Surgery in Practice and Science 14 (2023) 100192

Contents lists available at ScienceDirect

Surgery in Practice and Science

journal homepage: www.sciencedirect.com/journal/surgery-in-practice-and-science

Reduced rates of pneumonia after implementation of an electronic checklist for the management of patients with multiple rib fractures at a Level One Trauma Center

Kevin Yeh [a], Nicole Spence [b], Brendin R Beaulieu-Jones [c], Michael Taylor [d], Ansel Jhaveri [b], Kathleen Centola [c], Tricia Charise [c], Janet Orf [c], Aaron Richman [c,*]

[a] *Department of Pharmacy, Boston University Medical Center, Boston, MA, USA*
[b] *Department of Anesthesiology, Boston University Medical Center, Boston, MA, USA*
[c] *Department of Surgery, Boston University Medical Center, 725 Albany St, 3rd Floor, Suite 3A, Boston, MA 02118, USA*
[d] *Department of Surgery, Lakeland Regional Health Medical Center, Lakeland, FL, USA*

A R T I C L E I N F O

Keywords:
Rib fractures
Analgesia
Epidural
Pneumonia
Trauma
Checklist
Quality improvement

A B S T R A C T

Background: Traumatic rib fractures are associated with increased morbidity and mortality, with complications including pneumothorax, difficult to control pain, and pneumonia. Use of a bundled, multi-disciplinary approach to the care of patients with multiple rib fractures has been shown to reduce morbidity and mortality. In this study, we investigate the implementation of a checklist for the multidisciplinary management of patients with multiple rib fractures who present to an urban, level 1 trauma center and safety-net hospital.
Study design: This was a single-institution, retrospective cohort study to assess changes in treatment characteristics and patient outcomes before and after implementation of a comprehensive checklist for the management of high-risk patients with three or more traumatic rib fractures at a level-one trauma center. The primary outcome was pneumonia rates with secondary outcomes of mechanical ventilation rates and mechanical ventilation days, ICU length of stay, mortality, and non-opioid and opioid consumption (morphine milligram equivalents).
Results: A total of 104 patients met study eligibility, including 51 patients who presented during the pre-protocol period and 53 patients who received care after implementation. We observed that the checklist was utilized and reviewed in 83% of patients during the post-protocol period. Pneumonia rates were significantly lower in the post-protocol group (35.3% vs 15.1%, $p = 0.017$). There was no difference in the number of patients who required mechanical ventilation or the duration of mechanical ventilation. On unadjusted analysis, median overall length of stay (11.5 days vs 13 days, $p = 0.71$), median ICU stay (4 days vs 5 days, $p = 0.18$), and rate of in-hospital mortality (11.8% vs 7.6%, $p = 0.47$) was not different between the two time periods.
Conclusion: In patients with chest wall trauma and associated rib fractures, implementation of a standardized, multidisciplinary checklist to ensure utilization of multimodal analgesia and non-pharmacological interventions was associated with decreased pneumonia rates at our institution.

Background

Chest wall trauma and associated rib fractures are common in trauma patients with an incidence ranging from 9 to 21% [1–4]. Traumatic rib fractures are associated with increased morbidity and mortality, with complications including pneumothorax, difficult to control pain, and pneumonia. These adverse outcomes are more common and severe in elderly patients [5]. In addition to increased morbidity and mortality, traumatic rib fractures incur high healthcare expenditures due to intensive care unit (ICU) level of care and prolonged hospital length of stay. Between 2007 and 2016, Sadore and colleagues [6] estimated that rib fractures accounted for up to $469 million in healthcare expenditures with an average expense ranging from $8008 to $29,037 per event, with flail chest having the highest overall cost. Long-term complications in patients with rib fractures include impaired pulmonary function tests and exercise intolerance. Additionally, patients suffer lost productivity from missed work days, usual activities, and may have persistent pain [7–9].

* Corresponding author.
E-mail address: Aaron.Richman@bmc.org (A. Richman).

https://doi.org/10.1016/j.sipas.2023.100192
Received 28 May 2023; Received in revised form 11 June 2023; Accepted 14 June 2023
Available online 15 June 2023

Use of a bundled, multi-disciplinary approach to the care of patients with multiple rib fractures has been shown to reduce morbidity and mortality. Todd and colleagues [10] initiated a clinical pathway including pain consult and optimization of non-pharmacologic measures, which decreased ICU and hospital length of stay, pneumonia rates, and mortality. Burton and colleagues [11] implemented a multimodal pain regimen, which included a pain control guideline and multimodal pain order set in the electronic health record (EHR) that demonstrated a significant decrease in average opioid usage during the first five days of hospitalization. Similarly, Kelley and colleagues [12] developed and implemented a chest trauma protocol, which consisted of intravenous opioids, non-opioids, non-invasive ventilation and incentive spirometry, and was associated with a significant decrease in adverse pulmonary events.

While the benefits of protocolized management of patients with rib fractures have been documented, less is described regarding effective approaches for protocol implementation and monitoring completion of care components. In addition, given resource limitations in many trauma centers, challenges regarding the management of polytrauma patients, and added nuances regarding care delivery at a safety-net hospital, we sought to investigate the effectiveness of using a checklist – which was reviewed daily and integrated into the daily progress note within the electronic record – to facilitate protocolized care of patients with multiple rib fractures.

Methods

Clinical setting and context

Our hospital is a level one trauma, academic medical center with a 28-bed Surgical ICU (SICU). With more than 120,000 emergency department (ED) visits per year, it has the busiest trauma and emergency medicine services in New England. Between 2014 and 2021, about 43% of adult patients presenting to the ED after sustaining traumatic injury were 50 year of age or older.

Prior to the study intervention, treatment of patients with multiple, traumatic rib fractures was not standardized, and no institutional treatment guidelines were established. This gap in care was identified by the SICU pharmacist, who brought together key stakeholders to establish evidence-based and multidisciplinary treatment guidelines. In particular, using the Institute for Healthcare Improvement (IHI) model [13], the group sought to improve the utilization of multi-modal analgesia and non-pharmacologic modalities by implementing a treatment checklist, embedded directly within the electronic health record (EHR), for patients admitted with multiple rib fractures.

Study design

We performed a single-institution, retrospective cohort study at our urban, level 1 trauma center and safety-net hospital to assess changes in treatment characteristics and patient outcomes before and after implementation of a comprehensive checklist for the management of high-risk patients with three or more traumatic rib fractures (Fig. 1). The period prior to implementation of the checklist occurred 4/1/2019 to 9/26/2020, and the intervention period was 12/22/2020 to 5/29/2022. The study was approved by Boston University's Institutional Review Board (IRB number H-42,891, "Implementation of a Rib Fractures Checklist to Reduce Pneumonia Rates in the Surgical Intensive Care Unit at a Level One Trauma Center", approved 8/3/2022).

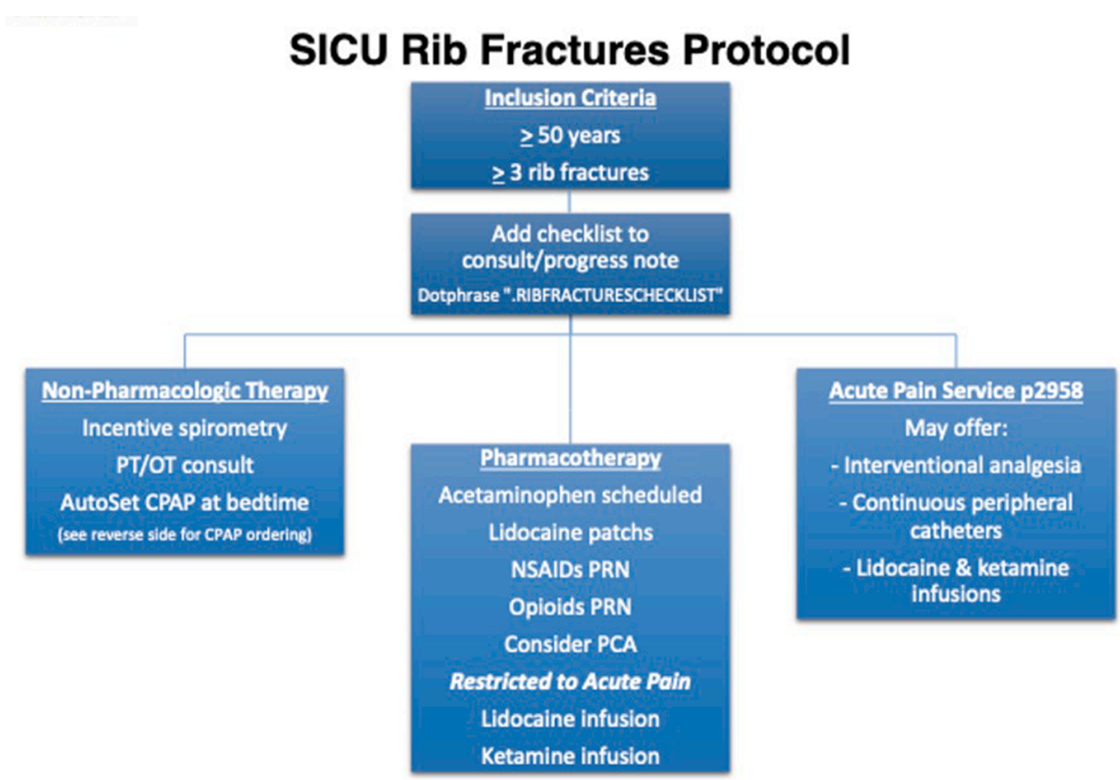

Fig. 1. In this study, we investigate the implementation of a electronic checklist for the multidisciplinary management of patients with multiple rib fractures who present to an urban, level 1 trauma center and safety-net hospital. The checklist was developed collaboratively by a multidisciplinary committee consisting of one critical care pharmacist, two surgical intensivists, one anesthesiologist, three nurse practitioners (NPs), and one respiratory therapist. The final checklist was based on current evidence and consensus opinion. The checklist was embedded into ICU admission note, and subsequent daily progress notes. Use of the checklist and its components were left to the discretion of the attending ICU physician. Review and completion of the checklist was documented daily in the electronic medical record.

Patient population

Based on preexisting practices, patients greater than or equal to 50 years of age who presented with three or more rib fractures were admitted to the ICU for initial management. Given this practice, this criteria was established as the study inclusion criteria. No specific exclusion criteria were established; patients with penetrating trauma who suffered rib fractures were not excluded.

Intervention

The checklist was developed collaboratively by a multidisciplinary committee consisting of one critical care pharmacist, two surgical intensivists, one anesthesiologist, three nurse practitioners (NPs), and one respiratory therapist. The final checklist was based on current evidence and consensus opinion. Review of the checklist was initially performed daily by the rounding SICU pharmacist, however, missed opportunities were identified during off-hours and weekends where a rounding pharmacist was not present. The decision was then made to embed the checklist into the SICU admission note, and subsequent daily progress notes. Use of the checklist and its components were left to the discretion of the attending ICU physician. Review and completion of the checklist was documented daily in the electronic medical record.

The EHR-embedded checklist recommended the use of scheduled acetaminophen, non-opioid analgesics, patient controlled analgesia (PCA), AutoSet continuous positive airway pressure (CPAP), and consults to physical therapy (PT), occupational therapy (OT), and Acute Pain Service (APS) (Fig. 1), unless otherwise contraindicated. The inpatient APS provided consultation regarding optimal pharmacologic and non-pharmacologic analgesic management. Services included epidural placement; however, regional blocks or catheters were not offered or available post-operatively during the study period. The checklist was intended for all patients aged 50 years and greater with three or more rib fractures.

Data collection and outcomes

Patient demographics including age, gender, pre-existing comorbidities, history of opioid use defined as history of opioid use disorder or history of chronic opioid use prior to admission, mechanism of injury, injury severity score (ISS), thoracic abbreviated injury scale (AIS), APACHE II, number of rib fractures were compared pre- and post-implementation of the checklist. The primary outcome metric measured was occurrence of hospital or ventilator-acquired pneumonia, defined as pneumonia occurring >48 h after admission or >48 h after initiation of mechanical ventilation, respectively. Pneumonia was identified by reviewing the EHR patient care notes and was included if they completed a full course of appropriate antibiotics as determined by the SICU team. Secondary outcome metrics measured were hospital and ICU length of stay, opioid requirements expressed as morphine milligram equivalents (MMEs) during the first seven days of hospitalization, intubation and re-intubation rates, days of mechanical ventilation and all-cause mortality. Process metrics measured included daily review of the checklist defined by documentation in the SICU admission note, use of incentive spirometry (IS), consults to PT, OT and APS, AutoSet CPAP at night, initiation of acetaminophen within 24 h, use of non-steroidal anti-inflammatory drugs (NSAIDs), gabapentinoids, tramadol, lidocaine patches or infusions, ketamine infusions, and neuraxial or regional analgesia. Adherence to the checklist was counted if it was documented in the EHR, with or without all elements implemented.

Statistical analysis

Descriptive statistics were completed to summarize the baseline patient attributes and presenting clinical characteristics for the entire study population, and separately for patients before and after implementation of the rib fracture protocol. Chi-square analysis or Kruskal-Wallis test by ranks was performed to assess for differences between the two cohorts. Completion of individual components of the rib fracture protocol, as well as a composite measure (including completion of PT/OT evaluation, use of IS, administration of scheduled acetaminophen within the first 24 h of admission and consultation of APS) was assessed in the two groups. Primary and secondary outcomes were described for the entire study cohort and by intervention period; differences were assessed using Chi-square or Kruskal-Wallis test, as appropriate. In addition, patient demographics, injury characteristics and patient outcomes, specifically length of ICU stay, length of total hospitalization and in-hospital mortality were compared among patients with and without pneumonia. Multivariate linear regression was performed to assess for associations between pneumonia and select outcomes, specifically length of ICU stay, length of total hospitalization and in-hospital mortality. Based on our conceptual model, we included the following exposures in the model: age, sex (dichotomous), diabetes (dichotomous), current or former smoker (dichotomous), ISS, APACHE II score (ordinal), number of rib fractures, and whether the patient required mechanical ventilation (dichotomous).

Statistical analysis was performed using STATA (Version 15.1; StataCorp, College Station, TX).

Results

A total of 104 patients who met study inclusion criteria were identified; 51 patients who presented during the pre-checklist period and 53 patients who received care after checklist implementation. In both periods, the majority of patients were male (68.6% vs 54.7%, $p = 0.15$) [Table 1]. Median (IQR) age was 67 (57–78), with no differences between periods ($p = 0.24$). Among all patients, 20.2% and 46.2% had a diagnosis of diabetes and hypertension, respectively. Half of all included patients were either a current smoker (23.1%) or former smoker (26.9%). There were no significant differences in baseline characteristics and comorbidities among the two cohorts. Across all patients, the most common mechanisms of injury were falls (47.1%), motor vehicle collision (MVC) (24.0%) and pedestrian strike (16.4%). The mechanism of injury was not statistically different between the two groups ($p = 0.2$); however, in the post-protocol period, patients more often presented after MVC (28.3% vs 19.6%).There were no differences in the number of rib fractures, ISS, thoracic AIS and APACHE II scores between groups.

With regard to checklist implementation, we observed that the checklist was reviewed in 83% of patients during the post-checklist period [Table 2]. The composite measure, which included completion of PT/OT evaluation, use of IS, administration of scheduled acetaminophen within the first 24 h of admission and consultation of APS, was completed in 56.6% of patients during the post-checklist period. In terms of individual components of the protocol, we observed an increase after checklist implementation in the rate of scheduled acetaminophen ordered within the first 24 h (98.1% vs 78.4%), rate at which AutoSet CPAP was ordered (35.8% vs 2.0%), and consultation of the acute pain service (69.8% vs 13.6%) – however, the APS was not implemented until January 2020. There was no difference in the rate of PT/OT evaluation (96.1% vs 94.3%) nor the rate of IS use (74.5% vs 77.4%) after checklist implementation.

The primary outcome of pneumonia rate was significantly lower in the post-checklist group (35.3% vs 15.1%, $p = 0.017$) [Table 3]. Patients in the post-checklist group demonstrated a non-significant trend toward fewer re-intubations (9.8% vs 1.9%, $p = 0.08$). After checklist implementation, there was no significant difference in the number of patients that required mechanical ventilation or the duration of mechanical ventilation. On unadjusted analysis, median total length of stay (11.5 days vs 13 days, $p = 0.71$), median ICU stay (4 days vs 5 days, $p = 0.18$), and rate of in-hospital mortality (11.8% vs 7.6%, $p = 0.47$) were not different between cohorts.

With regard to in-hospital non-opioid and opioid administration, we

Table 1
Baseline patient attributes and clinical characteristics.

Characteristic	All (*N* = 104)	Pre-Protocol (*N* = 51)	Post-Protocol (*N* = 53)	P-value*
Male, n (%)	64 (61.5)	35 (68.6)	29 (54.7)	0.15
Age, median (IQR)	67 (57–78)	67 (55–77)	67 (58–79)	0.24
Diabetes, n (%)	21 (20.2)	8 (15.70	13 (24.5)	0.26
Hypertension, n (%)	48 (46.2)	24 (47.1)	24 (45.3)	0.86
COPD, n (%)	5 (4.8)	3 (5.9)	2 (3.8)	0.62
Current smoker, n (%)	24 (23.1)	15 (29.4)	9 (17.0)	0.13
Former smoker, n (%)	28 (26.9)	15 (29.4)	13 (24.5)	0.58
History of opioid use, n (%)	9 (8.7)	4 (7.8)	5 (9.4)	0.77
Mechanism of Injury				
Assault	4 (3.9)	2 (3.9)	2 (3.8)	0.22
Fall	49 (47.1)	24 (47.1)	25 (47.1)	
Motor vehicle collision	25 (24.0)	10 (19.6)	15 (28.3)	
Motorcycle collision	8 (7.7)	7 (13.7)	1 (1.9)	
Pedestrian strike	17 (16.4)	7 (13.7)	10 (18.9)	
Other	1 (1.0)	1 (2.0)	0 (0)	
ISS, median (IQR)	17 (10.5–22)	17 (13–25)	14 (10–22)	0.09
Thorax AIS, n (%)				0.17
Minor	1 (1.0)	1 (2.0)	0 (0)	
Moderate	25 (24.0)	4 (7.8)	21 (39.6)	
Serious	74 (71.2)	44 (86.3)	30 (56.6)	
vSevere	2 (1.9)	1 (2.0)	1 (1.9)	
Critical	2 (1.9)	1 (2.0)	1 (1.9)	
APACHE II, median (IQR)	10 (7–14)	10 (6–15)	9 (7–13)	0.97
APACHE II, n (%)				0.82
1–4	5 (4.8)	2 (4.7)	3 (5.7)	
5–9	40 (38.5)	18 (41.9)	22 (41.5)	
10–14	27 (26.0)	12 (27.9)	15 (28.3)	
15–19	8 (7.7)	3 (7.0)	5 (8.4)	
20–24	8 (7.7)	6 (14.0)	2 (3.8)	
25–29	4 (3.9)	2 (4.7)	2 (3.8)	
Not reported / available	12 (11.5)	8 (15.7)	4 (7.6)	
Number of rib fractures, n (%)				0.67
3–4,	46 (44.2)	20 (39.2)	26 (49.1)	
5–6	28 (26.9)	15 (29.4)	13 (24.5)	
7–9	15 (14.4)	7 (13.7)	8 (15.1)	
≥10	15 (14.4)	9 (17.7)	6 (11.3)	
Bilateral rib fractures, n (%)	40 (38.5)	19 (37.3)	21 (39.6)	0.80
Flail chest, n (%)	5 (4.8)	4 (7.8)	1 (1.9)	0.16
Rib plating, n (%)	5 (4.8)	3 (5.9)	2 (3.8)	0.62
Intubated on admission$	29 (27.9)	16 (31.4)	13 (24.5)	0.44
Required mechanical ventilation	34 (32.7)	17 (33.3)	17 (32.1)	0.89

IQR: interquartile range; COPD: chronic obstructive pulmonary disease; ISS: injury severity score; AIS: abbreviated injury scale; APACHE: acute physiologic and chronic health evaluation.
* Student *t*-test, Kruskal-Wallis rank test or chi-square analysis as appropriate.
$ Intubated in the field or emergency department, prior to ICU admission and/or evaluation by trauma intensivist.

observed that use of lidocaine patches and neuraxial interventions was significantly higher in the post-intervention group (78.4% vs 92.5%; p = 0.04, 15.7% vs 32.1%; p = 0.05, respectively) [Table 4]. Opioid consumption (MME) in the first seven days of admission was not different between groups.

On unadjusted analysis, patients who developed pneumonia in either time period had a higher ISS, APACHE II scores, intubation rates, and duration of mechanical ventilation [Table 5]. Median age was lower among patients with pneumonia (65 years vs 67 years, p = 0.05). Patient comorbidities did not differ among patients with and without pneumonia. Across both time periods, patients with pneumonia had longer overall hospital and ICU length of stay.

Table 2
Use of rib fracture checklist among eligible patients.

Component	Completion, N (%)	
	Pre-checklist (*N* = 51)	Post-checklist (*N* = 53)
Checklist reviewed	N/A	44 (83.0%)
PT/OT consultation	49 (96.1%)	50 (94.3%)
Incentive spirometry	38 (74.5%)	41 (77.4%)
AutoSet CPAP at bedtime		
Ordered	1 (2.0%)	19 (35.8%)
Contraindication (nasal fracture)	N/A	1 (1.8%)
Intubated and mechanical ventilation	17 (33.3%)	17 (32.1%)
Normal O2 saturation	N/A	5 (9.4%)
Not ordered, no comment	33 (64.7%)	11 (20.8%)
Scheduled Acetaminophen	40 (78.4%)	52 (98.1%)
Acute pain consultation*	3 (13.6%)	37 (69.8%)
Composite measure$	N/A	30 (56.6%)

PT: Physical therapy; OT: occupational therapy; CPAP: continuous positive airway pressure.
* Acute pain service was initiated January 6, 2020.
$ Composite measure = PT/OT, IS, scheduled acetaminophen and APS consultation.

Table 3
Primary outcomes before and after implementation of SICU rib fracture checklist.

Characteristic	All (*N* = 104)	Pre-Protocol (*N* = 51)	Post-Protocol (*N* = 53)	P-value*
Hospital / ventilator pneumonia	26 (25.0)	18 (35.3)	8 (15.1)	0.017
Required mechanical ventilation	34 (32.7)	17 (33.3)	17 (32.1)	0.89
Days required, median (IQR)	6 (4–17)	6 (4–12)	6 (4–19)	0.85
1–2 days, n (%)	7 (20.6)	3 (17.7)	4 (23.5)	0.89
3–6 days, n (%)	11 (32.4)	6 (35.3)	5 (29.4)	
7–9 days, n (%)	0 (0)	0 (0)	0 (0)	
≥10 days, n (%)	16 (47.1)	8 (47.1)	8 (47.1)	
Required re-intubation	6 (5.8)	5 (9.8)	1 (1.9)	0.08
Length of stay, median (IQR)				
Intensive care unit	4.5 (3–11)	5 (3–12)	4 (3–10)	0.18
Total hospital stay	12.1 (7.9–22.5)	11.5 (7.9–23.5)	13 (8–19.0)	0.71
Deceased, n (%)	10 (9.6)	6 (11.8)	4 (7.6)	0.47

IQR: Interquartile range.
* Student *t*-test, Kruskal-Wallis rank test or chi-square analysis as appropriate.

On multivariable analysis, adjusted for age, sex, history of diabetes, past smoking use, ISS, APACHE II, number of rib fractures, and requirement for mechanical ventilation, pneumonia was positively associated with longer ICU (β=7.3, 95% CI: 2.7–11.9) and hospital (β=12.4 95% CI: 0.5–24.3) length of stay [Supplemental Table 1]. Number of rib fractures and requirement for mechanical ventilation were both associated with ICU LOS. After adjustment as above, diagnosis of pneumonia was not associated with in-hospital mortality.

Discussion

Rib fractures in the elderly carry a high risk of morbidity and mortality [1–4]. Complications significantly increase when patients experience more than three rib fractures [5]. We identified an area of opportunity at our institution to improve the care we provide to this patient group by standardizing our practices. To our knowledge, this is the first study describing the utilization of a checklist to advance an evidence-based approach to caring for patients with traumatic rib fractures, whereas prior studies describe use of a pathway or medication

Table 4
Prescribed opioid and non-opioid medications before and after rib fracture checklist.

Characteristic	All (N = 104)	Pre-Protocol (N = 51)	Post-Protocol (N = 53)	P-value*
In-hospital medication use				
NSAID, N (%)	34 (32.7)	15 (29.4)	19 (35.9)	0.48
mg per day, median (IQR)	18.2 (9.4–39)	19.3 (10.7–75)	16.9 (5.6–37.5)	0.612
Gabapentin, N (%)	25 (24.0)	14 (27.5)	11 (20.8)	0.42
Mean mg per day, median (IQR)	333.3 (171.2–675)	457.1 (171.2–814.3)	300 (150–675)	0.61
Acetaminophen, N (%)	92 (88.5)	40 (78.4)	52 (98.1)	0.002
Mean mg per day, median (IQR)	2218.8 (1449.4–2858.1)	2371.4 (1912.5–3006.3)	2159.4 (1500–2856.3)	0.123
Tramadol, N (%)	5 (4.8)	4 (7.8)	1 (2.0)	0.16
Mean mg per day, median (IQR)	25 (20–58.3)	41.7 (22.5–654.2)	6.25 (No IQR)	N/A
Opioids, N (%)	101 (97.1)	49 (96.1)	52 (98.1)	0.54
Mean mg per day, median (IQR)	15.8 (26.6–46.5)	30.1 (16.7–46.5)	24.0 (11.6–51.7)	0.34
Lidocaine patch, N (%)	89 (85.6)	40 (78.4)	49 (92.5)	0.04
Lidocaine infusion, N (%)	2 (1.9)	1 (2.0)	1 (1.9)	0.98
Ketamine infusion, N (%)	3 (5.7)	0 (0)	3 (5.7)	0.09
Epidural, N (%)	25 (24.0)	8 (15.7)	17 (32.1)	0.05
Patient-controlled analgesia, N (%)	6 (5.8)	3 (5.9)	3 (5.7)	0.96
Post-discharge prescriptions				
Opioids, N (%)	52 (75.0)	26 (51.0)	26 (49.1)	0.84
Oxycodone, N	39	17	22	N/A
Hydromorphone, N	8	4	4	N/A
Tramadol, N	3	3	0	N/A
Other, N	2	2	0	N/A
Total MME, median (IQR)**	75 (37.5–150)	75 (40–150)	77.5 (37.5–150)	0.54
Tylenol and/or NSAID, N (%)	82 (78.9)	37 (72.6)	45 (84.9)	0.12

IQR: Interquartile range; MME: morphine milligram equivalents; NSAID: non-steroidal anti-inflammatory drugs.
* Mean mg per day is the mean mg consumed per day for HD-0 to HD-7 among patients consumed a non-zero amount of the listed medication.
** Total MME prescribed is not available for 17 patients discharged to a facility with an opioid prescription without a specified quantity.

Table 5
Injury attributes and outcomes among patients with hospital/ventilator pneumonia.

	No Pneumonia (N = 78)	Pneumonia (N = 26)	P-Value
Male, n (%)	45 (57.7)	19 (73.1)	0.16
Age, median (IQR)	67 (58–80)	65 (56–71)	0.05
COPD, n (%)	3 (3.9)	2 (7.7)	0.43
Current smoker, n (%)	17 (21.8)	7 (26.9)	0.59
Former smoker, n (%)	23 (29.5)	5 (19.2)	0.31
ISS, median (IQR)	15.5 (10–20)	19.5 (14–34)	0.002
APACHEII, median (IQR)	9 (7–12.5)	12.5 (7–21.5)	<0.001
Number of rib fractures, median (IQR)	5 (4–6)	6 (3–10)	0.06
Intubated on admission	13 (16.7)	16 (61.5)	<0.001
Mechanical ventilation	15 (19.2)	19 (73.1)	<0.001
Length of stay [days], median (IQR)			
Intensive care	3.5 (3–6)	12.5 (9–26)	<0.001
Hospital	9.7 (7–15)	26.1 (18.3–42.1)	<0.001
Deceased	7 (9.0)	3 (11.5)	0.70

COPD: chronic obstructive pulmonary disease; ISS: injury severity score; APACHE: acute physiologic and chronic health evaluation.

order-set [10,11]. While a protocolized approach is likely beneficial, as evidenced by prior studies, protocol use may be limited by patient identification and consistent application of the protocol. After implementing a protocol checklist embedded in the electronic record, we observed a significant decrease in pneumonia rates. Our checklist was developed based on current evidence and best practice [13,14], and the current study provides an example for streamlining protocolized, evidence-based care.

Our pneumonia rate prior to checklist implementation is reflective of what was observed by Bulger et al. [5]. Although their patients were older, we had similar thoracic AIS and ISS. Our observed outcomes of mean ventilator days, ICU length of stay, and hospital length of stay were also similar. Patients who developed pneumonia were more likely to be intubated, have a higher ISS, and require a longer ICU and hospital length of stay. As mentioned, rib fractures incur a significant amount in healthcare expenditures, and requiring mechanical ventilation can increase that cost significantly [6]. In 2005, Dasta et al. discovered that patients admitted to an ICU whom required mechanical ventilation had a two- to three-time increase in ICU cost when compared to patients that did not require mechanical ventilation [15]. Of note, our study demonstrated a trend for decreased need for re-intubation after checklist implementation. Given the implications for quality and costs, measures to minimize need for intubation and mechanical ventilation in this patient population should be prioritized.

As mentioned prior, Todd et al. implemented a clinical pathway that included patients with greater than four rib fractures and greater than 45 years of age [10]. Our patients had similar baseline characteristics, albeit slightly different inclusion criteria. In Todd et al.'s study, patients that met pathway criteria received a pain consult for pain management optimization, RT consult for volume expansion, PT/OT consult, nutrition consult, and NP assessment of co-morbid factors. Comparing interventions, our checklist included many of the core components of their pathway. They observed a significant decrease in pneumonia (18% vs 7%, $p = 0.003$) and mortality rates (13% vs 4% $p = 0.004$) following pathway implementation. In the current study, we observed a similar reduction in pneumonia rates, although our pre-checklist pneumonia rates were higher. This may be attributed to our patients requiring more mechanical ventilation days and/or the smaller sample size in our current study, which may also explain why we did not observe a concomitant decrease in mortality rate during the post-intervention period.

Unlike Burton et al.'s findings [11], we did not observe significant decrease in opioid usage following implementation of protocolized care. This may be attributed to patients in the post-checklist group having more moderate AIS scores as compared to the pre-intervention cohort.

Additionally, median ISS score was higher in the current study, indicating higher injury severity. Patients in Burton's study had a higher rate of non-opioid analgesics usage than our patients: twice as much for NSAIDs, three times as much for gabapentinoids. This may be due to practice preference differences between institutions. Their study did utilize lidocaine patches; however, they did not report overall utilization. Additionally, they did not report data on neuraxial interventions, which may have impacted their outcomes.

When comparing our pre- and post-checklist pharmacotherapy utilization, the increased initiation of acetaminophen within 24 h, lidocaine patches, and neuraxial/regional interventions likely resulted in improved pain control, which can improve compliance and efficacy of IS. When combined with other interventions, IS has been shown to decrease postoperative pulmonary complications [16]. The use of non-invasive CPAP is associated with decreased mortality and rates of pneumonia when compared to invasive positive pressure ventilation [17]. Utilization of CPAP was low in our study; thus, it is unclear if higher utilization would have impacted our outcomes.

Our study is limited due to its single-center, retrospective nature. In addition, compliance to checklist review was not 100%. Initially, implementation and review of the checklist was performed by the rounding SICU pharmacist during weekdays; however, in order to facilitate more universal compliance, including on weekends and holidays, we incorporated the checklist to default into the SICU admission and progress note. At present, there are pending changes in the EHR to build an order-set to include the aforementioned interventions in our checklist. Furthermore, during the study period, the inpatient APS did not provide regional anesthetic blocks or catheters for post-operative patients; future research should evaluate the role and potential added value of this modality in this patient population.

In conclusion, in high-risk patients with chest wall trauma and associated rib fractures, implementation of a electronic checklist to ensure utilization and optimization of multimodal analgesia and non-pharmacological interventions was associated with decreased rates of pneumonia without a concurrent increase in patient opioid consumption.

Disclosures

No conflicts of interests or financial disclosures to declare.

Brief title

Implementation of a Multidisciplinary Rib Fracture Checklist.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.sipas.2023.100192.

References

[1] Flagel BT, Luchette FA, Reed RL, et al. Half-a-dozen ribs: the breakpoint for mortality. Surgery 2005;138:717–23. discussion 23-5.

[2] Ziegler DW, Agarwal NN. The morbidity and mortality of rib fractures. J Trauma 1994;37(6):975–9. https://doi.org/10.1097/00005373-199412000-00018.

[3] Bergeron E, Lavoie A, Clas D, et al. Elderly trauma patients with rib fractures are at greater risk of death and pneumonia. J Trauma 2003;54(3):478–85. https://doi.org/10.1097/01.TA.0000037095.83469.4C.

[4] Cameron P, Dziukas L, Hadj A, Clark P, Hooper S. Rib fractures in major trauma. Aust NZ J Surg 1996;66(8):530–4. https://doi.org/10.1111/j.1445-2197.1996.tb00803.x.

[5] Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. J Trauma 2000;48(6):1040–6. https://doi.org/10.1097/00005373-200006000-00007. discussion 1046-7PMID: 10866248.

[6] Sarode AL, Ho VP, Pieracci FM, Moorman ML, Towe CW. The financial burden of rib fractures: national estimates 2007 to 2016. Injury 2021;52(8):2180–7. https://doi.org/10.1016/j.injury.2021.05.027.

[7] Amital A, Shitrit D, Fox BD, et al. Long-term pulmonary function after recovery from pulmonary contusion due to blunt chest trauma. Isr Med Assoc J 2009;11:673–6.

[8] Kerr-Valentic MA, Arthur M, Mullins RJ, Pearson TE, Mayberry JC. Rib fracture pain and disability: can we do better? J Trauma 2003;54:1058–63. discussion 63-4.

[9] Beal SL, Oreskovich MR. Long-term disability associated with flail chest injury. Am J Surg 1985;150:324–6.

[10] Todd SR, McNally MM, Holcomb JB, et al. A multidisciplinary clinical pathway decreases rib fracture- associated infectious morbidity and mortality in high-risk trauma patients. Am J Surg 2006;192:806–11.

[11] Burton SW, Riojas C, Gesin G, et al. Multimodal analgesia reduces opioid requirements in trauma patients with rib fractures. J Trauma Acute Care Surg 2022;92(3):588–96. https://doi.org/10.1097/TA.0000000000003486.

[12] Kelley KM, Burgess J, Weireter L, et al. Early use of a chest trauma protocol in elderly patients with rib fractures improves pulmonary outcomes. Am Surg 2019;85(3):288–91.

[13] Langley GL, Moen R, Nolan KM, Nolan TW, Norman CL, Provost LP. The improvement guide: a practical approach to enhancing organizational performance. 2nd ed. San Francisco: Jossey-Bass Publishers; 2009.

[14] Witt CE, Bulger EM. Comprehensive approach to the management of the patient with multiple rib fractures: a review and introduction of a bundled rib fracture management protocol. Trauma Surg Acute Care Open. 2017;2(1):e000064. https://doi.org/10.1136/tsaco-2016-000064. Published 2017 Jan 5.

[15] Dasta JF, McLaughlin TP, Mody SH, Piech CT. Daily cost of an intensive care unit day: the contribution of mechanical ventilation. Crit Care Med 2005;33(6):1266–71. https://doi.org/10.1097/01.ccm.0000164543.14619.00.

[16] Cassidy MR, Rosenkranz P, McCabe K, Rosen JE, McAneny D. I COUGH: reducing postoperative pulmonary complications with a multidisciplinary patient care program. JAMA Surg 2013;148(8):740–5. https://doi.org/10.1001/jamasurg.2013.358.

[17] Gunduz M, Unlugenc H, Ozalevli M, Inanoglu K, Akman H. A comparative study of continuous positive airway pressure (CPAP) and intermittent positive pressure ventilation (IPPV) in patients with flail chest. Emerg Med J 2005;22(5):325–9. https://doi.org/10.1136/emj.2004.019786.