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Original Research Article

Improved Outcomes Associated with the Liberal Use of Thoracic Epidural Analgesia in Patients with Rib Fractures

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Abstract

Objective. Each year, more than 150,000 patients with rib fractures are admitted to US trauma centers; as many as 10% die. Effective pain control is critical to survival. One way to manage pain is thoracic epidural analgesia. If this treatment reduces mortality, more frequent use may be indicated.

Methods. We analyzed the patient registry of a level II trauma center. All patients admitted with one or more rib fractures (N = 1,347) were considered. Patients who were not candidates for epidural analgesia (N = 382) were eliminated. Mortality was assessed with binary logistic regressions.

Results. Across the total population, mortality was 6.7%; incidence of pneumonia was 11.1%; mechanical ventilation was required in 23.8% of patients, for an average duration of 10.0 days; average stay in the hospital was 7.7 nights; and 49.7% of patients were admitted to the ICU for an average of 7.2 nights. Epidural analgesia was administered to 18.4% of patients. After matching samples for candidacy, patients who received epidurals were 3.7 years older, fractured 2.6 more ribs, had higher injury severity scores, and were more likely to present with bilateral fractures, flail segments, pulmonary contusions, hemothoraces, and pneumothoraces. Despite greater injury severity, mortality among these patients was lower (0.5%) than those who received alternative care (1.9%). Controlling for age, injury severity, and use of mechanical ventilation, epidural analgesia predicted a 97% reduction in mortality.

Conclusion. Thoracic epidural analgesia associates with reduced mortality in rib fracture patients. Better care of this population is likely to be facilitated by more frequent reliance on this treatment.

Key Words. Pain Management; Regional Pain; Thoracic; Trauma; Epidural; Analgesic; Anesthesiology; Opioids

Introduction

Rib fractures are the most common injury in blunt thoracic trauma [1–3]. While they are reported to be present in 7% to 10% of all patients admitted to US trauma centers [3–5], the actual prevalence might be higher as many cases escape detection during admission [1,6,7]. In total, it is estimated that 150,000 [8] to 300,000 [9] patients with rib fractures are admitted to US hospitals each year [9]. Depending on the age of the patient and the severity of the injury, rib fractures have a high risk of mortality [5,10–13]. Although some hospitals report mortality rates as low as 4% to 6% [12–14], rates of about

10% are more commonly reported, and risk doubles among patients age 65 years or older [3,5,6,11,15,16].

Much of this risk is secondary to pain-induced changes in breathing mechanics [17–22]. Pain can impair a patient's ability to clear airway secretions by coughing and deep breathing, which can elevate the risk of pneumonia and ultimately lead to respiratory failure and the need for ventilatory support [19–21,23,24]. For many reasons (e.g., altered hemodynamics, retention of airway secretions), the pain a patient experiences following an injury can be more dangerous than the injury itself [5,23,25]. Thus, effective pain management is vital to the success of the treatment [24,26,27].

Patients who present with fewer than three fractured ribs usually receive nonopioid analgesics [26] and have a low risk of complications and mortality [2,5]. If pain relief is inadequate, other systemic modes of pain control may be administered, such as intravenous opioids [26]. In the presence of three or more fractured ribs, however, systemic drugs might not be sufficient. As the number of fractures increases, so does the likelihood that regional modes of analgesia will become the primary treatment [5,26]. Regional analgesia comes in a variety of forms, including intercostal nerve blocks, intrapleural nerve blocks, thoracic paravertebral blocks, and thoracic epidural analgesia (TEA) [23,26]. Although TEA may be the preferred mode of pain management for patients with multiple rib fractures [28], it is underutilized in this population. In large analyses of the NTDB, only 2% of patients with one or more rib fracture, 7% of patients with six or more rib fractures [5], and 8% of patients with flail injuries received TEA [29].

The current study is a retrospective analysis of institutional data. The purpose of this investigation was to examine the effectiveness of TEA in reducing mortality associated with rib fracture injuries.

Methods

This study retrospectively evaluated the patient registry of a Level II trauma center that opened in November 2010 (St. Vincent Hospital, Indianapolis, IN, USA). All patients admitted between November 2010 and December 2015 were considered for analysis. The study was approved by the hospital's institutional review board in September 2014.

Data Acquisition and Management

All data were retrieved from the hospital's trauma registry. The documented ICD9 codes were compared with written descriptions of each patient's injuries to determine which patients sustained rib fractures, how many ribs were fractured, whether the injuries were unilateral or bilateral, and the presence of associated injuries such as flail segments and pulmonary contusions. Patient sex and age, the methods of treatment, and the treatment outcomes were also exported. Written data (e.g., mechanism of injury, medications used) were assigned nominal values. Where timing of a variable was important (e.g., whether anticoagulation medications were administered prior to or after admission), data were extracted by comparing time stamps on the procedure codes.

Patient Selection

Patients were considered for analysis if they were admitted to the trauma center during the study period with at least one fractured rib. Many of these patients were not eligible to receive TEA. To compare the effectiveness of the treatment, patient samples were matched for TEA candidacy. In eliminating noncandidates, we attempted to compare outcomes of patients who were treated with TEA to those of patients who could have been treated with TEA but received alternative modes of pain control. Three exclusionary criteria were identified and enforced:

1. Early patient mortality. Patients who die within 24 hours of admission are often too severely injured to respond to any treatment, and, depending on the time of admission, many of them miss the opportunity to be seen by an anesthesiologist; thus, TEA is not available to them.

2. Early intubation and ventilatory support. Avoiding ventilatory support is the primary goal of TEA administration; once intubated, patient symptoms are typically managed with intravenous opioids and sedatives. Thus, patients who are intubated and mechanically ventilated upon arrival or within 12 hours of admission are not likely to be candidates for TEA.

3. Anticoagulation use prior to admission. TEA is contraindicated in patients who are currently on anticoagulation or antiplatelet medications, owing to an increased likelihood of bleeding into the epidural space. Thus, in general, these patients are not eligible to receive TEA.

Data Reported

We present a general description of rib fracture patients (demographics, characteristics of injury, and overall outcomes) that represents our entire patient population. All comparisons of treatment efficacy (TEA vs non-TEA) are derived from patient samples matched for TEA candidacy.

Statistical Analyses

Dichotomous data (e.g., mortality, presence of complications, use of mechanical ventilation) were analyzed with binary logistic regressions. Independent samples *t* tests were used to compare group means (TEA vs non-TEA and survival vs mortality); wherever Levene's test for equality of variances was significant, equal variances were not assumed. Chi-square tests were used to compare categorical variables (e.g., inflection points). When

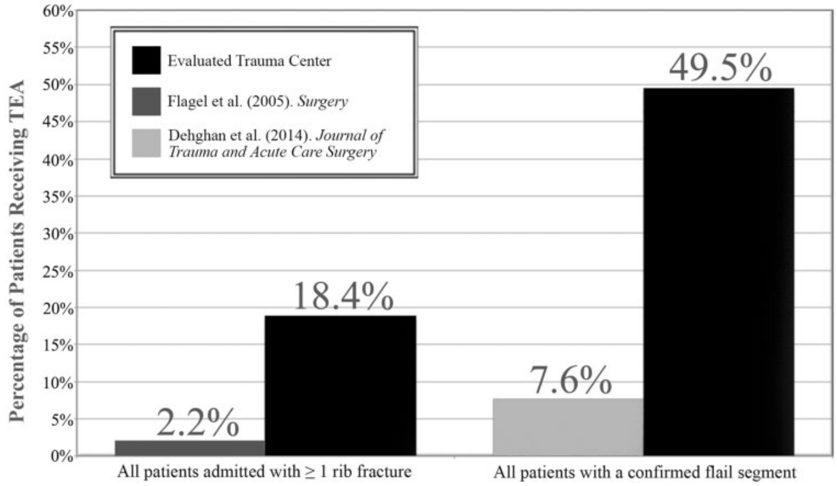

Figure 1 Comparison of TEA administration rates among patients with rib fracture injuries: evaluated trauma center vs national averages. On the left is the percentage of all patients admitted with rib fractures; on the right is the percentage of patients who presented with documented flail segments.

generating prediction equations, predictor variables were eliminated if they had tolerance values of 0.10 or lower or variance inflation factors of 10 or higher. If any data were missing, cases were excluded pairwise. Normal probability plots were assessed to ensure minimal deviance from line of best fit. Scatter plots were used to ensure well-distributed means and identify outliers. All analyses were first conducted on the total samples. Patients who met the exclusionary criteria were then eliminated, and analyses were repeated.

All statistical tests were conducted using SPSS version 22 (IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA).

Results

There were 13,016 patients treated at the investigated trauma center during the five-year study period; 10.3% of them (N = 1,347) presented with rib fractures. They were age 55.5 ± 20.3 years, predominantly white (91.6%) males (67.4%), and they were typically injured in motor vehicle crashes (36.4%) or falls (33.7%). They presented with an injury severity score (ISS) of 16.0 ± 10.4 and had 4.0 ± 3.0 fractured ribs.

Rates of TEA Administration Across the Total Population

TEA was administered much more frequently compared with rates reported at other hospitals. Nationally, TEA is administered to 2.2% of all rib fracture patients [5] and 7.6% of those with confirmed flail segments [29]. At our institution, 18.4% of all rib fracture patients and 49.5% of those with flail segments received TEA (Figure 1). Both nationally and at our facility, a greater number of fractures increases the likelihood that TEA will be administered (Figure 2).

Characteristics of Samples Matched for TEA Candidacy

Enforcing our exclusionary criteria resulted in the elimination of 382 patients. Among the 965 remaining TEA candidates, 212 patients received TEA and 753 received alternative care. Patients receiving TEA had a mean ISS that was 2.9 points higher ($P < 0.001$), they fractured 2.6 more ribs ($P < 0.001$), they were 8.3 times more likely to present with flail chest ($P < 0.001$), they were 1.9 times more likely to have bilateral fractures ($P = 0.001$), they were 2.2 times more likely to have a pulmonary contusion ($P < 0.001$), and they were 1.8 times more likely to have a pneumothorax ($P < 0.001$). Despite greater injury severity among patients treated with TEA, their mortality rate (0.5%) did not exceed that of patients treated by other means (1.9%; $P = 0.149$) (Table 1). Only 1 patient who received TEA died: an 86-year-old man who sustained seven fractures in a fall. This patient was above the inflection points for mortality for both number of ribs fractured (≥ 6) and age (≥ 80 years). After controlling for TEA candidacy, patients older than age 80 years were 11.1 times more likely to die than those younger than age 80 years ($P < 0.001$) and patients with six or more fractured ribs were 3.2 times more likely to die than those with five or fewer fractures ($P = 0.016$). Patients above both inflection points were 21.6 times more likely to die ($P < 0.001$).

If patients who survived and died are divided by the use of TEA, comparisons can be drawn between the survivors who received TEA and the patients who received alternative care and died (Table 2).

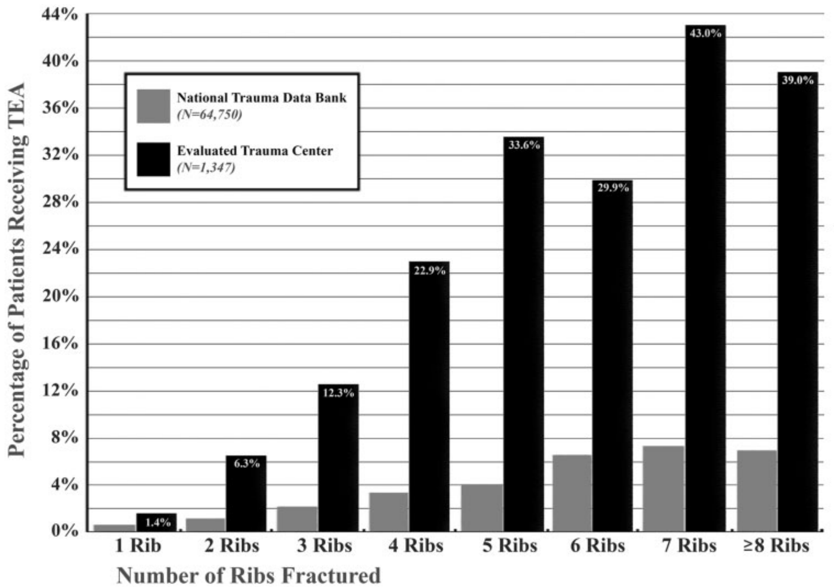

Figure 2 Percentage of rib fracture patients who receive TEA nationally (lighter columns) and at the evaluated trauma center (darker columns). On the x-axis, patients are grouped by the number of ribs fractured.

Table 1 Demographics, injury characteristics, and mortality across samples matched for TEA candidacy

	Non-TEA	TEA	*P*
N	753	212	
% male sex	65.7	67.9	0.552
Age (years)	54.5 ± 20.5	58.2 ± 18.0	0.011
Number of ribs fractured (mean ± SD)	3.1 ± 2.1	5.7 ± 2.4	<0.001
Injury severity score (mean ± SD)	12.8 ± 7.0	15.7 ± 7.4	<0.001
% flail segment	2.0	16.5	<0.001
% bilateral fracture	8.9	17.3	0.001
% pulmonary contusion	13.0	28.8	<0.001
% pneumothorax	23.5	47.6	<0.001
% hemothorax	5.5	18.4	<0.001
% hemopneumothorax	2.0	9.9	<0.001
% urinary retention	3.8	6.7	0.102
% mortality	1.9	0.5	0.149

Statistically, the only characteristics that differed between survivors who received TEA and the patients who did not receive TEA and died were age, number of fractured ribs, and incidence of pulmonary contusions. The survivors were 16.6 years younger ($P = 0.001$), they fractured 1.6 more ribs ($P = 0.021$), and 28.9% of them presented with pulmonary contusions; this is compared with no cases of pulmonary contusions among patients who did not receive TEA and died ($P = 0.018$). The patients who did not receive TEA and died were 5.6 times more likely to require mechanical ventilation ($P < 0.001$) and 6.0 times more likely to experience acute respiratory failure ($P = 0.013$).

Independent Predictors of Mortality Across Samples Matched for TEA Candidacy

The variables that predicted mortality when tested independently were mortality threshold for age ($P < 0.001$), mortality threshold for number of ribs fractured ($P = 0.023$), and the use of mechanical ventilation ($P < 0.001$).

Age (Mortality Threshold)

If a patient was age 80 years or older, the odds of mortality were 11.87 times greater (95% confidence interval [CI] of odds ratio: 4.00, 35.25; $P < 0.001$).

Table 2 Demographics, injury characteristics, and treatment outcomes of survivors and nonsurvivors who did and did not receive TEA across samples matched for TEA candidacy

	TEA Died	TEA Survived	No TEA Died	No TEA Survived	P
N	1	211	14	739	
% male sex	Male	67.8	64.3	65.8	0.787
Age (years) (mean ± SD)	86	58.0 ± 17.9	74.6 ± 21.3	54.1 ± 20.3	0.001*
N ribs fractured (mean ± SD)	7	5.7 ± 2.4	4.1 ± 2.3	3.1 ± 2.1	0.021*
Injury severity score (mean ± SD)	17	15.6 ± 7.4	14.4 ± 6.0	12.8 ± 7.0	0.549
% flail segment	No	16.6	0.0	2.0	0.097
% bilateral fracture	No	17.4	0.0	9.0	0.100
% pulmonary contusion	No	28.9	0.0	13.3	0.018*
% pneumothorax	No	47.9	21.4	23.6	0.055
% hemothorax	No	18.5	21.4	5.1	0.784
% hemopneumothorax	No	10.0	0.0	2.0	0.145
% pneumonia	Yes	10.0	21.4	4.5	0.178
% needing ventilation	Yes	11.4	64.3	4.8	<0.001*
Vent duration (days) (mean ± SD)	15	12.8 ± 9.6	7.4 ± 5.1	9.9 ± 12.3	0.125
LOS in hospital (days) (mean ± SD)	24	8.5 ± 5.9	8.1 ± 7.2	5.1 ± 5.8	0.839
% admitted to icu	Yes	59.7	92.9	33.8	0.013*
LOS in icu (days) (mean ± SD)	23	5.4 ± 6.7	7.0 ± 5.9	3.8 ± 5.7	0.395
% acute respiratory failure	Yes	2.4	14.3	0.5	0.013*
% respiratory distress syndrome	Yes	0.9	0.0	0.4	0.714

*= significance between subjects who received TEA and survived and those who did not receive TEA and died.

Number of Ribs Fractured (Mortality Threshold)

If a patient had six or more fractured ribs, the odds of mortality were 3.29 times greater (95% CI of odds ratio: 1.18, 9.19; $P = 0.023$).

Use of Mechanical Ventilation

If a patient received mechanical ventilation as a component of treatment, the odds of mortality were 30.07 times greater (95% CI of odds ratio: 9.96, 90.82; $P < 0.001$). The duration a patient spent on ventilation was not a significant predictor ($P = 0.430$).

Use of TEA

The use of TEA did not significantly predict mortality on its own ($P = 0.182$). When including age and injury severity in the regression equation, TEA became a significant predictor of mortality ($P = 0.009$).

Prediction Equation for Mortality Across Samples Matched for TEA Candidacy

Variables Included in the Prediction Equation

Mortality threshold for age, mortality threshold for number of ribs fractured, the use of mechanical ventilation, and the use of TEA are presented in Table 3.

There were 950 patients (98.4%) with sufficient data to be included in this analysis. The logistic regression model was significant ($P < 0.001$), correctly classifying 98.5% of all cases. The model elicited a Nagelkerke R^2 value of 0.494, indicating that about 49% of the variance in mortality can be explained by this collection of predictors.

In this model, patients older than age 80 years were 41.34 times more likely to die (95% CI of odds ratio: 8.22, 207.98; $P < 0.001$), patients who fractured six or more ribs were 5.76 times more likely to die (95% CI of odds ratio: 1.43, 23.29; $P = 0.014$), patients needing mechanical ventilation were 64.73 times more likely to die (95% CI of odds ratio: 9.86, 118.37; $P < 0.001$), and the use of TEA reduced a patient's odds of mortality by 96.9% (95% CI of odds ratio: 0.00, 0.42; $P = 0.009$).

Discussion

These data support the hypothesis that the use of TEA associates with a lower risk of mortality among patients with rib fractures. Much of this effect appears to be an attenuation of the rise in mortality that accompanies more severe injuries.

Among samples matched for TEA candidacy, compared with patients who received alternative treatments, those who were treated with TEA were older ($P = 0.011$), fractured more ribs ($P < 0.001$), experienced more bilateral fractures ($P = 0.001$), had a higher ISS ($P < 0.001$),

Table 3 Variables predicting mortality in the binary logistic regression equation

Variable	β	SE	Wald	DF	P	Odds ratio
Age (mortality threshold)	3.722	0.824	20.390	1	<0.001	41.344
Rib fractures (mortality threshold)	1.752	0.712	6.045	1	0.014	5.764
Use of mechanical ventilation	4.216	0.768	30.168	1	<0.001	67.728
Use of TEA	−3.476	1.325	6.878	1	0.009	0.031
Constant	−7.261	0.949	58.508	1	<0.001	0.001

β = coefficient for the constant; DF = degrees of freedom for the Wald chi-square test; SE = standard error around the coefficient for the constant; Wald = Wald chi-square test.

and presented with greater incidences of flail chest ($P < 0.001$), pulmonary contusions ($P < 0.001$), hemothoraces ($P < 0.001$), and pneumothoraces ($P < 0.001$). Despite these differences, the mortality rate of patients treated with TEA (0.5%) did not exceed the mortality rate among patients who received alternative care (1.9%; $P = 0.149$).

Regarding injury severity, the best individual predictor of mortality in our patient population was a threshold at six or more fractured ribs. Across samples matched for TEA candidacy, fracturing six or more ribs associated with a 3.2-fold increase in mortality ($P = 0.016$). This threshold was particularly driven by patients who did not receive TEA. Among patients who were candidates for TEA but did not receive the treatment, fracturing six or more ribs associated with a 4.5-fold increase in mortality ($P = 0.002$). These findings are consistent with the largest analysis of the NTDB, which also found the "breakpoint for mortality" to exist at the sixth rib [5]. With five or fewer fractures, the national mortality rate was 6.6%; with six or more fractures, that risk increased to 21.6% [5]. At our facility, across the total patient population, the mortality rate was 4.3% among patients with five or fewer fractures and 13.1% among patients with six or more fractures ($P < 0.001$).

We also found an inflection point at age 80 years; this relationship existed across the total population ($P < 0.001$) and across samples matched for TEA candidacy ($P < 0.001$). Among matched samples, patients who were age 80 years or older were 11.1 times more likely to die.

Among TEA candidates, the only patient who received the treatment and died exceeded the mortality thresholds for both age and number of ribs fractured. If patients above the threshold for age (N = 147) were eliminated, mortality became an all-or-none phenomenon in which every patient who received TEA survived while 0.8% of patients who did not receive TEA died. Likewise, if patients above the threshold for number of ribs fractured (N = 204) were eliminated, every patient who received TEA survived while 1.2% of non-TEA patients died. Lastly, if patients above both thresholds were eliminated (N = 26), no TEA patient died while 1.5% of patients who did not receive TEA died.

When including these mortality thresholds in a binary logistic regression, along with use of mechanical ventilation, administering TEA to a patient associated with a 96.9% reduction in the odds of mortality ($P = 0.009$). Given these outcomes, it seems ideal to administer TEA as a first line of defense for rib fracture patients who exceed the mortality thresholds for age and/or number of ribs fractured. Despite this indication, the national reliance on TEA remains low. In an analysis of the NTDB, only 2.2% of rib fracture patients received the treatment [5]. By comparison, at our institution, 1.6% of patients with a single fracture and 23.0% of patients with multiple fractures received TEA. Compared with the national average, rib fracture patients at St. Vincent are 8.4 times more likely to be treated with TEA. To achieve these rates of administration, our facility employs a dedicated Anesthesia Pain Service (APS). APS is a care team that includes anesthesiologists who are on duty for a week at a time, with responsibilities limited to the trauma center, and nurses who are trained to provide 24/7 patient monitoring. The anesthesiologists are available to place epidurals during the daytime hours, adjusting dosage whenever necessary, and if complications arise during the nighttime hours, they are available for consultation by telephone. This care structure has facilitated greater reliance on TEA among patients with rib fractures and, in turn, reduced mortality.

Although the number of hospitals employing a similar service is increasing, many have yet to implement the practice. In 2011, Nasir and colleagues [30] sampled 301 US hospitals, evaluating whether an APS structure was in operation. While 75% of respondents confirmed having such a service, the response rate was only 36%. A noted limitation is that many institutions may have declined participation owing to their lack of resources. Other reports vary, finding APS services to be in place at 30–70% of North American and European hospitals [31]. Given our encouraging survival rates with rib fracture patients receiving TEA, it seems advisable for other hospitals that do not yet employ an APS care structure to consider its implementation.

Limitations

These data were acquired retrospectively from an available patient registry. We were unable to control for confounding factors such as time of admission, injury severity was not matched between patient groups, and there was no randomization of pain management procedures. However, these data suggest that, despite being at higher risk of death, patients treated with TEA are more likely to survive. After matching samples for TEA candidacy, one patient who received TEA and 14 who did not receive TEA died. Repetition of this analysis and aggregation of data from larger samples will be needed to confirm our observations regarding the effectiveness of TEA in the care of patients with rib fractures.

Conclusions

The use of TEA as a component of rib fracture care associates with a reduction in patient mortality. In our population, the administration of TEA predicted a 97% reduction in risk. Much of our success in patient outcomes seems attributable to the prompt availability of epidural catheter placement, facilitating greater reliance on the treatment. Thus, an APS model for rib fracture care may be considered as a roadmap for other programs to implement.

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