

A multidisciplinary clinical pathway decreases rib fracture–associated infectious morbidity and mortality in high-risk trauma patients

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Abstract

Background: We initiated a multidisciplinary clinical pathway targeting patients greater than 45 years of age with more than 4 rib fractures. The purpose of the current study was to evaluate the effect of this pathway on infectious morbidity and mortality.

Methods: This was a prospective cohort study. Data evaluated included patient demographics, injury characteristics, pain management details, lengths of stay, morbidity, and mortality. Univariate and multivariate analyses were performed using a significance level of $P < .05$.

Results: When adjusting for age, injury severity score, and number of rib fractures, the clinical pathway was associated with decreased intensive care unit length of stay by 2.4 days (95% confidence interval [CI] –4.3, –0.52 days, $P = .01$) hospital length of stay by 3.7 days (95% CI –7.1, –0.42 days, $P = .02$), pneumonias (odds ratio [OR] 0.12, 95% CI 0.04 to 0.34, $P < .001$), and mortality (OR 0.37, 95% CI 0.13 to 1.03, $P = .06$).

Conclusions: Implementation of a rib fracture multidisciplinary clinical pathway decreased mechanical ventilator-dependent days, lengths of stay, infectious morbidity, and mortality. © 2006 Excerpta Medica Inc. All rights reserved.

Keywords: Mortality; Multidisciplinary clinical pathway; Pain management; Pneumonia; Rib fractures

Thoracic trauma accounts for 10% to 15% of trauma admissions and 25% of traumatic deaths [1,2]. In this population, rib fractures are present in greater than two thirds of patients [2,3]. Recent studies have demonstrated the impact of rib fractures after blunt trauma in the elderly population [4,5]. Bulger et al documented that patients older than 65 years of age with more than 4 rib fractures were more likely

to die or suffer serious setbacks when compared to those aged 15 to 64 [5].

Although elderly trauma patients are a vulnerable group, multiple studies have documented that age-related morbidity increases before age 65 in the trauma population [6–11]. Easter proposed that patients as young as 40 years of age exhibit increased morbidity [12]. With this knowledge in hand, we previously studied our population to determine the relationship between age and number of rib fractures in blunt trauma patients [13]. We demonstrated that patients older than age 45 who had more than 4 rib fractures were at increased risk for prolonged mechanical ventilator depen-

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dent days, shock trauma intensive care unit length of stay, and overall hospital length of stay. Secondary to these findings, we instituted an aggressive rib fracture multidisciplinary clinical pathway to target this at-risk population. The purpose of the current study was to evaluate the effect of this pathway on infectious morbidity and mortality. We hypothesized that implementation would decrease infectious morbidity and mortality.

Methods

This was a prospective observational cohort study performed at Memorial Hermann Hospital in Houston, TX, which is the lead regional Level I Trauma Center for Trauma Service Area Q, which includes nine counties in the upper Gulf Coast of Texas with a population of approximately 4.5 million. Based on our previous retrospective study, we instituted a multidisciplinary clinical pathway in February 2002 targeting patients greater than 45 years of age with more than 4 rib fractures. Patients with concurrent severe traumatic brain injury, defined as a Glasgow Coma Scale score ≤ 8 and an abnormal brain computed tomography scan, were admitted to the Neurosurgery Trauma Intensive Care Unit and thus were not candidates for the study.

Patients meeting the aforementioned criteria were admitted to a monitored bed (Surgical Intermediate Care Unit or Shock Trauma Intensive Care Unit) where they received patient-controlled analgesia and incentive spirometry upon admission. On the first 3 days of hospital admission, the bedside nurse evaluated the patients on three criteria: pain, inspiratory volume, and cough. Pain was assessed during incentive spirometry or coughing using a visual analogue scale (score from 1 to 10) with failure being a score greater than 6. Inspiratory volume was determined using the incentive spirometer. A volume less than 15 mL/kg was considered failure [14]. For the third criteria, the bedside nurse performed a subjective assessment of the patient's cough, with a weak cough being considered failure. Patients who failed 1 or more of these criteria on any of the first 3 days of hospital admission were entered into the multidisciplinary clinical pathway.

Fig. 1 depicts the multidisciplinary pathway. Enrollment mandated focused efforts from the respiratory therapy, pain, physical therapy, and nutrition services. The respiratory therapists implemented the trauma service's volume expansion protocol, which utilizes aerosolized pharmacologic therapies, the EzPAP positive airway pressure system (Smiths Medical, St Paul, MN), and other escalating invasive therapies. The pain service was pivotal in maximizing pain control. They prescribed oral pain medications (including nonsteroidal anti-inflammatory medications), intravenous pain medications, and epidural analgesia. The goal of the physical therapists was to optimize mobility via strengthening, range of motion, and balance exercises. The nutrition service monitored the nutritional status of the patient and optimized it utilizing varying diets and supplements. Once an enrolled participant passed all 3 of the entrance criteria on 3 consecutive days, he or she was removed from the multidisciplinary clinical pathway. Enrollees who no longer required Shock Trauma Intensive Care Unit or Surgical

Intermediate Care Unit level of care prior to being removed from the pathway were transferred to the ward with a high-risk respiratory care consult.

A prospective cohort of 150 patients since the pathway's inception in February 2002 served as the study group (post-pathway patients). For comparison, a historic control of 150 patients prior to the pathway's inception served as the control group (pre-pathway patients). Participants in both groups were older than 45 years of age with more than 4 rib fractures.

Data were obtained from the Trauma Registry, pharmacy database, infection control continuous quality improvement database, and electronic medical record. The Trauma Registry was reviewed for patient demographics (age, race, gender, and mechanism of injury), injury characteristics (chest abbreviated injury scale scores, injury severity scores, number of rib fractures, and the presence of flail chests, sternal fractures, pulmonary contusions, hemothoraces, pneumothoraces, combination hemo/pneumothoraces, and thoracostomy tubes) and mortality. Details of the pain management regimen, including the utilization of nonsteroidal anti-inflammatory drugs, patient-controlled analgesia pumps, and epidural catheters, were obtained from the pharmacy database. The infection control continuous quality improvement database was queried to identify pneumonias (using standard Centers for Disease Control and Prevention definitions), mechanical ventilator dependent days, shock trauma intensive care unit length of stay, and total hospital length of stay. The electronic medical record was used to confirm the aforementioned data.

In comparing the 2 study groups, the Student *t* test was used for continuous data. If the assumptions of this test were not met, the appropriate test (Mann-Whitney *U* test) was applied. A chi-square analysis was used for categorical data. When appropriate, this was substituted with the Fisher exact test. Univariate and multivariate (linear and logistic regression) analyses were performed to determine associations between the utilization of the multidisciplinary clinical pathway and mechanical ventilator-dependent days, lengths of stay, infectious morbidity, and mortality. Numeric data are presented as means \pm SD and median (interquartile range) where appropriate. The odds ratios (ORs) and the 95% confidence intervals (CIs) were calculated. A *P* value less than .05 was considered significant. Number Cruncher Statistical Systems (Kaysville, UT), 2004 was used for all statistical analyses.

The collection and review of data was approved by The University of Texas Health Sciences Center at Houston Committee for the Protection of Human Subjects and the Memorial Hermann Hospital Institutional Review Board.

Results

A prospective cohort of 150 patients from February 2002 to October 2004 served as the study group and was compared to a historic control of 150 patients from February 1999 to February 2002. The study patients compared to the historic controls were younger [56 (51–65) years vs. 60.5 (52–72) years, *P* = .02] but similar in terms of their gender [94 males (63%) vs. 97 males (65%), *P* = .72].

Table 1 displays the injury characteristics of the 2 groups. The study group was similar in terms of their chest

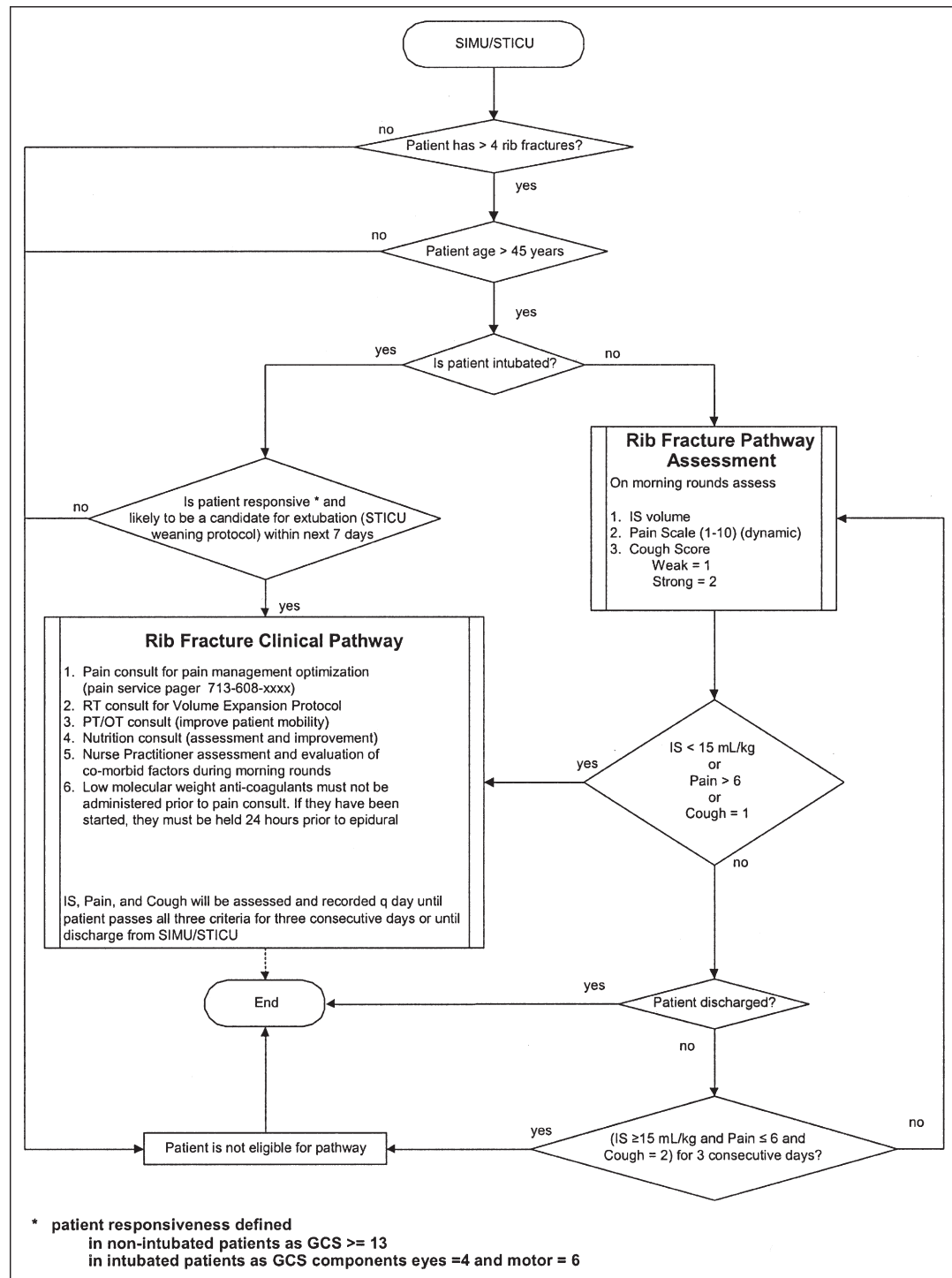


Fig. 1. Rib fracture multidisciplinary clinical pathway. SIMU = Surgical Intermediate Care Unit; STICU = Shock Trauma Intensive Care Unit; IS = incentive spirometry; RT = respiratory therapy; PT = physical therapy; OT = occupational therapy; GCS = Glasgow Coma Scale.

abbreviated injury scale score [4 (3–4) vs. 4 (3–4), $P = .17$] and injury severity score [21 (17–29) vs. 21 (17–29), $P = .67$] in comparison to the historic controls. Despite this, the study patients had more rib fractures, flail chests, hemothoraces, pneumothoraces, and hemo/pneumothoraces.

Overall, the pain management intervention altered patient care significantly. Post-pathway patients were pre-

scribed patient-controlled analgesia significantly more than pre-pathway patients [138 (92%) vs. 47 (31%), $P < .0001$]. Similarly, post-pathway patients witnessed a significant increase in epidural catheter utilization [63 (42%) vs. 17 (11%), $P < .0001$]. An additional 16 (11%) post-pathway patients were offered or had an unsuccessful attempt at epidural catheter analgesia.

Table 1
Injury characteristics of the two study groups

	Control group (pre-pathway patients) (n = 150)	Study group (post-pathway patients) (n = 150)	P value
No. of rib fractures	6 (5–7)	7 (6–9)	<.0001
Flail chest	7 (5%)	41 (27%)	<.0001
Sternal fracture	8 (5%)	15 (10%)	.13
Pulmonary contusion	55 (37%)	50 (33%)	.55
Hemothorax	22 (15%)	65 (43%)	<.0001
Pneumothorax	58 (39%)	79 (53%)	.01
Hemo/pneumothorax	21 (14%)	43 (29%)	<.002
Thoracostomy tube	75 (50%)	54 (36%)	.01

Table 2 depicts the unadjusted univariate analyses when comparing the outcome data of the 2 study groups. Post-pathway patients had nonsignificantly decreased shock trauma intensive care unit and hospital lengths of stay, yet statistically significant decreased pneumonia and mortality rates. When adjusting for age, injury severity score, and number of rib fractures, the clinical pathway was associated with decreased shock trauma intensive care unit length of stay by 2.4 days (95% CI $-4.3, -0.52$ days, $P = .01$), hospital length of stay by 3.7 days (95% CI $-7.1, -0.42$ days, $P = .02$), incidence of pneumonia (OR 0.12, 95% CI 0.04 to 0.34, $P < .001$), and mortality (OR 0.37, 95% CI 0.13 to 1.03, $P = .06$).

Comments

The true incidence of rib fractures following trauma is unknown and difficult to quantify [15]. However, recent studies suggest that 10% of trauma center admissions possess rib fractures and rib fractures are considered a marker of severe associated injuries [4,16–19]. Dependent on the injured rib, the associated injuries may involve the heart, great vessels, liver, and/or spleen. Fractured ribs are also frequently associated with underlying thoracic trauma (i.e., pulmonary contusions, hemothoraces, pneumothoraces, and combination hemo/pneumothoraces). These injuries contribute to the pulmonary morbidity seen in multi-system trauma.

Recent studies have demonstrated the impact of rib fractures after blunt trauma in the elderly population [4,5]. Bergeron et al documented that despite lower indices of injury severity, mortality was significantly increased in patients greater than 65 years of age with rib fractures [4]. They concluded that elderly patients with rib fractures should receive special attention. Although trauma patients older than 65 years of age are a vulnerable group, multiple studies have documented that age-related morbidity increases before age 65 in the trauma population [6–11]. Previously, we demonstrated that patients older than age 45 years who had more than 4 rib fractures were at increased risk for prolonged mechanical ventilator-dependent days, shock trauma intensive care unit length of stay, and overall hospital length of stay [13]. Secondary to these findings, we instituted an aggressive rib fracture multidisciplinary clinical pathway to target this at risk population.

Our current study focuses on the effectiveness of this pathway. The study group had similar indices of injury to the control group as evidenced by their chest abbreviated injury scale scores and injury severity scores. The high injury severity scores represent rib fracture patients as severely injured trauma patients. Similarly, Bergeron et al documented a mean injury severity score of 19.9 among their patients, and Bulger et al found a mean injury severity score of 21 [4,5]. Likewise, the high abbreviated injury scale scores depict the severity of the thoracic trauma in the study cohort. The 1990 revision of the abbreviated injury scale scores defines a 4 as representing a severe “threat to life” for a given injury in a particular body region [20].

Despite the similar injury indices, the post-pathway patients had statistically significant more rib fractures. The associated injuries due to these rib fractures included flail chests, sternal fractures, pulmonary contusions, hemothoraces, pneumothoraces, and combination hemo/pneumothoraces. All of these were increased in the post-pathway patients except for sternal fractures and pulmonary contusions. Trunkey estimated that 50% of rib fractures cannot be detected by plain anteroposterior chest roentgenograms [21]. Throughout the course of this study, we increased our utilization of chest computed tomography scans in the initial evaluation of blunt trauma patients. We believe that this change in practice may have accounted for our increased diagnoses of rib fractures and their associated thoracic injuries.

On unadjusted univariate analyses, the post-pathway patients had non-significant decreased shock trauma intensive care unit and hospital lengths of stay, yet a statistically significant decreased incidence of pneumonia and mortality. When adjusting for age, injury severity score, and number of rib fractures, the clinical pathway was associated with decreased shock trauma intensive care unit length of stay, hospital length of stay, incidence of pneumonia, and mortality.

Enrollment in the rib fracture multidisciplinary clinical pathway mandated focused efforts from the respiratory therapy service, pain service, physical therapy service, and nutrition service. Of these, the aggressive utilization of the pain service was the one care arm lacking prior to pathway inception. Pain service consultation altered care plans significantly. The post-pathway patients were prescribed patient-controlled analgesia and epidural catheter analgesia significantly more than the pre-pathway patients. We believe this aggressive pain control was critical to the success of our

Table 2
Unadjusted univariate analyses of the outcome data of the two study groups

	Control group (pre-pathway patients) (n = 150)	Study group (post-pathway patients) (n = 150)	P value
Mechanical ventilator-dependent days	1.8 ± 6.0	2.6 ± 6.7	.28
Intensive care unit days	5.3 ± 8.1	3.8 ± 8.1	.13
Hospital days	14.3 ± 16.9	11.7 ± 10.9	.11
Pneumonia rate	27 (18%)	7 (5%)	.0003
Mortality rate	20 (13%)	6 (4%)	.004

pathway. This is supported in the literature [17,18,22–26]. Wisner et al documented that epidural analgesia decreased pulmonary complications and mortality in elderly trauma patients [22]. Similarly, multiple studies have reported comparable outcome measure improvements to include decreased mechanical ventilator-dependent days, lengths of stay, pulmonary complications, and mortality [17,18,23–26].

Ours is not the first rib fracture multidisciplinary clinical pathway reported in the literature. In 2001, Easter documented a similar pathway aimed at optimizing the mobilization, respiratory care, and pain management of rib fracture patients [27]. Similarly, the success of our pathway implementation has been corroborated by Sesperez et al [28]. They concluded that clinical pathways improve patient outcomes in five key trauma conditions including rib fractures.

In conclusion, increased morbidity has been proposed in trauma patients as young as 40 years of age [12]. In our previous study, we demonstrated that patients older than 45 years of age who had more than 4 rib fractures were at increased risk for prolonged mechanical ventilator-dependent days, shock trauma intensive care unit length of stay, and overall hospital length of stay [13]. Secondary to these findings, we instituted a rib fracture multidisciplinary clinical pathway to target this at risk population. In this study, we document that implementation decreased mechanical ventilator dependent days, lengths of stay, infectious morbidity, and mortality.

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Discussion

Dan Vargo, M.D. (Salt Lake City, UT): Clinical pathways have been shown to improve outcomes in many clinical situations. From the Parkland formula to ambulation guidelines after joint replacement, elimination of dogmatic variations in care has led to better patient care. This manuscript outlines a clinical pathway for the management of pain after chest trauma. It utilizes age and number of rib fractures, in addition to admission to the ICU or intermediate care unit as criteria for eligibility. Criteria include things that document a decrease in vital capacity: IS and cough. In their 150 patients compared to historical controls, the chest AIS is similar. Despite this, there is a decrease in associated morbidity and mortality, in addition to a decrease in the number of chest tubes placed in the study group despite more chest injuries. Also, there is a longer time spent on mechanical ventilation in the study group compared to the historical controls. The increased injury as noted is probably explained by the use of CT scan, but the decrease in tube thoracostomy would not be explained by this. In addition, it would not explain the increased amount of times spent on the ventilator. An outcome is also not provided for patients who went out of the unit while still on their clinical pathway.

So with this, I have a few questions for the authors. First, were patients ever transferred directly from the ICU to the floor while they were still on the pathway? And if so, what is the rate of return for these patients? In your manuscript,

you document that these patients were taken off the pathway when they went to the floor and so it would be interesting to see that the pathway actually led to a decreased rate of return to the intensive care unit. Secondly, why were patients intubated longer in the study group? You have patients who have a decreased infection rate, but yet they are on the ventilator longer which we would all love to have in our ICUs; so could it be that they benefited from having that extra day in the ICU for either better pain management or for clearance of secretions or so forth? Third, you show an increased use of PCA and epidural in your study patients. Does this mean that surgical house staff or the people who are taking care of these patients just don't understand what pain control is and why did you need the pain service to be involved to show you that these patients needed to have better pain control? And then lastly, why would you only use these criteria in patients over the age of 45? If it documents that you have a better outcome, I would argue that most of my pain management problems are not greater than the age of 45, they are in the young healthy male 20- to 45-year-old who will sit there, and cry and whimper instead of going through and doing any pulmonary toilet.

Patrick J. Offner, M.D., F.A.C.S. (Wheatridge, CO): It is remarkable that patients were on the ventilator longer, yet your pneumonia rate was decreased. And I have to wonder: was there another difference between your control group and your study group? In other words, in the study period, did you implement any other protocols, for instance ventilator bundles? Were you elevating the head of the bed? Were you changing your nutrition at all? Were you doing other things that just this rib fracture pathway that could have affected your pneumonia rate?

Roxie M. Albrecht, M.D. (Oklahoma City, OK): I have one question. I got a copy of your manuscript ahead of time

and I noticed that you included patients that were over the age of 45. However, in your results section, there was nobody between the ages 45 and 51. They don't break their ribs?

S. Rob Todd, M.D. (Houston, TX): Dr. Vargo in reference to the first question about bounce-backs from the floor to the ICU. When patients went directly from the ICU to the floor, they received a "high risk pulmonary." This means they receive aggressive pulmonary care by Respiratory Therapy and mobilization by Physical Therapy. The second question as far as why these patients might possibly be intubated longer, I propose that this was secondary increased chest trauma. When we look at these patients, they had more rib fractures, pulmonary contusions, hemothorax, etc. Unfortunately, by the chest AIS they get a 4, but their ISS did not reflect an increase in severity to their chest trauma. I think they may have had worse chest trauma and required longer ventilation. As far as your third question, the PCA utilization, all patients were ordered PCAs on admission and we only used the pharmacy database to retrieve those because they had all the data for us specifically, but all patients were supposed to have a PCA ordered on admission. Obviously 92% were done. And the fourth question, why don't we do this on all of our patients? We actually for the most part do these days. I think it probably would be interesting to look at those patients younger than 45 and see how they perform. I suspect they would make a statistical difference in their infectious morbidity and mortality. Dr. Offner, the biggest thing that we did differently we weren't doing prior to implementation of this pathway was aggressive pain management (specifically epidural utilization). Dr. Albrecht, the numbers you are referring to represent the interquartile range, 51–65 years of age.