma, where early deaths are the primary contributors to a trauma center's mortality rate, the rescue of patients with complications might not be related to overall trauma center mortality. We assessed the extent to which trauma center mortality was reflected by the center's ability to rescue patients with major complications.

Methods: Data were derived from the National Trauma Databank, and limited to adults with an Injury Severity Score ≥9 and to centers with adequate complication reporting. Regression models were used to produce center-level adjusted rates for mortality and complications. Centers were ranked on their adjusted mortality rate and divided into quintiles.

Results: Of 76,048 patients, 9.6% had a major complication and 7.9% died. The mean complication rate in the quintile of centers with the highest mortality rates was 11.1%, compared with 7.7% in the quintile of centers with the lowest mortality rates ($p = 0.03$). In addition, mortality among patients with complications differed significantly across quintiles. The mean mortality among patients with complications was 20.3% in the quintile of centers with the highest overall mortality rates, compared with 11.1% in the quintile of centers with the lowest overall mortality rates ($p < 0.001$).

Conclusions: Unlike reports from elective surgery, complication rates after severe injury differ across centers and parallel mortality rates. Centers with low overall mortality are more successful at rescuing patients who experience complications. A lower risk of complications and better care of those with complications are both at play in high-performing trauma centers.

Key Words: Complications, External benchmarking, Quality improvement.

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Acute care hospitals must meet standardized criteria and undergo a rigorous process of external verification before becoming designated trauma centers.[1] Despite this verification process, which aims to ensure consistent, high quality care for all injured patients, mortality varies considerably across trauma centers.[2,3] Recognition of variation in performance across trauma centers has led the American College of Surgeons Committee on Trauma to establish the Trauma Quality Improvement Program. This external benchmarking program compares risk-adjusted mortality across trauma centers and has, as its vision, to improve quality of care through the identification of structures and processes of care associated with high performing centers.[2,3] However, those most relevant to reducing mortality and morbidity after severe injury remain to be identified.

Previous reports in the elective surgical setting suggest that variations in the management of surgical complications contribute significantly to the differences in postoperative mortality rates observed across centers.[4,5] Specifically, although complication rates after elective surgery are relatively stable across centers, the mortality associated with these complications appears to vary considerably across institutions.[4,5] These findings support the hypothesis that a center's ability to identify and "rescue" patients with postoperative complications is associated with improved performance, and "failure to rescue" patients with complications accounts for a substantial proportion of postoperative deaths.

Complications after trauma center admission increase patient morbidity, mortality, and hospital costs[6–8] but the extent to which the failure to rescue these patients contributes to variations in mortality across centers is not clear. In contrast to elective surgical procedures, there are several reasons why variations in mortality rates among patients with complications might be unrelated to overall trauma center mortality. First, the majority of deaths in trauma occur in the hours immediately after injury, which suggests that deaths among patients with complications might play a relatively minor role in a trauma center's mortality rate.[9] Moreover, the overall rate of complications among injured patients, and opportunities for prevention of these complications, differs markedly from those seen in the elective setting. Finally, outcomes after trauma-related complications may be less modifiable, and rescue of patients may therefore be unrelated to overall quality of care. Given these uncertainties, we set out to evaluate trauma centers' ability to rescue patients with complications to determine whether this was a factor explaining variations in mortality rates across centers.

PATIENTS AND METHODS

We performed a retrospective cohort study of severely injured patients in the National Trauma Databank (NTDB) of the ACS, and evaluated the relationship between trauma center complication rates, overall mortality rates and the mortality rates among patients with complications.

Inclusion and Exclusion Criteria

Level I and II trauma centers with ACS or state designation and contributing data to NTDB (version 8.2) in 2007 were included. We limited our analyses to centers contributing at least 200 patients to the cohort. In addition, centers were limited to those contributing Abbreviated Injury Scale (AIS) scores for at least 90% of patients and comorbidities for at least 20% of patients, to ensure robust risk adjustment. As one of the primary objectives of this study was to assess the relationship between hospital mortality and complication rates, centers that did not report at least one pneumonia or urinary tract infection were excluded.

At eligible centers, we identified patients aged 16 years and older with an Injury Severity Score (ISS) of ≥9. Patients with an Emergency Department (ED) discharge disposition of dead on arrival were excluded. Patients injured as a result of poisoning, suffocation, drowning, overexertion, environmental causes or burns were also excluded. We excluded patients aged 65 years and older with isolated hip fractures as a consequence of a fall, as inclusion of these patients in trauma registries varies across centers.[10] Patients with isolated hip fractures were identified as those having AIS 98 codes corresponding to hip fractures (851810.3, 851812.3, and 851818.3) in the absence of other significant injuries.

Major complications were identified among patients surviving at least 2 days. Patients with a length of stay of 1 day were not included in calculations of complication rates. A major complication was defined as systemic sepsis, pneumonia, pulmonary embolism, acute respiratory distress syndrome, acute renal failure, or cardiovascular complication (cardiac arrest, myocardial infarction, and cerebrovascular accident). These complications have previously been identified as having the highest attributable mortality among trauma patients.[6] ICD-9 diagnoses were used to supplement information coded in the NTDB complications field.[6]

Study Outcomes

Risk-adjusted mortality rates were calculated for each center. First, a logistic regression model was developed to predict the expected number of deaths at each center, after adjustment for baseline patient and injury characteristics. This model incorporated patient age, gender, race, number of comorbidities, mechanism of injury, ISS, motor Glasgow Coma Scale (mGCS) score in the ED, shock in the ED (systolic blood pressure <90 mm Hg), transfer status, and severe injury (AIS ≥3) in the head, chest and abdominal regions.

The predicted probability of death for each patient was summed at the center level to obtain a predicted mortality rate for each center. In addition, the predicted number of deaths at each center was compared with the observed number of deaths, producing an observed to expected (O/E) mortality ratio. Each center's O/E mortality ratio was multiplied by the overall mortality rate in the study cohort to yield a risk-adjusted mortality rate at each center. Finally, centers were divided into quintiles of risk-adjusted mortality.

In addition to mortality rates, risk-adjusted complication rates were calculated across centers. Although in previous reports examining the relationship between center mortality rates and complication rates, complication rates were not risk-adjusted,[4,5] the possibility of a heterogeneous case mix across centers in the present study necessitated adjustment of complication rates to account for relevant confounders. In addition, previous reports suggest that the absence of appropriate risk adjustment can lead to spurious associations between hospital mortality rates and complication rates.[11] To calculate risk-adjusted complication rates, a logistic regression model predicting the expected number of major complications at each study center was developed. In addition to the covariates included in the regression model for mortality, patients' pre-existing comorbid conditions, as defined in the National Trauma Data Standard, were also included. Comorbidities included in the model included cardiovascular comorbidities (congestive heart failure, angina, myocardial infarction, and hypertension), pulmonary comorbidities, diabetes mellitus, chronic renal failure (requiring or on dialysis), alcoholism, and obesity. Using this model, an O/E complication ratio was derived for each center, and was used to calculate risk-adjusted complication rates for each institution.

Finally, a third logistic regression model was constructed to calculate the predicted probability of death among patients who experienced a complication. Covariates included in this model were age, gender, race, mechanism of injury, ISS, mGCS score in the ED, shock in the ED, transfer status and severe injury (AIS ≥3) in the head, chest and abdominal regions. In addition, pre-existing comorbidities (cardiovascular comorbidities, pulmonary comorbidities, neurologic comorbidities, diabetes mellitus, chronic renal failure, alcoholism, obesity and malignancy) were included in the model. Risk-adjusted mortality among patients with complications was calculated for each center, using the same strategy as described previously.

We considered the possibility that differences in the incidence of complications across centers, rather than differences in the management of complications, might largely explain differences in mortality across hospitals. If this were the case, adjusting for the incidence of a complication would reduce variations in mortality rates across centers. With this hypothesis in mind, we reproduced our calculations of hospital risk-adjusted mortality, with and without incorporating the incidence of complications in our risk adjustment model.

Comparison of Outcomes Across Centers

Quintiles of risk-adjusted hospital mortality were used as the basic unit of hospital performance. Mean risk-adjusted complication rates, as well as mean risk-adjusted mortality rates among patients with a complication, were then compared across quintiles of overall hospital mortality. In addition, mortality rates adjusted for the incidence of complications were compared across quintiles of overall hospital mortality.

Statistical Analysis

At the patient level, means and standard deviations were calculated for continuous variables and absolute and relative frequencies were measured for discrete variables. Given the large sample sizes, comparisons across groups will virtually always result in p values <0.05 for differences that will be of no clinical significance. Thus, continuous and categorical variables were compared using the standardized difference. Standardized difference of $<10\%$ represents negligible imbalance in the covariate across groups.[12,13] At the institution level, medians and interquartile ranges were calculated for continuous variables and absolute and relative frequencies were measured for discrete variables. Medians were compared using the Kruskal-Wallis test, and proportions were evaluated using the χ^2 test. Mortality and complication rates across quintiles were compared using two-way analysis of variance; p values of <0.05 were considered statistically significant.

Risk-adjustment models were developed with logistic regression using the covariates described above. Shock status and mGCS was missing for 3% and 9% of patients, respectively; missing values were estimated using single imputation. Model discrimination was estimated using the c-statistic. The c-statistic (area under the receiver operating characteristic curve) was 0.9 for overall mortality (excellent discrimination), 0.8 for complications (good discrimination) and exceeded 0.7 for mortality among patients with complications (fair discrimination). Adequacy of model calibration was demonstrated using calibration curves. All data were analyzed using SAS (version 9.1, Cary, NC).

RESULTS

We identified 76,048 patients across 115 Level I and Level II centers. The overall mortality rate in our patient population was 7.9% (n = 5,980), and the rate of major complications was 9.6% (n = 7,274). The most frequent complications were pneumonia (5.9%), acute respiratory distress syndrome (2.4%), and sepsis (1.8%). The least common complications were cardiovascular complications (1.8%), acute renal failure (1.2%), and pulmonary embolism (0.7%). Centers were divided into quintiles of performance based on risk-adjusted mortality rates. When comparing patients at centers in the highest and lowest quintiles of mortality, they differed significantly in age and in the frequency of comorbidities, race, transfer status, and mechanism of injury (Table 1). However, across quintiles, there were no significant differences in injury severity, mGCS, incidence of shock or severe injury in the head, chest, or abdomen region (Table 2). Finally, to assess whether the case mix was comparable across quintiles of hospital performance, we compared the mean predicted mortality rates across quintiles. There was no statistically significant difference in mean predicted mortality rates across quintiles (Table 3), suggesting that the probability of death across the quintiles should be the same, which reflects that any observed differences in case mix across quintiles do not contribute to differences in mortality.

TABLE 1. Baseline Patient Characteristics

	Quintile of Center Performance					
	Lowest Mortality	2	3	4	Highest Mortality	Standardized Difference (%)*
Number of patients	14,754	18,209	14,231	14,992	13,862	
Mean age (SD) (yr)	47 (21)	46 (21)	46 (21)	44 (21)	44 (20)	14.6
Male gender (%)	10,045 (68)	12,419 (68)	9,927 (70)	10,711 (71)	9,729 (70)	4.3
Race (%)						
White	9,747 (66)	13,773 (76)	9,211 (65)	8,814 (59)	8,311 (60)	12.5
Black	1,181 (8)	1,522 (8)	1,712 (12)	3,463 (23)	1,897 (14)	19.3
Other	1,802 (12)	2,364 (13)	1,246 (9)	1,415 (9)	1,032 (7)	17.1
Missing	2,024 (14)	550 (3)	2,062 (14)	1,300 (9)	2,622 (19)	13.5
Comorbidities (%)						
0	8,786 (60)	11,621 (64)	10,038 (71)	9,269 (62)	9,021 (65)	10.3
1	3,767 (26)	4,066 (22)	2,753 (19)	3,649 (24)	3,322 (24)	4.6
≥2	2,201 (15)	2,522 (14)	1,440 (10)	2,074 (14)	1,519 (11)	11.9
Transfer patients (%)	5,174 (35)	4,767 (26)	4,089 (29)	3,255 (22)	3,298 (24)	24.3
Injury mechanism (%)						
MVC	7,022 (48)	9,620 (53)	7,200 (51)	7,419 (49)	7,481 (54)	12.0
Fall	5,159 (35)	5,496 (30)	4,241 (30)	3,911 (26)	3,607 (26)	18.0
Other blunt	1,538 (10)	1,652 (9)	1,493 (10)	1,506 (10)	1,465 (11)	3.3
Stabbing	383 (3)	551 (3)	400 (3)	539 (4)	390 (3)	0
Firearm	652 (4)	890 (5)	897 (6)	1,617 (11)	919 (7)	13.2

MVC, motor vehicle crash.
* Standardized difference was calculated for values across quintiles with lowest and highest mortality.

TABLE 2. Injury Severity

	Quintile of Center Performance					
	Lowest Mortality	2	3	4	Highest Mortality	Standardized Difference (%)*
Number of patients	14,754	18,209	14,231	14,992	13,862	
ISS (%)						
9–15	7,615 (52)	9,109 (50)	7,424 (52)	7,558 (50)	7,319 (53)	2.0
16–25	5,120 (35)	6,481 (36)	4,837 (34)	5,053 (34)	4,711 (34)	2.1
26–47	1,837 (12)	2,397 (13)	1,778 (12)	2,090 (14)	1,611 (12)	0
48–75	182 (1)	222 (1)	192 (1)	291 (2)	221 (2)	8.2
ED motor GCS (%)						
5–6	12,561 (85)	15,623 (86)	12,320 (87)	12,713 (85)	11,840 (85)	0
3–4	348 (2)	374 (2)	305 (2)	428 (3)	408 (3)	6.4
1–2	1,845 (13)	2,212 (12)	1,606 (11)	1,851 (12)	1,614 (12)	3.0
Shock in ED (%)	630 (4)	1,090 (6)	740 (5)	1,117 (7)	788 (6)	9.2
Severe injury AIS ≥3 (%)						
Head	5,846 (40)	7,174 (39)	5,469 (38)	6,053 (40)	5,511 (40)	0
Chest	4,318 (29)	6,166 (34)	4,678 (33)	4,975 (33)	4,503 (32)	6.5
Abdomen	1,109 (8)	1,496 (8)	1,131 (8)	1,360 (9)	999 (7)	3.8

* Standardized difference was calculated for values across quintiles with lowest and highest mortality.

TABLE 3. Trauma Center Outcomes by Quintile of Mortality

	Quintile of Center Performance					
	Lowest Mortality	2	3	4	Highest Mortality	*p*
Number of centers	23	23	23	23	23	
Mean predicted mortality (%)	7.1	7.8	7.6	8.2	7.1	0.233
Mean risk-adjusted mortality (%)	5.5	6.9	7.8	8.8	10.4	<0.001
Mean risk-adjusted complication rate (%)	7.7	8.3	9.7	10.6	11.1	0.026
Patients who experienced a complication						
Mean predicted mortality (%)	17.7	16.2	16.4	16.5	15.3	0.095
Mean risk-adjusted mortality (%)	11.1	11.8	15.8	18.3	20.3	<0.001

Mean predicted mortality: mean of centers' predicted mortality rates, as predicted through logistic regression.
Mean risk-adjusted mortality: mean of centers' observed, risk-adjusted mortality rates.

Having compared the patient and injury characteristics of patients across performance quintiles, we compared mortality and complication rates across quintiles. Risk-adjusted mortality rates at individual centers ranged from 0.7% to 12.7%. We examined mean risk-adjusted mortality across quintiles of trauma center performance, and identified clinically significant differences (Table 3). Although the mean adjusted mortality rate for centers in the highest performing quintile was 5.5%, centers in the quintile of lowest performance had a mean adjusted mortality rate of 10.4% ($p < 0.001$). Risk-adjusted complication rates at individual centers ranged from 1.7% to 21.1%. There were significant variations in mean risk-adjusted complication rates across quintiles of overall mortality. The mean adjusted complication rate in the highest performing quintile was 7.7%, compared with 11.1% in the lowest performing quintile ($p = 0.026$), suggesting that high performing centers had both lower mortality rates and lower complication rates.

Given the differences observed in both mean risk-adjusted mortality rates and mean risk-adjusted complication rates across quintiles of hospital performance, it is plausible that differences in mortality rates across centers are due to differing rates of complications. To test this hypothesis, we calculated risk-adjusted mortality rates for each center, with and without incorporating the occurrence of a complica-

TABLE 4. Mortality With and Without Adjustment for Complications

	Quintile of Center Performance					
	Lowest Mortality	2	3	4	Highest Mortality	*p*
Number of centers	23	23	23	23	23	
Mean risk-adjusted mortality (%)	5.5	6.9	7.8	8.8	10.4	<0.001
Mean risk-adjusted mortality, including complications in the model (%)	5.5	6.9	7.8	8.8	10.4	<0.001

TABLE 5. Trauma Center Characteristics by Quintile of Mortality

	Quintile of Center Performance					
	Lowest Mortality	2	3	4	Highest Mortality	*p*
Number of centers	23	23	23	23	23	
Median number of patients (IQR)	502 (340)	638 (756)	493 (406)	466 (474)	516 (589)	0.352
Level of designation						0.409
Level I	12	15	14	11	9	
Level II	11	8	9	12	14	
Academic status						0.677
University affiliated	7	12	9	9	9	
Non-university affiliated	16	11	14	14	14	
Hospital type*						0.239
For profit	2	0	3	0	2	
Nonprofit	21	23	20	23	20	

IQR, interquartile range.
* Hospital type for one center not known.

tion as a covariate. Adjusting for the incidence of complications did not decrease the significant variation in mean risk-adjusted mortality rate across quintiles of hospital performance (Table 4), suggesting that variations in mortality rates across centers are not explained entirely by differences in rates of complications.

To determine whether high performing centers had lower mortality rates as a function of their ability to rescue patients after a complication, we examined outcomes among patients who experienced at least one complication (Table 3). Among all patients that experienced a complication, mortality was 16.2% (n = 1,181). Risk-adjusted mortality among patients with complications varied significantly across quintiles of overall trauma center mortality. The mean risk-adjusted mortality rate after complications ranged from 11.1% in the quintile of centers with the highest performance, to as high as 20.3% in the quintile of centers with the lowest performance ($p < 0.001$), suggesting that at least in part, higher performing centers had lower mortality rates due to a lower incidence of death after severe complications.

We considered the possibility that center-level characteristics may be related to differences in mortality rates and complication rates across quintiles of hospital performance. We examined the distribution of patient volume, level of designation, teaching status, and hospital type across quintiles of hospital performance (Table 5). There was no significant variation in any of these hospital-level characteristics across quintiles of hospital performance.

DISCUSSION

Trauma center mortality varies significantly across institutions, leading to clinically relevant discrepancies in patient mortality between high- and low-performing centers. Although programs like the Trauma Quality Improvement Program aim to identify best practices at high performing centers, and disseminate these practices across all institutions, the types of practices which lead to significantly improved hospital performance are poorly understood. Previous reports indicate that, in the elective surgical setting, the outcomes of patients who experience in-hospital complications are closely linked to a hospital's overall performance, as measured by mortality. Specifically, although patients at both high and low performing hospitals experienced post-operative complications with equal frequency, high performing hospitals are characterized by lower mortality rates associated with these complications.[4,5]

In this study, we examined the association between trauma center mortality rates, complication rates and mortality rates among patients who experience complications. In contrast to the elective surgical setting, we discovered significant variations in complication rates between high and low mortality centers; centers with the lowest mortality had a 30% lower complication rates than centers with the highest mortality rates. Adjusting for the incidence of complications did not reduce this discrepancy in mortality rates observed between high- and low-performing centers. Furthermore, the mortality among patients who experienced a complication differed widely across centers. Mortality among patients with complications was almost twice as high at low-performing centers when compared with high performing centers. Together, these data strongly suggest that high-performing trauma centers are better at preventing or avoiding complications. In addition, when a complication does occur, successful rescue of those who experience a complication reduces the mortality rate within these high quality centers. These two factors contribute to, and account for, a substantial portion of the variation in mortality observed across trauma centers. In addition, our findings imply that processes of care which aid in the prevention and early recognition of complications, as well as those that enable the rescue of patients with complications, likely contribute to overall trauma center performance.

Given the wide variation of complication rates and failure to rescue rates observed in this study, our data suggest that, among severely injured patients, a significant proportion of complications, and deaths after complications, are potentially preventable through high quality care. Indeed, prospectively collected data suggest that errors in trauma care are common; one study demonstrated that error-free care was delivered to only 61% of patients and that errors in judgment and delays in diagnosis accounted for 70% of errors.[14] Our data suggest that ineffective prophylaxis and delays in diagnosis of complications, in addition to delayed diagnosis of injuries, may be occurring at lower performing centers. In addition, a number of specific mechanisms may account for the observed differences across centers in complication rates and failure to rescue rates. First, an intensivist model of critical care delivery may be relevant to all outcomes studied. This model of critical care delivery has previously been associated with reduced mortality after injury.[15] Furthermore, an intensivist staffing model has been linked to a reduced incidence of complications[16–18] and an increased use of evidence-based interventions, such as deep vein thrombosis and stress ulcer prophylaxis, spontaneous breathing trials, and interruption of continuous sedation.[19] As such, models of critical care staffing and care may contribute to the observed link between hospital mortality, complication rates, and failure to rescue rates seen in our patient population. Another potential variable which could account for variation in mortality and morbidity seen in our study is the aggressiveness or invasiveness of interventions. This facet represents a delicate clinical balance and is analogous to standing at the edge of the Grand Canyon. Increased use of aggressive interventions has been demonstrated to be associated with increased hospital mortality and may also be associated with an increased number of complications.[2,20–22]

The major limitation of our study is potential underreporting of complications in the NTDB. Internal NTDB analysis and peer reviewed studies have demonstrated that complications may be inadequately documented in the NTDB.[2,23,24] It is known that some centers do not report any complications at all, or report only a subset of complications.[23] We attempted to minimize the possibility of poor quality data by applying rigorous center-level inclusion criteria; only centers that consistently reported patient data, and complication data specifically, were included in the study. In addition, the complication rates observed in this study are similar to those reported in previous cohort studies from other, non-NTDB data sources, suggesting that the impact of underreporting was minimal in the selected cohort.[21,25] A further limitation was our exclusion of all centers that would have contributed fewer than 200 patients to the study. Although this was necessary to ensure that rates of rare events (death after a complication) could be reliably captured, the relationship between overall mortality, complication rates and failure to rescue rates may differ at small hospitals with fewer resources.

In conclusion, we have demonstrated extensive risk-adjusted variation in the incidence of severe complications across trauma centers. In addition, we have shown that trauma centers characterized by lower overall mortality rates are more successful at avoidance of complications and at rescuing patients that do experience a complication. Our findings suggest that processes that do not enable the prevention and recognition of complications, and that do not facilitate rescue of patients with severe complications, contribute to poor trauma center performance. Conversely, identifying processes of care that lead to more effective prophylaxis, diagnosis, and management of patients who experience complications can significantly modify the outcomes of these patients. These processes of care likely occur early within the injured patient's hospital stay and set a trajectory that undoubtedly impacts on survival. The prevention and management of complications should be targeted as a focused area in which improvements could significantly impact the overall quality of trauma care.

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DISCUSSION

Dr. Lenworth M. Jacobs, Jr. (Hartford, Connecticut): The authors have focused their attention on an important area of trauma management.

They have evaluated variations in morbidity and mortality between trauma centers and attempted to identify reasons for these differences.

In order to answer the questions they have utilized the National Trauma Databank of the American College of Surgeons and performed a retrospective cohort study.

They evaluated the relationship between complications, overall mortality rates, and mortality rates among trauma patients with complications.

They evaluated 76,000 patients at 115 Level I and Level II trauma centers who reported more than 200 patients to the NTDB. They used extensive statistical methodologies to define and compare the groups.

This included predicted probability of death as well as observed and expected death ratios at each trauma center. Actual risk-adjusted mortality rates ranged from .7 to 12.7 percent.

Complications of individual centers ranged from 1.7 to 21 percent. The authors have analyzed these large variations and arrived at certain conclusions.

1. Higher performing centers had lower mortality rates due to a lower incidence of death following severe complications.
2. Patients of both high and low performing hospitals had an equal frequency of postoperative complications. Higher performing hospitals had a lower mortality rate associated with these complications.
3. Mortality in patients with complications is twice as high in low performing centers compared to high performing centers.

The authors state that their findings imply that early recognition of complications and prevention of complications leads to early rescue of patients from these significant problems.

They conclude that processes that do not facilitate the rescue of patients with severe complications contribute to poor performance.

Furthermore, identification of these processes that lead to effective prophylaxis and diagnosis can significantly modify the outcomes of these patients.

Whereas these conclusions appear to be intuitively obvious, it is not clear that their data looked for or identified these processes of care which led to favorable outcomes.

This is an important paper which utilized a large database from over 100 trauma centers. An obvious problem, which the authors identified, that there are variables with age, types and severity of injuries, geographic location and the quality of treating physicians and their teams.

They have conducted a statistical tour de force with multiple different levels and kinds of analyses and regressions to attempt to focus the causes of the differences in outcome.

I have a number of questions for the authors. Did they look at or identify time from injury to treatment, delays in treatment or prolonged prehospital time as an important variable in increasing morbidity or mortality?

Were they able to identify from their extensive data mining any specific features which could be used to decrease morbidity and mortality? This would be more helpful than merely identifying processes of care which could lead to more effective care.

Were they able to identify problems with low volume centers versus high volume centers? Were there any important variations in complications and mortality rates with teaching centers versus community centers?

The membership would benefit from greater precision in the recommendations to those centers that have substantial complications and mortality.

Dr. Steven R. Shackford (San Diego, California): Dr. Spain, if you link or combine these two papers it will call to mind a subject that I think we need to consider. If you haven't already done this, please look at the mean age of the patients that had complications at the various centers.

As patients get older, particularly frail patients, surgeons are probably more likely to call palliative care after a complication develops. The first right of the patient is autonomy and they get to pick. Maybe they don't want an aggressive approach. So perhaps that might be worth looking at.

The last time that I looked at the data on rapid response teams – and there was a study I believe out of Australia in the *Lancet* and I think there was another one done here in the United States – they really didn't have an effect on mortality.

There was no difference in the group – as I recall, but you maybe can put some clarification on that because I think that Don Berwick is continuing to advocate for these RRTs at all hospitals. So please comment on that.

Dr. Patrick Reilly (Philadelphia, Pennsylvania): Two quick questions. One, I was sort of confused. In your risk adjusted complication rate, is that model for all of the complications together or did you come up with a separate model for each of the six complications?

And the second is sort of a statistical question. When you take the impact of complications and failure to rescue from complications, subtract that from the global variation in mortality, does that eliminate the difference between trauma centers? In other words, are complications important, or is it all about complications and failure to rescue?

Dr. Rod Smith (Chicago, Illinois): I also wondered if you were able to look at the frequency of the types of complications across the quintiles and also the number of complications because I don't know if you determined that each complication conferred the same amount of risk of death.

Dr. David Harrington (Providence, Rhode Island): Now, point of clarification, you organized by quintiles your adjusted mortality which is essentially observed through expected mortality ratio.

But I don't know whether it's fair to then say that observed to expected mortality ratios and rates of complications because really you would suggest that patients who have a higher predictive or lower predictive survival would have higher complication rates based on their injuries.

So is it fair to then look at rates of complications based on O to E ratios and really should you have based it on quintiles of predicted survival because then you'd be looking at places with higher events of complications because they're more severely injured by your predictive model.

So I don't know whether that leap follows all the way when you do adjusted mortality as you did.

Dr. Barbara Haas (Toronto): I will try to get through as many questions as I can.

The first question was whether time from injury to treatment or prehospital time could be accounted for. We agree that these are important variables. Unfortunately, we can't reliably capture them in NTDB. We tried to adjust for differences in patient physiologic reserve once they arrived at the emergency department by including such factors as shock and GCS in our model. But that's a valid point that we actually can't capture with the data that we have.

We were unable to identify any specific center level characteristics that were associated with overall performance, so we looked at volume, academic status, for-profit status, as well as Level I and II designation, and all of these were equally distributed across quintiles. So, unfortunately, we weren't able to identify any characteristics there.

Dr. Shackford asked whether mean age might play a role in terms of patients being more likely to be referred to palliative care. We did try to adjust for age but I acknowledge that that adjustment might not have been perfect.The majority of our patients were younger and I think that the overall incidence of patients being so elderly that they're referred to palliative care would have had a relatively minor impact, although that is a valid point and something that should be explored further, particularly if we focus on the outcomes among the elderly.

In terms of rapid response teams, Dr. Shackford is absolutely correct. The literature is actually quite equivocal. I believe that there's the study from Australia, and there is one I believe from England, and one showed that there was benefit and one showed that there was not. I think that the jury is still out on that. And I think it has a lot to do with how they are locally implemented. So I'm not sure that the presence or absence of a rapid response team would account for the differences we observed.

Dr. Reilly asked whether we performed a single model for our complications or multiple ones. We performed a single model that clustered all of our complications because the incidence of some of them was so low that it couldn't be modeled.

Dr. Smith asked me whether the frequency of complications varied. The directionality of the variation was equivalent across quintiles in the sense that they were more frequent in the lowest performing quintiles and less frequent in the highest performing. But there were no significant variations in terms of incidence, and overall, across quintiles, deaths among patients with complications accounted for 22 percent of all deaths. So we were talking about this on our team: roughly, if the lowest performing centers could match the failure to rescue rates of the highest performing centers, their absolute mortality would be reduced by about 1 percent and there would be approximately a 10 percent relative risk reduction. And these are all estimates.

I think I only have time for one more question and I think that's the most important one: were we able to identify processes of care that significantly impacted on rescue of patients. And I think that I can honestly say with NTDB data we can't accurately say that, and although it's a great resource, it can't answer all questions. I think TQIP, which will specifically look at processes of care, will be able to do that much more effectively, as will prospective studies and even qualitative studies that look at such factors as communication between physicians and teamwork. And I think that TQIP and smaller studies are the next step in our investigation.