The Association Between Pulmonary Contusion Severity and Respiratory Failure

S Whitney Zingg, D A Millar, Michael D Goodman, Timothy A Pritts, and Christopher F Janowak

BACKGROUND: Pulmonary contusions (PCs) have historically been viewed as a serious complicating factor in thoracic injury. Recently, there has been conflicting evidence regarding the influence of PCs on outcomes; however, many studies do not stratify contusions by severity and may miss clinical associations. We sought to identify if contusion severity is associated with worse outcomes. METHODS: A previously published chest wall injury database at an urban Level I trauma center was retrospectively reviewed. All severely injured subjects (defined as Injury Severity Score [ISS] ≥ 15) with moderate to severe thoracic injury (defined as a chest wall Abbreviated Injury Scale [AIS] ≥ 3) who required mechanical ventilation for > 24 h were stratified by contusion severity. Moderate to severe contusions were defined as AIS contusion ≥ 3 and Blunt Pulmonary Contusion 18 (BPC18) score ≥ 3. RESULTS: Over 5 y, 3,836 patients presented with chest wall injuries, of which 1,176 (30.6%) had concomitant contusions. When screened for inclusion criteria, 339 subjects with contusions and 211 subjects without contusions (no-PC) were identified. Of these, 234 had moderate to severe contusions defined by AIS contusion ≥ 3 (PC-A) and 230 had moderate to severe contusions by BPC18 ≥ 3 (PC-B). Compared to no-PC, both PC-A and PC-B groups had significantly lower mortality (17.9% and 17.4%, respectively, vs 28.9%); however, PC-A and PC-B groups had longer durations of mechanical ventilation (6 and 7 d, respectively, vs 5 d), longer ICU length of stay (10 and 10 vs 8 d), and longer overall hospital length of stay (15 and 15 vs 13 d). CONCLUSIONS: In severely injured polytrauma patients, PCs are seen with more severe chest injuries. Furthermore, moderate to severe contusions are associated with longer durations of mechanical ventilation, ICU length of stay, and hospital length of stay. Despite practice pattern changes, contusions appear to contribute significantly to the clinical course of the blunt chest wall injured patients. *Key words: Pulmonary contusions; chest injury; chest wall; thoracic trauma; injury scoring.* [Respir Care 2021;66(11):1665–1672. © 2021 Daedalus Enterprises]

Introduction

Pulmonary contusions (PCs) are a commonly encountered consequence of high-energy thoracic injury, affecting as many as 5.2% of all injured patients.[1] In severely injured patients (Injury Severity Score [ISS] > 15), the incidence may be as high as 50%.[2,3] Historically, contusions have been correlated with worse respiratory function, morbidity, and higher mortality. [4-6] Mortality in the setting of contusion ranges widely from 14–40%, and notable associations between contusions and ARDS have been identified.[1,5-7] However, much of the current contusion understanding is derived from animal studies from the 1970s through 1990s. These studies tested the evolution of contusions using resuscitation strategies common to that time period, consisting mostly of high-volume crystalloid resuscitation directed at maintaining "normal" blood pressures.[4] High-volume crystalloid resuscitation in the setting of injury has been found to exacerbate PCs,[4] causing perturbations to oxygenation, increasing the need for intubation and advanced mechanical ventilation strategies. As a result, current management of the injured patient employs reduced crystalloids that may reduce PC consequences.

Recently, there has been conflicting evidence regarding the impact of PCs on clinical outcomes, and some studies have suggested there may be only minor, if any, clinical consequences of contusions following blunt chest injury.[8-11] In 2008, Dinh and colleagues[12] suggested that only contusions seen on initial presentation were of clinical importance. Rodriguez and colleagues[9] came to the conclusion that in the

era of pan-cross-sectional imaging isolated contusions and those PCs seen only on computed tomography imaging are of little clinical importance. In 2017, Chrysou and colleagues[10] suggested that PCs are common but appear to have little effect on outcomes. These observations have been made over a heterogeneous array of methods and patient cohorts but followed a trend of analysis by differentiating only the presence or absence of contusions.

More recently, Dhar et al[11] evaluated PCs in the setting of populations at high risk for respiratory complications. This high-risk population was defined as severely injured subjects (ISS $\geq$ 15) with moderate to severe thoracic injury who required mechanical ventilation for $>$ 24 h. Finding no difference in outcomes between subjects with and without contusions, these authors echoed other studies concluding that PCs have contributed little to negative outcomes.[9-12] The recent trend to treat contusions as either being present or absent as opposed to graduated by severity may disregard clinically important implications. Several injury severity scales exist to grade PCs. The most widespread of these scales are the Abbreviated Injury Scale (AIS)[13] and the Blunt Pulmonary Contusion 18 (BPC18) score.[14] By stratifying PCs by severity, a population in greater need for academic scrutiny and meticulous respiratory support and care may be realized. We hypothesized that stratification of PCs by severity in an injured population would reveal that PCs are associated with worse outcomes.

QUICK LOOK

Current knowledge

Pulmonary contusions (PC) are a commonly encountered injury in the trauma patient, affecting as much as 5.2% of all injured patients. In recent years, there has been conflicting evidence on the impact of PCs on clinical outcomes. Some studies have suggested there may be only minor if any clinical consequences of PCs in the setting of blunt chest injury.

What this paper contributes to our knowledge

When present in a severely injured patient population requiring mechanical ventilation, more severe PCs demonstrated longer ICU and hospital lengths of stay. Subjects with any PCs were at an increased risk of developing respiratory failure for $>$ 48 h when adjusted for age, gender, and comorbid diabetes.

Methods

A retrospective review of patients sustaining blunt chest wall injuries over a 5-y period at a single urban American College of Surgeons–verified Level I trauma center was performed utilizing an institutional trauma registry. All adult subjects (age $>$ 15 y) sustaining bony chest wall injuries between January 2014 and December 2018 were included and screened for PCs. A portion of this database has been previously published;[15] however, the current data set was expanded to include PC information as detailed below. Data gathering and analysis was conducted following University of Cincinnati Institutional Review Board approval (IRB # 2017–2673).

In keeping with prior methods published by Dhar et al,[11] subjects included in the analysis had severe injuries (defined as ISS $\geq$ 15) with moderate to severe thoracic injury (defined as thoracic AIS $\geq$ 3) who required mechanical ventilation for $>$ 24 h. In an effort to screen more specifically for bony injuries, chest wall AIS (which is isolated to rib cage and sternal fractures) was used in place of thoracic AIS, which can be skewed by nonpulmonary cardiac and great vessel injuries. These subjects were then divided into 2 subgroups: those meeting inclusion criteria with PCs and those without contusions (no-PCs). Subjects with PCs were scored by 2 separate scoring systems into moderate to severe groups according to the contusions/laceration AIS (PC-A) and the BPC18 score (PC-B). Details of the PC scoring systems can be seen in Figure 1. Records were reviewed for data including demographics, hospitalization data, tracheostomy, complications, and 30-d readmissions. All imaging (including initial digital chest roentgenogram and chest computed tomography CT scan if available) was reviewed by 2 authors (SWZ and CFJ) for injury pattern and contusion severity using both of the scoring systems above according to previously described methods.[3,13,14] PC on imaging was defined as an area of increased lung parenchymal opacity without bronchial or vascular crowding. Moderate to severe contusion was defined as contusions/laceration AIS $\geq$ 3 and BPC18 $\geq$ 3. The AIS is the internationally recognized system for injury coding produced by the Association for the Advancement of Automotive Medicine, and scoring can range from 2–5. The BPC18 score is based on both the location and density

Dr Zingg is affiliated with the Department of Surgery, University of Cincinnati, Cincinnati, Ohio. Mr Millar, Mr Goodman, Mr Pritts, and Mr Janowak are affiliated with the Divisions of Trauma, University of Cincinnati Medical Center and West Chester Hospital Trauma, Cincinnati, Ohio.

Dr Zingg presented a version of this paper at the Chest Wall Injury Society Summit, held virtually April 22, 2020.

No funding was received for this work.

The authors have no conflicts to disclose.

Correspondence: Christopher F Janowak MD, University of Cincinnati, Department of Surgery, 231 Albert Sabin Way #ML 0558, Cincinnati, OH 45267. E-mail: christopher.janowak@uc.edu.

DOI: 10.4187/respcare.09145

AIS contusion	Definition
2	Unilateral minor contusion; < 1 lobe
3	Unilateral major contusion, ≥ 1 lobe
3	Unilateral minor laceration; < 1 lobe
3	Bilateral minor contusions, < 1 lobe
4	Bilateral major contusions, ≥ 1 lobe
4	Unilateral major laceration; ≥ 1 lobe
4	Bilateral minor lacerations; < 1 lobe
5	Bilateral major lacerations; ≥ 1 lobe

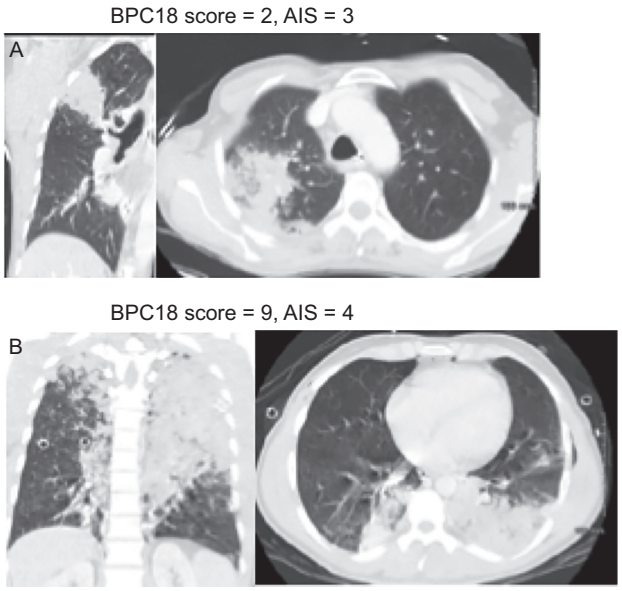

Fig. 1. Two scoring systems were utilized to grade pulmonary contusions, the Abbreviated Injury Scale (AIS) and the Blunt Pulmonary Contusion 18 (BPC18) score. The pulmonary contusion AIS ranges from 2–5 and is defined as seen in the table.[13] For the BPC18, the lung fields are divided into upper, middle, and lower thirds. Each third receives a score based on the density of the contusion in that area seen on cross-sectional imaging, ranging from 1–3.[14] Complete opacification of an entire lobe of the lung (A) would receive a BPC18 = 3, and opacification of an entire lung (B) would receive a 9 for that side.

of contusion and ranges from 1–18. Further clarification of the 2 scoring systems used with representative images can be seen in Figure 1.

Data were collected and analyzed using descriptive statistics and univariate analysis. Statistical analysis was performed using SPSS (Version 26; IBM, Armonk, New York) and SAS 9.4 (SAS Institute, Cary, North Carolina). Non-normally distributed continuous data were evaluated according to medians with interquartile ranges, and discrete data are presented as mean with percentage. Univariate statistics were evaluated using chi-squared or Fisher exact tests for categorical variables. Continuous variables were evaluated using nonparametric Mann-Whitney *U* tests. A multivariate logistic regression was used to assess whether the odds of respiratory failure are associated with a PC, while adjusting for other risk factors. Significance was determined by $P < .05$.

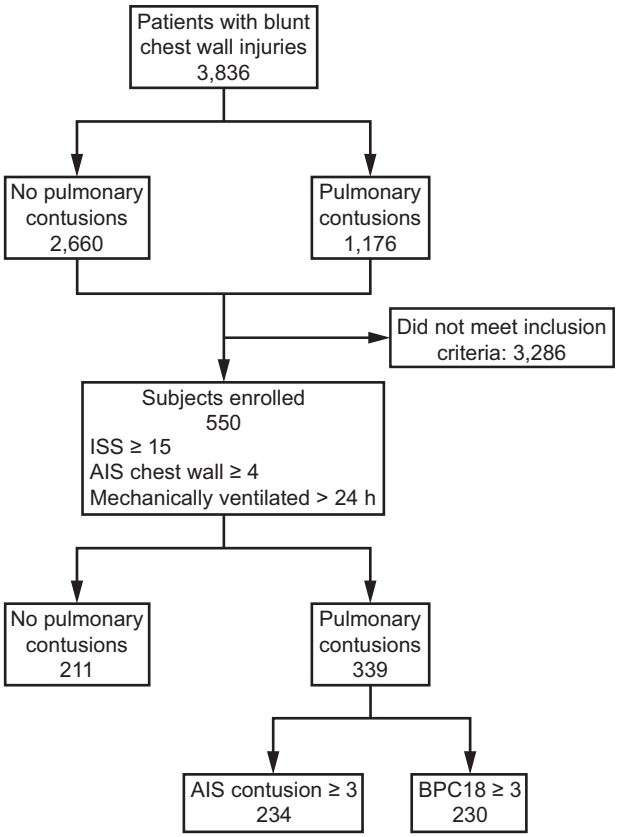

Fig. 2. Flow chart. ISS = Injury Severity Score; AIS = Abbreviated Injury Scale; BPC18 = Blunt Pulmonary Contusion Score 18.

Results

Over 5 y, 3,836 patients presented with chest wall injuries, of whom 1,176 (30.6%) had concomitant contusions. A total of 550 subjects met inclusion criteria and had severe injuries. Of these 550 subjects, 211 (7.9%) were found to have no-PC and 339 subjects had contusions (28.8%). The 339 subjects with PCs were stratified into moderate-severe contusions by a contusion scoring method; 234 (19.8%) met criteria for severe contusion by AIS (PC-A) scoring and 230 (19.5%) when stratified by BPC18 scoring (PC-B) (Fig. 2). The distribution of subjects with PCs between the 2 scoring systems can be seen in Figure 3.

Baseline characteristics as well as injury characteristics between no-PC, PC-A, and PC-B can be seen in Table 1. Compared to no-PC, all subjects with PCs had multiple characteristics that were significantly different. Notably, the subjects with contusions were significantly younger and had fewer preinjury respiratory disorders or diabetes. Additionally, both the PC-A and PC-B groups had significantly worse injuries with higher ISS, more ribs fractured, sternal fractures, hemothoraces, pneumothoraces, and greater need for tube thoracostomy. Between the 2 scoring systems, the PC-B group had a significantly higher rate of

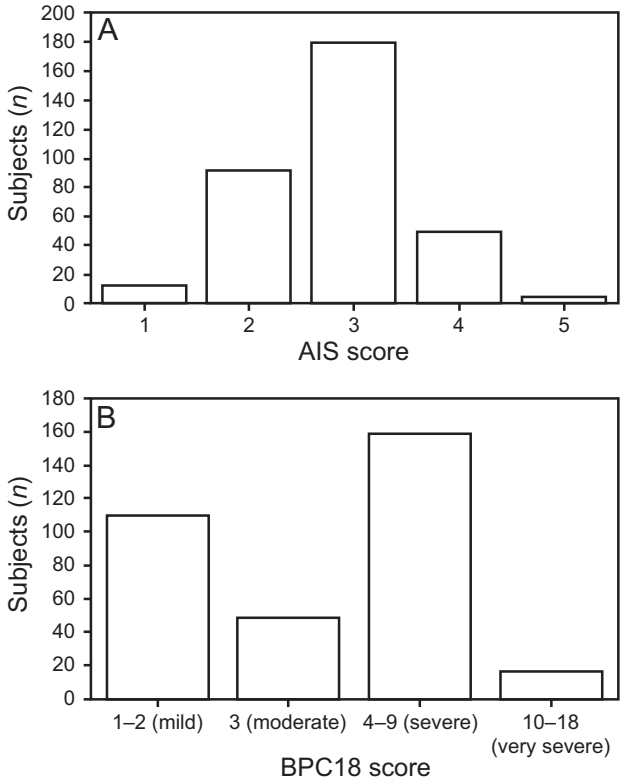

Fig. 3. Distribution of subjects with contusion by AIS contusion/laceration (A) and BPC18 scoring (B). AIS = Abbreviated Injury Scale; BPC18 = Blunt Pulmonary Contusion 18 score.

drug use compared to no-PC, but there were no significant differences between the subjects grouped by PC-A and PC-B.

When comparing clinical outcomes (Table 2), there was a significantly higher mortality rate in no-PC compared to either PC-A or PC-B (28.9% vs 17.9% vs 17.4%, respectively, all $P < .001$). By contrast, both the PC-A and PC-B groups had longer duration of ventilatory support (median 6 and 7 d vs 5 d, $P = .006$ and .002 respectively), longer ICU length of stay (median 10 and 10 d, respectively, vs 8 d, $P = .03$ and .005 respectively), and longer overall hospital length of stay (median 15 and 15 d, respectively, vs 13 d, $P = .003$ and .002 respectively) than no-PC. There were significantly more cardiac complications in the no-PC group than PC-B (13.4% vs 7.4%, $P = .041$), but this did not meet significance between no-PC and PC-A (13.4% vs 7.7%, $P = .050$). Notably there were no differences in other pulmonary complications, tracheostomy, and readmission rates across all groups. There were no significant difference in outcomes between PC-A and PC-B.

To determine whether PCs affect respiratory failure, we analyzed our data to identify associations with respiratory failure as defined by mechanical ventilation > 48 h. Of the 550 subjects meeting inclusion criteria, 404 were identified to have acute respiratory failure. Those subjects with respiratory failure were more likely to have PCs as well as comorbid diabetes (Table 3). A multivariate logistic regression demonstrated PCs are associated with a 2.2 times increased risk of acute respiratory failure after adjusting for diabetes, age, and gender (Table 4).

Discussion

PCs are commonly encountered in trauma patients with blunt chest injury, and in our study, we found that nearly one-third of all subjects with chest wall injuries had a concomitant contusion. Our data demonstrate that contusions are not a homogenous population and more severe contusions, as assessed radiographically, are associated with worse clinical outcomes. By following previously published methods,[11] we found that a high-risk chest wall injury population graded by contusion severity had significantly longer duration of ventilator needs, longer ICU stays, and longer hospital stays than similarly injured subjects without contusion. We also found that the moderate to severe contusion groups as assessed by either the contusions/laceration AIS or the BPC18 scale were not significantly different in chest wall injury or outcomes.

Our results differ from recent studies that suggest PCs do not significantly impact outcomes. In the study by Dhar et al,[11] selecting a group of injured subjects requiring mechanical ventilation and stratifying by the presence or absence of contusion produced 2 groups without significant differences in age or comorbid conditions. By contrast, we found that our no-PC population was significantly older, which is in line with prior studies.[3,16] It may then be unsurprising that this cohort of older subjects had higher rates of preexisting respiratory diseases as well as diabetes. This may also indicate that younger subjects have a greater likelihood of PCs due to the transmission of energy through a more compliant, less ossified chest wall. More important to outcome analysis, we found that both the PC-A and PC-B subpopulations had significantly worse overall and thoracic-specific injuries. No mention of chest wall injury analysis was made by Dhar et al[11] beyond the thoracic AIS comparison, which was already part of the injury severity screening process. The significant differences we observed between those subjects with PCs and those without did not have a clear explanation, and further study may reveal that either injury mechanism or physiologic changes in the older population may reduce the likelihood of contusions. Regardless, despite using the previously described screening process, it is certainly possible that starting out with unequal populations may yield unequal outcomes.

When we analyzed our population for clinical outcomes, we identified marked increases in duration of critical care and hospital needs. When we calculate average duration of mechanical ventilation, we find our average of 10.5–11 d with and without contusion compares well with Dhar et

Table 1. Comparison of Characteristics Between Subjects With and Without Contusions

Characteristic	No-PC	PC-A	PC-B	*P*		
	$n = 211$	$n = 234$	$n = 230$	No-PC versus PC-A	No-PC versus PC-B	PC-A versus PC-B
Age, y	56 (45–66)	41 (27–56)	41 (28–54)	< .001	< .001	.87
Male	144 (68.2)	178 (76.1)	176 (76.5)	.13	.05	.92
BMI	29.3 (25–34)	29.1 (24–33)	28.8 (24–34)	.23	.26	.94
Comorbid conditions, *n* (%)						
Respiratory disorder	30 (14.2)	16 (6.8)	14 (6.1)	.01	.005	.76
Diabetes	36 (17.1)	19 (8.1)	17 (7.4)	.004	.002	.78
Smoking	71 (33.6)	72 (30.8)	69 (30.0)	.52	.42	.85
Alcoholism	34 (16.1)	30 (12.8)	28 (12.2)	.32	.24	.85
Drug Use	22 (10.4)	37 (15.8)	41 (17.8)	.09	.02	.56
Psychiatric disorder	31 (14.7)	27 (11.5)	23 (10.0)	.03	.13	.60
Injury characteristics						
ISS	27 (22–38)	29.5 (22–41)	33 (24–41)	< .001	< .001	.70
Rib score	1 (1–3)	2 (1–4)	2 (1–4)	< .001	< .001	.45
Pulmonary contusion	–	234 (100)	230 (100)	–	–	> .99
Thoracic AIS	–	3 (3–3)	3 (3–3)	–	–	> .99
BPC18	–	4 (3–6)	5 (4–7)	–	–	< .001
Ribs fractured	6 (4–9)	8 (4–12)	9 (5–12)	< .001	< .001	.54
Total ribs fractures	6 (4–9)	9 (4–14)	10 (5–14)	< .001	< .001	.43
Flail segments	8 (3.8)	34 (14.5)	35 (15.2)	.004	.002	.83
Sternal fracture	40 (19.0)	93 (39.7)	92 (40.0)	< .001	< .001	.95
Hemothorax	61 (28.9)	128 (54.7)	131 (57.0)	< .001	< .001	.62
Pneumothorax	87 (41.2)	192 (82.1)	190 (82.6)	< .001	< .001	> .99
Chest tube	72 (34.1)	152 (65.0)	160 (69.6)	< .001	< .001	.29

Categorical variables are presented as *n* (%); non-normally distributed continuous variables are expressed as median (IQR).
PC = pulmonary contusion
BMI = body mass index
ISS = injury severity score
AIS = Abbreviated Injury Scale
BPC18 = Blunt Pulmonary Contusion 18 score
PC-A = pulmonary contusion with AIS contusion/laceration ≥3
PC-B = pulmonary contusion with BPC18 ≥ 3

al.[11] However, noting the non-normal distribution of our data, we found that our median duration of mechanical ventilation was much shorter overall and also significantly shorter in the absence of contusions. This association was unaffected by excluding early deaths. The apparent discrepancy between our findings and those by Dhar et al[11] is that the use of Student *t* test assumes that the data are distributed normally. Using a nonparametric test such as the Mann-Whitney *U* test is better suited to testing the independence of non-normally distributed groups.

The protracted time on the ventilator as well as increased ICU and hospital length of stay observed in our population are consistent with other studies.[2,6] The apparent contrast between these findings and the overall unchanged rate of other complications (other than a trend toward significance for cardiac complications in the setting of contusions) does not have a clear explanation but may be due to the unequalness of those with and without PCs. However, the increased mortality in the no-PC group may be due to the older population having higher rates of chronic illness (respiratory disorder, diabetes, and psychiatric illness).

When we addressed the relationship between all PCs and the risk of respiratory failure, we demonstrated a 2.2 times increased risk of respiratory failure when adjusting for cofactors. This suggests that regardless of contusion severity all contusions in our severe-injury cohort are associated with increased risk of prolonged mechanical ventilation. This in turn may help explain the increased ICU and hospital stay observed, as those with respiratory failure would seemingly require a longer duration of higher-level care.

The contemporary case against the significance of contusions was well laid out by Robinson.[17] In our study, under 20% of patients with contusions were studied, and the majority not studied had minor contusions that posed little clinical consequence. Four factors can be attributed to the diminished significance of contusions, including increased utilization of lung-protective ventilatory strategies, improved damage control resuscitation strategies that minimize crystalloid use, improved ICU sedation techniques, and better multimodal analgesia. It is unlikely that PC rates have decreased, as the widespread availability of cross-sectional imaging allows identification of

Table 2. Comparison of Outcomes Between Subjects With and Without Contusions

Outcome	No-PC	PC-A	PC-B	*P*		
	n = 211	*n* = 234	*n* = 230	No-PC versus PC-a	No-PC Versus PC-B	PC-A versus PC-B
Hospital length of stay, d	13 (7–19)	15 (10–23)	15 (9–23)	.003	.002	.94
ICU length of stay, d	8 (4–15)	10 (5–18)	10 (5–18)	.01	.005	.80
Ventilator days, d	5 (2–12)	6 (3–15)	7 (3–17)	.006	.002	.75
Mortality	61 (28.9)	42 (17.9)	40 (17.4)	.006	.004	.89
Pulmonary complications	174 (82.5)	192 (82.1)	190 (82.6)	.91	.98	.89
Respiratory failure (>48 h)	178 (84.4)	216 (92.3)	187 (81.3)	.01	.39	.89
Unplanned intubation	23 (10.9)	15 (6.4)	22 (9.6)	.09	.65	.20
Pneumonia	50 (23.7)	48 (20.5)	57 (24.8)	.42	.79	.27
Pulmonary embolism	4 (1.9)	11 (4.7)	9 (3.9)	.10	.22	.67
ARDS	9 (4.3)	15 (6.4)	16 (7.0)	.32	.22	.80
Cardiac complications	28 (13.3)	18 (7.7)	17 (7.4)	.05	.041	.90
Myocardial infarction	7 (3.3)	5 (2.1)	4 (1.7)	.44	.28	.75
Cardiac arrest	22 (10.4)	13 (5.6)	13 (5.7)	.06	.12	.96
Infectious complications	64 (30.3)	74 (31.6)	74 (32.2)	.77	.67	.89
Pneumonia	50 (23.7)	48 (20.5)	57 (24.8)	.42	.79	.27
Sepsis	7 (3.3)	7 (3.0)	6 (2.6)	.84	.67	.79
Osteomyelitis	2 (0.9)	3 (1.3)	1 (0.4)	.74	.51	.29
Wound infection	7 (3.3)	9 (3.8)	7 (3.0)	.77	.86	.64
CAUTI	14 (6.6)	20 (8.5)	19 (8.3)	.45	.50	.94
CLABSI	5 (2.4)	4 (1.7)	3 (1.3)	.62	.39	.72
Tracheostomy	50 (23.7)	65 (27.8)	71 (30.9)	.33	.09	.46
Readmission	25 (11.8)	46 (24.2)	30 (13.0)	.69	.70	.84
For Injury	16 (7.6)	38 (20.3)	29 (12.6)	.21	.08	.62
For chest Complaint	5 (2.4)	18 (9.6)	13 (5.7)	.40	.08	.34

Categorical variables are presented as *n* (%); non-normally distributed continuous variables are expressed as median (IQR).
PC = pulmonary contusion
PC-A = pulmonary contusion with AIS contusion/laceration ≥ 3
PC-B = pulmonary contusion with BPC18 ≥ 3
CAUTI = catheter-associated urinary tract infection
CLABSI = central line-associated blood stream infection

Table 3. Subject Characteristics, Comorbid Conditions, and Complications Versus Respiratory Failure (Yes vs No)

	Respiratory Failure (*n* = 404)	No Respiratory Failure (*n* = 146)	*P*
Pulmonary contusion	269 (67)	70 (48)	< .001
Age, y	48.1 ± 17.3 (48)	50.2 ± 19.3 (51.5)	.25
Male	301 (74)	102 (70)	.28
BMI	30.3 ± 7.4 (29.4)	29.6 ± 7.3 (28.4)	.27
Comorbid conditions, *n* (%)			
Respiratory disorder	45 (11)	10 (7)	.14
Diabetes	62 (15)	8 (5)	< .001
Smoking	133 (33)	44 (30)	.63
Hypertension	130 (32)	38 (26)	.17
Psychiatric disorder	57 (14)	14 (10)	.16

Categorical variables are presented as *n* (%); non-normally distributed continuous variables are expressed as mean ± SD (median).
BMI = body mass index

more and lower severity contusions. Rather the rate at which PCs "blossom" and create physiologic stress is unclear, and the unpredictability is a challenge for clinicians. Being able to predict which contusions are at high risk for worsening, which may influence the timing of additional treatments such as surgical stabilization of

Table 4. Logistic Regression Predicting Respiratory Failure > 48 h (Stepwise) Among All Severely Injured Subjects

Variable	Odds Ratio (95% CI)	*P*
Pulmonary Contusion	2.22 (1.48–3.35)	<.001
Diabetes	4.03 (1.83–8.86)	<.001
Age, y	0.99 (0.98–1.00)	.37
Gender	1.26 (0.82–1.95)	.28

rib fractures, is an important emerging topic of investigation. Also, identification of patients who are at an increased risk for respiratory failure may allow for implementation of early aggressive respiratory therapies. Conceptualizing PCs across a common spectrum of severity, as opposed to oversimplifying contusions as either present or absent, is an important step in this process.

Our current study has several limitations. First, as a retrospective review of a single institution, it is possible that our findings may represent a cohort of subjects unique to a particular region. Second, our study did not control for the reason for intubation, whether intubation was performed in the prehospital setting, concomitant severity of head injury, or need for emergency surgery. A variety of pathologies can lead to respiratory failure necessitating mechanical ventilatory support, which may influence hospital course. Furthermore, practice pattern variation in ICU supportive care may also affect outcomes observed. We feel that these limitations are relatively minor and likely do not change the overall trajectory of the care and response to care of the significantly injured trauma patient. Importantly, by excluding minor contusions, it is reasonable to expect that a moderate to severe PC group should have worse outcomes, but it was unanticipated that subjects with contusions and without contusions would have unequal baseline characteristics. Better characterization of PCs with particular emphasis placed on discerning factors associated with contusion progression is a necessary tool for injury prognostication and optimizing timing of interventions.

While the structure of this study was to analyze a high-risk cohort in keeping with prior published design, we must acknowledge that design improvements are possible. Future investigation should categorize PCs by severity including more minor contusions and examine the consequences of PC progression both radiographically and physiologically. This may yield novel characteristics that can inform better therapeutic decision-making and treatment strategies in patient with severe contusions.

Conclusions

We found that moderate to severe PCs were associated with significantly increased duration of mechanical ventilation, ICU length of stay, and overall hospital length of stay in a population at high risk for respiratory problems. All PCs were associated with increased risk of respiratory failure when adjusted for age, gender, and comorbid diabetes. We also demonstrated that the respective AIS and BPC18 score are effective for revealing contusions associated with worse outcomes. Future contusion studies should utilize graduated contusion severity to elucidate a subpopulation whose contusions will progress and display clinical consequences.

ACKNOWLEDGEMENTS

The authors would like to thank Dina Gomaa and Ann Salvator for their assistance in this work.

REFERENCES

1. Fahr M, Jones G, O'Neal H, Duchesne J, Tatum D. Acute respiratory distress syndrome incidence, but not mortality, has decreased nationwide: a national trauma data bank study. Ann Surg 2017;83(4):323-331.
2. Huber S, Biberthaler P, Delhey P, Trentzsch H, Winter H, van Griensven M. Predictors of poor outcomes after significant chest trauma in multiply injured patients: a retrospective analysis from the German Trauma Registry (Trauma Register DGU). Scand J Trauma Resus Emerg Med 2014;22(1):52.
3. De Moya MA, Manolakaki D, Chang Y, Amygdalos I, Gao F, Alam HB, et al. Blunt pulmonary contusion: admission computed tomography scan predicts mechanical ventilation. J Trauma 2011;71(6):1543-1547.
4. Simon B, Ebert J, Bokhari F, et al; Eastern Association for the Surgery of Trauma. Management of pulmonary contusions and flail chest. J Trauma Acute Care Surg 2012;73(5 Suppl 4):S351-S361.
5. Miller PR, Croce MA, Kilgo PD, Scott J, Tc F. Acute respiratory distress syndrome in blunt trauma: identification of independent risk factors. Am Surg 2002;68:845-850.
6. Prunet B, Bourenne J, David JS, Bouzat P, Boutonnet M, Cordier P-Y, et al. Patterns of invasive mechanical ventilation in patients with severe blunt chest trauma and lung contusion: a French multicentric evaluation of practices. J Intensive Care Soc 2019;20(1):46-52.
7. Tignanelli CJ, Hemmila MR, Rogers MA, Raghavendran K. Nationwide cohort study of independent risk factors for acute respiratory distress syndrome after trauma. Trauma Surg Acute Care 2019;4(1):1-9.
8. Ganie FA, Lone H, Lone GN, et al. Lung Contusions: a clinicopathological entity with unpredictable clinical course. Bull Emerg Trauma 2013;1(1):7-16.
9. Rodriguez RM, Friedman B, Langdorf MI, et al. Pulmonary contusion in the pan-scan era. Injury 2016;47(5):1031-1034.
10. Chrysou K, Halat G, Hoksch B, Schmid RA, Kocher GJ. Lessons from a large trauma center: Impact of blunt chest trauma in polytrauma patients-still a relevant problem? Scand J Trauma Resus Emerg Med 2017;25(1):1-6.
11. Dhar SM, Breite MD, Barnes SL, Quick JA. Pulmonary contusions in mechanically ventilated subjects after severe trauma. Respir Care 2018;63(8):950-954.
12. Dinh M, Brzozowski M, Kiss A, Schull M. The prognostic significance of pulmonary contusions on initial chest radiographs in blunt trauma patients. Eur J Trauma Emerg Surg 2008;34(2):148-153.
13. Thorax. In: Gennarelli TA, Wodzin E, eds. The Abbreviated Injury Scale 2005 Update 2008. Association for the Advancement of Automotive Medicine; 2008.

14. Tyburski JG, Collinge JD, Wilson RF, Eachempati SR. Pulmonary contusions: quantifying the lesions on chest x-ray films and the factors affecting prognosis. J Trauma 1999;46(5):833-838.
15. Baker JE, Skinner M, Heh V, et al. Readmission rates and associated factors following rib cage injury. J Trauma Acute Care Surg 2019;87(6):1269-1276.
16. Miller C, Stolarski A, Ata A, et al. Impact of blunt pulmonary contusion in polytrauma patients with rib fractures. Am J Surg 2019;218(1):51-55.
17. Robinson BRH. Does the diagnosis of pulmonary contusions really matter in the modern ICU? Respir Care 2018;63(8):1073-1075.