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Original Research Article

Implications of Thoracic Epidural Analgesia on Hospital Charges in Rib Fracture Patients

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Abstract

Objective. Rib fractures are present in more than 150,000 patients admitted to US trauma centers each year. Those who fracture two or more ribs are typically treated with oral analgesic drugs and are discharged with few complications. The cost of this care generally reflects its brevity. When a patient fractures three or more ribs, there is an elevated risk of complication. In response, treatments are often broadened and their durations prolonged; this affects cost. While health, function, and survival have been widely explored, patient billing has not. Thus, we evaluated the financial implications of one mode of treatment for patients with rib fractures: thoracic epidural analgesia (TEA).

Methods. We retrospectively analyzed the registry of a level II trauma center. All patients who fractured one or more ribs (n = 1,344) were considered; 382 of those patients were not candidates for epidural placement and were eliminated from analyses. Epidural placement was determined by individual clinicians. We used multiple linear regressions to determine predictors of cost.

Results. After eliminating patients who were not eligible to receive TEA, the average patient bill was $59,123 ($10,631 per day of treatment). The administration of TEA predicted a 25% reduction in total billing (99% CI = -$21,429.55– −$7,794.66) and a 24% reduction in per-day billing (99% CI = −$3,745.99– −$1,276.14).

Conclusions. Patients who received TEA were more severely injured and required longer treatments; controlling for these variables, the use of TEA associated with reductions in the cost of receiving care. From an administrative and insurance perspective, more frequent reliance on TEA may be indicated.

Key Words. **Analgesic; Anesthesiology; Epidural; Pain Management; Pain Medicine; Regional Pain; Thoracic; Trauma; Treatment Outcome**

Introduction

Each year, between 150,000 [1] and 300,000 [2] patients are admitted to US trauma centers with rib fractures (about 7% to 10% of all trauma patients) [3–5]. The true incidence of this injury may be even higher as not all rib fractures are detected at admission [6,7]. Many of these patients—especially those who are older and have more severe injuries—undergo extensive treatment [8]. Patients who present with three or more rib fractures have an elevated risk of complication [9]. Much of this risk is a consequence of pain-induced changes in ventilatory mechanics [10,11]. Patients who experience pain with coughing and deep breathing tend to avoid those behaviors, which limits the clearance of airway secretions. Retention of those secretions increases the risk of pulmonary complications (e.g., pneumonia). These complications precipitate respiratory failure; respiratory failure often necessitates ventilatory support, and the requirement of ventilatory support elevates the risk of mortality [5,10–18]. In short, pain can initiate a deleterious cascade that ends in poorer treatment outcomes. In turn, poorer treatment outcomes result in higher treatment costs [1,19,20]. Effective pain management is thus vital to a treatment's therapeutic success and its cost-effectiveness [13,21,22].

Thoracic epidural analgesia (TEA) is one mode of pain control. While TEA has been shown to reduce morbidity [16,23] and mortality [5,23–26] among patients with multiple rib fractures, data reporting its effect on treatment cost are limited. We identified eight studies that quantified treatment costs of patients with rib fracture injuries: four reports come from US hospitals [1,11,27,28], one from an Australian hospital [19], one from a Japanese hospital [20], one from a Swedish hospital [29], and one from an Italian hospital [30]. In other studies, topics such as "cost-effectiveness" were mentioned, but no financial records or statistics were reported [18,31,32].

In 1991, Mackersie and colleagues [11] evaluated patients receiving epidurals who were admitted to a university medical center in California. They randomized 32 patients to a treatment group that received an opioid (fentanyl) either intravenously ($n = 17$) or through thoracic catheters ($n = 15$). This seems to be the first study to report financial outcomes of rib fracture care and the only study to mention TEA. The only cost data reported (means $\pm$ standard deviation) exist in a table: The hospital charges for epidural patients were \$21,000 $\pm$ 10,000 while the charges for intravenous patients were \$15,000 $\pm$ 16,000. Cost data were not analyzed via inferential statistics, and the only other reference to financial outcomes was a disclosure that, because injury severity score (ISS) and length of stay (LOS) were higher in the epidural group, controlling for these factors eliminated the difference in cost.

The remaining seven studies that reported financial outcomes of rib fracture patients did not evaluate TEA; it was neither involved, nor assessed. Five of these studies reported on the cost-effectiveness of surgical fixation; most found that, although the procedures carried an additional cost, they reduced the incidence of complications and shortened the duration of care, which reduced total treatment expense [1,19,20,29]; Majercik and colleagues [27] found improvements in treatment outcomes but not cost. Finally, Gonzalez et al. [28] and Menditto et al. [30] focused on patient observation and triage rather than treatment, evaluating the cost-effectiveness of more selective hospital admission.

The purpose of the current study was to evaluate the influence of TEA on patient billing and hospital expense among patients treated for rib fracture injuries at a level II trauma center.

Methods

We retrospectively analyzed the registry of an ACS-verified level II trauma center (St. Vincent Hospital, Indianapolis, IN, USA). All patients who were admitted with rib fractures between November 2010 (the date that it opened) and December 2015 were included in our analyses. We evaluated the cost of care, comparing those who received TEA with those who did not receive TEA. This study was approved by the hospital's institutional review board in September 2014.

Data Acquisition and Management

All data concerning patient demographics, injury characteristics, course of treatment, and treatment outcomes were exported from the institution's trauma registry; all cost data were obtained from the financial department and are based on actual resource utilization (e.g., cost of supplies, procedures, and personnel).

We examined all patients who were admitted with one or more rib fractures. After composing the database of rib fracture patients, we compared the International Classification of Disease (ICD9) codes of each patient with the written reports of their injuries to determine and validate the presence, number, and location of rib fractures, as well as the incidence of associated injuries (e.g., flail segments). In addition to the characteristics of injury, we compiled demographic records, modes of treatment, and treatment outcomes. Where data only existed as written reports (e.g., mechanism of injury), we assigned those variables numeric codes. Wherever the timing of treatment was important (e.g., timing of intubation), we compared the time stamps of the relevant procedure codes with the time of admission.

Outcome Variables

The primary outcome was treatment cost, which was evaluated in four ways: 1) the total amount of money charged to the patient for treatment (patient billing), 2) the total amount of money charged to the patient per day of treatment (per day billing), 3) the total amount of money paid by the hospital to deliver care to the patient (hospital expense), and 4) the ratio of patient billing to hospital expense (billing:expense ratio).

In investigating the predictors of cost, we analyzed interrelationships between patient demographics, injury severity, and the mode of treatment, particularly the administration of TEA. We also assessed the effects of mortality, pneumonia, mechanical ventilation, and LOS in the hospital and ICU on patient billing and hospital expense.

Patients Excluded from Analysis

Many patients who did not receive TEA were not candidates for its use. To make valid comparisons of treatment outcomes (TEA vs alternative care), the patients who were never candidates had to be eliminated from the database, leaving only patients who received TEA and those who could have received TEA, but did not. Before conducting analyses, we identified three criteria for exclusion. Patients who met any of the following criteria were eliminated:

1. Patient Mortality Within 24 Hours of Arrival. Patients who succumb to their injuries within the first 24 hours are often the most severely injured, and many are unlikely to respond to any treatment. Moreover, depending on the day and time of admission, some of these patients do not survive long enough to be seen by an anesthesiologist; thus, they miss the opportunity to have an epidural placed.

2. Intubation and Mechanical Ventilation upon Arrival or Within 12 Hours of Admission. Many of the most severely injured patients develop respiratory failure quickly and are intubated before being seen by an anesthesiologist. A major goal of administering TEA is to avoid the need for intubation. Once a patient is receiving ventilatory support, pain is generally managed with continuous doses of narcotics; these patients are deeply sedated and are no longer candidates for epidurals.

3. Use of an Anticoagulant Prior to Treatment. Anticoagulation medications (e.g., Coumadin, Plavix) elevate the patient's risk of bleeding into the epidural space; this can cause spinal cord compression and paralysis. Thus, TEA is typically contraindicated in these patients (Figure 1).

Data Analyses

Group means (e.g., cost of treatment for patients receiving TEA and patients receiving alternative care) were compared with independent sample *t* tests. TEA and alternative treatment groups were compared on categorical data (e.g., whether patients are above or below a cut-point) with chi-square tests. These analyses were conducted on the full sample ($n = 1,344$) as well as the study sample ($n = 962$) to generate profiles of the average rib fracture patient and the average TEA candidate, respectively.

The primary outcome variables (patient billing, hospital expense, per-day billing, and billing:expense ratio) were analyzed with forward stepwise regressions. The predictors included were: age, ISS, number of ribs fractured, presence of bilateral fractures, presence of a flail segment, presence of a pulmonary contusion, presence of a pneumothorax, presence of a hemothorax, incidence of pneumonia, incidence of respiratory distress syndrome, incidence of acute respiratory failure, mortality, use of mechanical ventilation, use of TEA, LOS in the hospital, whether subjects were admitted to the ICU, and LOS in the ICU.

Significance was set at a *P* value of less than 0.01; all nonsignificant predictors were eliminated. All variables with Pearson correlations greater than 0.70 or variance inflation factors of three or more were eliminated. Confidence intervals were set at 99%. All statistical tests were conducted using SPSS version 22 (IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA).

Results

Characteristics of the Total Sample

During the five-year study period, 13,021 patients were admitted to the trauma center; 1,344 of these patients had rib fractures. On average, these patients were age 55.5 ± 20.3 years (range = 15–98 years), fractured 4.0 ± 3.0 ribs (range = 1–24), and had an ISS of 16.0 ± 10.4 (range = 1–75). Two-thirds of our patients were male, 92% were white, and the most common mode of injury was automotive accidents (36.5%), followed by falls (33.6%). The average patient bill was \$89,209 ± \$123,094 (range = \$2,448 to \$1,487,194). The average bill per day was \$12,099 ± \$9,116. Per-day billing among patients who died was 2.8 times greater than that of patients who survived ($P < 0.001$); total billing was not statistically different ($P = 0.207$). Overall, patients who did and did not receive TEA were billed similar amounts ($P = 0.895$). The average hospital expense per patient was \$13,611 ± \$43,807 (range = \$61–\$985,080). Although hospital expense was similar between patients who did and did not receive TEA ($P = 0.225$), the charge:cost ratio was lower in patients treated with TEA ($P < 0.001$).

Across the total sample, patient billing was related to the number of ribs fractured, with a cut-point at six ribs. If a patient fractured six or more ribs, there was a 62% increase in patient billing ($P < 0.001$) and a 117% increase in hospital expense ($P = 0.004$). Patient billing was also related to age ($P < 0.001$). There was a cut-point at age 70 years: compared with patients younger than age 70 years, those who were age 70 years or older were charged 41% less ($P < 0.001$) and cost the hospital 51% less ($P < 0.001$). Part of the diminishing costs among older patients may be related to injury severity: patients who were age 70 years or older had an ISS that was 4.7 points lower than those who were younger than age 70 years ($P < 0.001$).

Characteristics of Patients Eliminated from Analysis

There were 41 patients who died within 24 hours. These patients had much more severe injuries, but because of the relatively short treatments, total billing was 65% lower ($P < 0.001$) and overall hospital expense was 80% lower ($P < 0.001$). There were 265 patients who were intubated within 12 hours of admission. These patients also had much more severe injuries, but patient billing was 3.7 times greater ($P < 0.001$) and hospital expense was 4.0 times greater ($P < 0.001$). There were 91 patients who were on an anticoagulation medication upon arrival at the hospital. These patients fractured the same number of ribs ($P = 0.620$) and had a lower ISS

($P < 0.001$) but were 19.6 years older ($P < 0.001$). There were no differences in patient billing ($P = 0.108$) or hospital expense ($P = 0.245$). There were 382 patients who met one or more of the criteria for exclusion and were eliminated from analyses.

Characteristics of the Study Sample

The study sample includes 962 patients. On average, they were age 55 years (range = 15–98 years), fractured 3.7 ribs (range = 1–13), and had an ISS of 13.4 (range = 1–57). Median patient billing was $35,560 (range = $3,792–$832,930) and was proportionate to hospital LOS; median billing per day was $8,925 (range = $812–$80,852). The median hospital expense per patient was $3,450 (range = $61–$648,901) (Table 1).

TEA was administered to 22% of the candidates. Those who received TEA had more severe injuries than those who did not: They fractured 2.6 more ribs ($P < 0.001$), were 8.3 times more likely to present with a flail segment ($P < 0.001$), had double the rates of bilateral fractures ($P = 0.001$), pulmonary contusions ($P < 0.001$), and pneumothoraces ($P < 0.001$), triple the rate of hemothoraces ($P < 0.001$), and had a mean ISS that was 2.9 points higher ($P < 0.001$).

The greater severity of injury among TEA patients resulted in hospital stays that were 3.5 days longer ($P < 0.001$). They were also 72% more likely to be admitted to the ICU ($P < 0.001$) and, if admitted, remained there for an additional 1.6 days ($P = 0.030$). Patients receiving TEA were twice as likely to require mechanical ventilation ($P = 0.003$); if ventilated, the duration was similar ($P = 0.196$).

Across the study sample, patients who received TEA were also more expensive to treat compared with those receiving alternative care. Patient billing was 45% greater (difference of $24,101, $P < 0.001$), and hospital expense was 170% greater (difference of $10,991, $P = 0.021$). However, patients who did not receive TEA were charged 33% more per day of treatment (difference of $2,766, $P < 0.001$).

Cut Points Within the Study Sample

Eliminating patients who were not candidates for TEA strengthened the cut point at six ribs (Figure 2). Fracturing six or more ribs resulted in a 73% increase in patient billing ($P < 0.001$) and a 170% increase in hospital expense ($P < 0.001$) (Figure 3). The cut point for age weakened after enforcing the exclusion criteria. There were no significant differences in hospital expense ($P = 0.390$), but patient billing was 15% lower among patients age 70 years or older ($P = 0.038$). The severity of injury continued to be higher for patients younger

Table 1 Demographic data, injury and treatment characteristics, and financial outcomes

Variable	Total population (N = 962)	TEA (N = 212)	Alternative care (N = 750)	P
Age	55.2 ± 20.0	58.2 ± 18.0	54.4 ± 20.5	0.010
Sex	66.3% male	67.9% male	65.9% male	0.576
Number of ribs fractured	3.7 ± 2.5	5.7 ± 2.4	3.1 ± 2.1	<0.001
Injury severity score	13.4 ± 7.2	15.7 ± 7.4	12.8 ± 7.0	<0.001
% bilateral fractures	10.8%	17.3%	8.9%	0.001
% flail segment	5.2%	16.5%	2.0%	<0.001
% pulmonary contusion	16.5%	28.8%	13.1%	<0.001
% hemothorax	8.3%	18.4%	5.5%	<0.001
% pneumothorax	28.9%	47.6%	23.6%	<0.001
% hemopneumothorax	3.7%	9.9%	2.0%	<0.001
% mechanical ventilation	7.2%	11.8%	5.9%	0.003
Duration of ventilation	10.7 ± 10.7	12.9 ± 9.4	9.4 ± 11.2	0.196
Hospital length of stay	5.8 ± 6.0	8.6 ± 6.0	5.1 ± 5.8	<0.001
% admitted to ICU	40.4%	59.9%	34.9%	<0.001
ICU length of stay	4.5 ± 6.2	5.5 ± 6.9	3.9 ± 5.8	0.030
% pneumonia	6.0%	10.4%	4.8%	0.003
% resp. distress syndrome	0.6%	1.4%	0.4%	0.097
% acute resp. failure	1.2%	2.8%	0.8%	0.019
% mortality	1.6%	0.5%	1.9%	0.148
Patient billing	59,122.67 ± 72,598.50	77,912.23 ± 80,234.97	53,811.49 ± 69,430.69	<0.001
Hospital expense	8,904.95 ± 33,937.87	17,473.74 ± 68,637.13	6,482.84 ± 11,134.61	0.021
Per-day billing	10,631.13 ± 6,251.96	8,480.76 ± 3,386.58	11,247.17 ± 6,731.93	<0.001
Charge:cost ratio	11.45 ± 6.0: 1	9.6 ± 3.2: 1	12.0 ± 6.5: 1	<0.001
Payment on account	20,271.04 ± 30,844.22	27,468.27 ± 41,488.81	18,233.90 ± 26,769.53	0.002

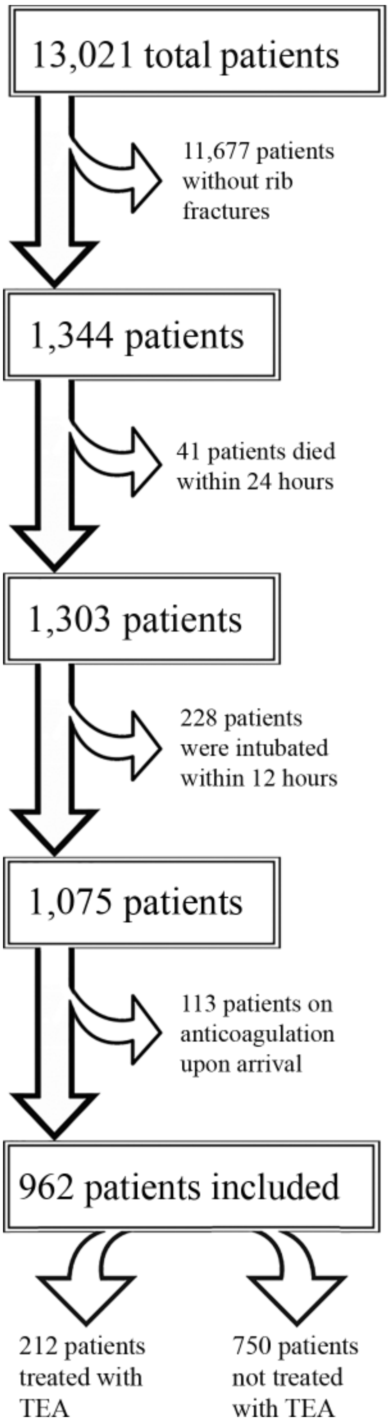

Figure 1 Decision tree to eliminate patients based on exclusion criteria.

than age 70 years: ISS was 2.9 points higher ($P < 0.001$); they were twice as likely to present with pulmonary contusions ($P < 0.001$), 48% more likely to have a pneumothorax ($P = 0.002$), and 71% more likely to experience bilateral fractures ($P = 0.019$).

Variables that Predict Patient Billing in the Study Sample

The stepwise regression model that best predicted patient billing included: hospital LOS, use of mechanical ventilation, ISS, use of TEA, age, incidence of acute respiratory failure, presence of bilateral fractures, and admission to the ICU ($R^2 = 0.810$, standard error of the estimate = 31,949.56, $F = 491.72$, $P < 0.001$) (Table 2). With all other variables held constant, administering TEA to a patient was associated with a 25% reduction ($14,612) in patient billing (99% CI = −$21,429.55– −$7,794.66).

Variables that Predict Hospital Expense in the Study Sample

The stepwise regression model that best predicted hospital expense included: hospital LOS, presence of a flail segment, use of mechanical ventilation, presence of bilateral rib fractures, and presence of a hemothorax ($R^2 = 0.242$, standard error of the estimate = 30,067.82, $F = 58.99$, $P < 0.001$) (Table 3). The use of TEA did not significantly predict hospital expense ($P = 0.462$).

Variables that Predict Per-Day Billing in the Study Sample

The stepwise regression model that best predicted hospital expense included: age, use of TEA, ISS, hospital LOS, and use of mechanical ventilation ($R^2 = 0.115$, standard error of the estimate = 5,905.88, $F = 24.48$, $P < 0.001$) (Table 4). With all other variables held constant, administering TEA to a patient was associated with a 24% reduction ($2,511) in per-day billing (99% CI = −$3,745.99– −$1,276.14).

Variables that Predict Charge:Cost Ratio in the Study Sample

The stepwise regression model that best predicted hospital expense included: hospital LOS, admission to the ICU, and age ($R^2 = 0.152$; standard error of the estimate = 5.49, $F = 57.11$, $P < 0.001$) (Table 5). With all other variables held constant, administering TEA to a patient predicted a 24% reduction ($2,511) in per-day billing (99% CI = −$3,745.99– −$1,276.14). The use of TEA did not significantly predict changes in charge:cost ratio but did exhibit a trend (99% CI = −2.00–0.29, $P = 0.053$).

Discussion

Rib fractures are a common injury in US trauma centers, present in 7–10% of all admitted patients [3,4]. At our institution, during the five-year study period, 10.3% of our patients presented with at least one fractured rib. Treating these patients can be expensive, and those expenses are typically related to the severity of injury. Among our entire sample, the mean patient bill for those

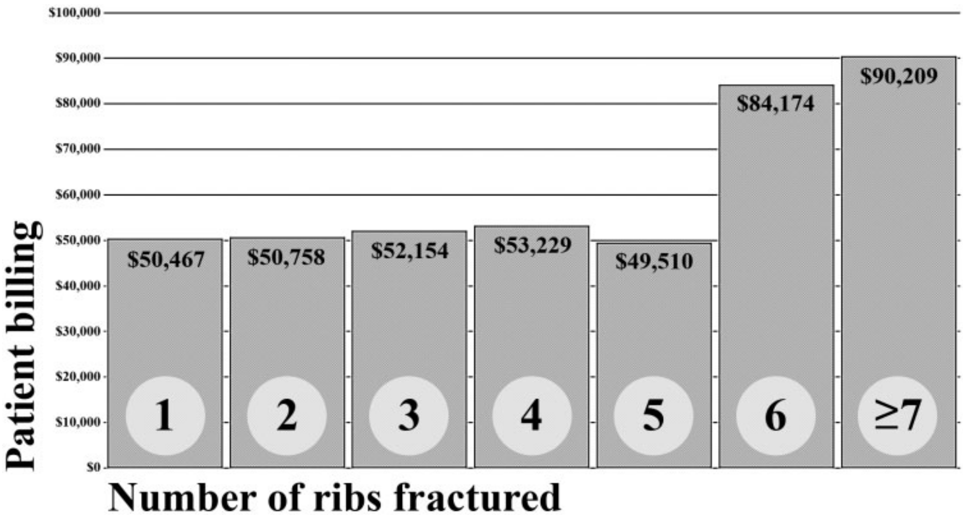

Figure 2 Average patient billing based on number of ribs fractured (study sample matched for TEA candidacy).

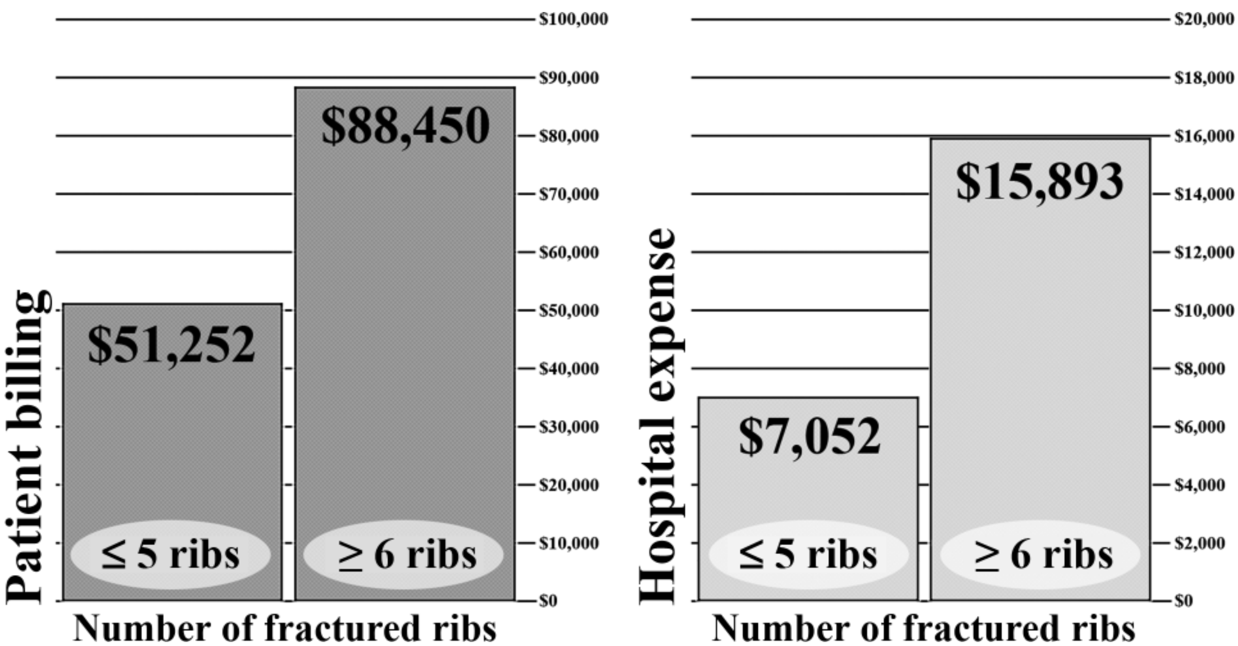

Figure 3 Average patient billing and hospital expense based on cut point of six fractured ribs (study sample matched for TEA candidacy).

who fractured five or fewer ribs was $77,526 while it was $125,852 for those who fractured six or more ribs ($P < 0.001$). In our analyses, we explored ways to reduce these charges without diminishing the treatment's quality. One method that emerged as significant was the administration of TEA.

Not all patients were candidates to receive TEA, owing to the presence of contraindications such as early mortality, early intubation, or anticoagulation use upon arrival. At our trauma center, 72% of all rib fracture patients (n = 962) were eligible. These patients were considered our study sample. Among this group, the mean patient bill was $59,123, the mean hospital expense was $8,905, and the presence of six or more fractures associated with a 73% increase in the former ($P < 0.001$) and a 170% increase in the latter ($P < 0.001$). Holding all other predictors constant, administering TEA to patients in the study sample associated with a 25% reduction in total billing ($P < 0.001$) and a 24% reduction in per-day billing ($P < 0.001$); this equates to a total predicted savings of about $14,600.

Table 2 Linear regression analysis predicting total patient billing

Variable	Unstandardized β	99% confidence interval	*t*	*P*	VIF
Hospital LOS, days	$9,115.47	$8,500.45 to $9,730.49	38.26	<0.001	1.90
Use of mechanical ventilation	$33,719.59	$19,891.97 to $47,547.20	6.29	<0.001	1.70
Use of TEA	−$14,612.11	−$21,429.55 to −$7,794.66	−5.53	<0.001	1.10
Injury severity score	$869.16	$424.53 to $1,313.80	5.05	<0.001	1.42
Acute respiratory failure	$43,360.22	$17,111.37 to $69,609.08	4.26	<0.001	1.10
Age, years	−$215.04	−$355.31 to −$74.69	−3.96	<0.001	1.07
Presence of bilateral fractures	$11,667.98	$2,760.78 to $20,575.18	3.38	0.001	1.05
Admission to ICU	$6,790.85	$200.32 to $13,381.38	2.66	0.008	1.44

LOS = length of stay; VIF = variance inflation factor.

Table 3 Linear regression analysis predicting hospital expense

Variable	Unstandardized β	99% confidence interval	*t*	*P*	VIF
Flail segment	$31,291.68	$19,611.20 to $42,972.15	6.92	<0.001	1.05
Hospital LOS, days	$1,302.42	$762.85 to $1,841.98	6.23	<0.001	1.65
Use of mechanical ventilation	$23,087.72	$10,388.72 to $35,786.73	4.69	<0.001	1.61
Presence of bilateral fractures	$10,821.75	$2,538.94 to $19,104.56	3.37	0.001	1.02
Presence of hemothorax	$12,036.92	$2,697.78 to $21,376.05	3.33	0.001	1.05

LOS = length of stay; VIF = variance inflation factor.

Table 4 Linear regression analysis predicting patient billing per day

Variable	Unstandardized β	99% confidence interval	*t*	*P*	VIF
Use of TEA	−$2,511.07	−$3,745.99 to −$1,276.14	−5.25	<0.001	1.08
Age, years	−$49.03	−$74.60 to −$23,46	−4.95	<0.001	1.07
Hospital LOS, days	−$203.32	−$313.47 to −$93.17	−4.76	<0.001	1.80
Use of mechanical ventilation	$4,498.39	$2,049.83 to $6,946.96	4.74	<0.001	1.65
Injury severity score	$128.70	$52.39 to $205.01	4.35	<0.001	1.22

LOS = length of stay; VIF = variance inflation factor.

Table 5 Linear regression analysis predicting charge:cost ratio

Variable	Unstandardized β	99% confidence interval	*t*	*P*	VIF
Hospital LOS, days	−0.24	−0.33– −0.16	−7.39	<0.001	1.24
Admission to the ICU	−2.22	−3.25– −1.19	−5.56	<0.001	1.23
Age, years	−0.04	−0.06– −0.02	−4.28	<0.001	1.01

LOS = length of stay; VIF = variance inflation factor.

Despite these encouraging findings, TEA is not commonly used to treat patients with rib fracture injuries. In a 2005 analysis of the National Trauma Data Bank (NTDB), only 2% of patients were admitted with one or more fractures and 7% of those with six or more fractures received TEA [5]. In a 2014 analysis of the NTDB, TEA was only administered to 8% of patients who presented with a flail segment [33]. Moreover, in published reports in which TEA is widely used, there are no financial analyses; instead, the authors remain focused exclusively on morbidity and mortality. While those may be the most important outcomes, it gives us no insight into the cost-effectiveness of the treatment and may lead to excessive billing. For example, one approach to reduce mortality in rib fracture patients is the "multidisciplinary clinical pathway." This is an aggressive approach that involves several pain management techniques (oral, IV, and epidural), respiratory therapy (e.g., aerosolized pharmocoligic therapies and positive airway pressure), physical therapy (e.g., range of motion and balance exercises), and nutrition services (dietary monitoring and supplement administration). When employing this combination of treatments, one hospital reduced its mortality rate from 13% to 4% [8]. However, the costs of delivering these treatments were not disclosed. Without access to those data, it is difficult to speculate the cost-effectiveness of the treatment, and its extensive nature is likely to be expensive to both the hospital and the patient. It is possible that some of the services (e.g., nutrition services) are adding more cost than value and it would be helpful to know the individual contribution of each therapeutic component to the treatment outcomes.

While the administration of TEA does require an anesthesiologist to be on duty and may therefore carry additional costs related to personnel and resource utilization, if it eliminates complications, reduces the need for or duration of mechanical ventilation, and facilitates an earlier discharge from the hospital, the total treatment costs are likely to be reduced [1,19,20,29]. In our sample, this phenomenon was found, as measured by reductions in both patient billing and hospital expense.

Limitations

The current study was not a randomized, controlled trial, and not all patients who were candidates for TEA received the treatment owing to the timing of admission and availability of anesthesiologists to render care. Thus, factors beyond our control may have affected costs. However, it is probable that these factors were randomly distributed across patients, and thus these data are likely to reflect the true savings in the cost of care among patients with multiple rib fractures. Despite this, many of our analyses must be interpreted with caution as hospital costs are seldom ideal in their distribution; in our study sample, patient billing had a skewness of 4.1 and kurtosis of 24.9. Although we set a conservative level of significance ($P < 0.01$), additional studies with large samples will be useful in confirming our observations.

Conclusions

As the first known study to analyze how TEA associates with the cost of care in patients with rib fracture injuries, its use appears to predict significant reductions in total patient billing and daily charges. From an administrative and insurance perspective, more frequent reliance on TEA may be indicated. As a first step, other hospitals should report the cost-effectiveness of their care models among patients with rib fractures.

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