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Impact of blunt pulmonary contusion in polytrauma patients with rib fractures

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ABSTRACT

Background: We investigated the impact of blunt pulmonary contusion (BPC) in patients with rib fractures.

Methods: Adult patients with rib fractures caused by blunt mechanisms were enrolled over 3 years at a Level 1 trauma center. BPC was defined according to percentage of lung affected as: moderate (1–19% contusion) or severe (≥20% contusion).

Results: In total, 1448 of the 7238 admitted patients had rib fractures. Of these, 321 (22.2%) had BPC: 236 moderate and 85 severe. Patients with BPC were more likely to be admitted to the ICU (moderate: OR 1.55, 95% CI 1.10–2.19; severe: OR 2.74, 95% CI 1.41–5.32). Significantly increased rates of pneumonia (OR 2.52, 95% CI 1.43–4.90) and empyema (OR 4.80, 95% CI 1.07–21.54) were found for moderate and severe BPC, respectively.

Conclusions: ICU admission and infectious pulmonary complications were more likely with BPC. The presence of BPC on admission CT is also prognostic of increased resource utilization.

Introduction

Blunt chest trauma (BCT) accounts for more than 15% of trauma admissions.[1] BCT is associated with rib fractures in 39% of cases and blunt pulmonary contusion (BPC) in up to 75% of cases.[2,3] Patients with BPC have been shown to have a higher rate of pneumonia, acute respiratory distress syndrome (ARDS), respiratory failure and death.[4–8] Pulmonary contusions develop slowly over the course of 24–48 h after the initial insult, as blood and fluid accumulate in the alveolar spaces adjacent to the injured lung parenchyma. This edema disrupts normal lung structure, impairing gas exchange and causing a ventilation/perfusion mismatch.[9,10] A patient's initial respiratory status may be deceptive due to the evolving nature of pulmonary contusions; therefore, a high index of suspicion for respiratory deterioration has been recommended for patients with BCT.[11]

Previous studies have used computed tomography (CT) to quantify pulmonary contusions and thereby identify outcomes in patients with isolated chest trauma.[12,13] However, for patients with multiple system injuries after BCT, outcomes based on the extent of BPC found on initial CT evaluations are not well defined. We hypothesized that the presence of BPC on initial CT imaging is predictive of outcomes for polytrauma patients with rib fractures. Thus, the objective of this study was to evaluate and compare morbidity and mortality among patients with rib fractures and BPC at initial presentation.

Material and methods

We retrospectively evaluated all trauma patients admitted to Albany Medical Center (a New York State and American College of Surgeons verified level 1 trauma center) between January 2011 and December 2014. All adult patients (age ≥18 years) with one or more rib fractures caused by blunt mechanisms were included in the study. Institutional review board approval was obtained prior to the

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initiation of the review.

Patients were divided into two groups based on the presence (BPC group) or absence (N-BPC group) of pulmonary contusions. CT scans of patients with BPC were reviewed by two radiologists using a standardized procedure developed by Wagner et al., in which the laterality and amount of pulmonary contusion present were expressed as the percentage of each lung affected.[12] Patients with BPC were further subgrouped by the severity of their contusions, based on a pre-established threshold for increased risk of developing ARDS[13]: moderate contusions (M-BPC, 1–19% total lung contusions) and severe contusions (S-BPC, ≥20% total lung contusions).

Data collection

Data were collected from the Albany Medical Center trauma registry using *International Classification of Disease, Ninth Edition* (ICD-9) codes. Demographic data including age, sex, Injury Severity Score (ISS), Glasgow Coma Scale (GCS) score, Chest Injury Score (Chest IS), and associated injuries were collected. Comorbidities that were present on admission were also assessed, including current or past history of tobacco use, morbid obesity, obstructive sleep apnea, chronic respiratory failure, asthma, chronic obstructive asthma, chronic airway obstruction, bronchitis, emphysema, congestive heart failure, heart disease, chronic kidney disease, and anemia (Table 1).[14]

The primary outcome of interest was hospital mortality. Secondary outcomes included pulmonary complications: development of pneumonia, hemothorax, pleural effusion, and empyema. Admittance to the intensive care unit (ICU), hospital length of stay (LOS), intensive care unit LOS, need for ventilation, and ventilator days were also captured.

Statistical analysis

Mortality and composite pulmonary complications, hospital and ICU length of stay, and ventilator days were compared across the pulmonary contusion categories using the chi-squared test and analysis of variance as appropriate. Variables considered as potential confounders included age, ISS, GCS, and number of ribs fractured; they were adjusted for using multivariable logistic and linear regression. Statistical significance was considered to be $p < 0.05$. Statistical analysis was performed using Stata 14.0 (StataCorp, College Station, TX, USA).

Table 1
International classification of diseases, 9th *Edition* (ICD-9) codes.

Condition	ICD-9 Code
Comorbidities	
Current or history of tobacco use	158.2, 305.1
Morbid obesity	278.01
Obstructive sleep apnea	327.23
Chronic respiratory failure	518.83
Asthma	493.90
Chronic obstructive asthma	493.20
Chronic airway obstruction	496
Bronchitis	490
Emphysema	518.1, 492.8, 492.0
Congestive heart failure	428.0
Heart disease	416.8, 429.9
Chronic kidney disease	585.2–585.4, 585.6, 585.6, 585.9, 403.91
Anemia	285.9, 280.9
Outcomes	
Pneumonia	486
Hemothorax	860.2
Pleural effusion	511.9
Empyema	510.9
Respiratory failure	518.51, 581.81, 581.84

Results

There were 7238 admissions to the trauma center during the study period, with 1734 adult patients having one or more rib fractures. A total of 1448 patients had at least one rib fracture due to blunt mechanisms. Of these patients, 321 (22.2%) were found to have BPC; 236 (73.5%) had M-BPC and 85 (26.5%) had S–BPC. A total of 1151 patients (79.5% of the study population) received a CT scan of the chest on admission. Patients who did not undergo CT scans were presumed to have no pulmonary contusion present on admission.

Across the N–BPC, M-BPC, and S–BPC groups, there were significant differences in age, ISS, chest IS, GCS, and number of ribs fractured (Table 2). Patients with contusions were younger and more severely injured, as reflected by their ISS, chest IS, and GCS scores. Patients with BPC were more likely to have fractured more than seven ribs. The most common mechanism of injury in patients with BPC was motor vehicle collision. There was no difference seen in comorbidities between the groups.

All outcomes were compared using patients with no pulmonary contusions as the reference group. There was no significant difference in mortality between the N–BPC, M-BPC, and S–BPC groups, although there was a trend towards increased mortality in the S–BPC group (Table 3). Patients with any level of BPC were significantly more likely to be admitted to the ICU and to be placed on a ventilator. Patients with severe contusions were significantly more likely to experience composite pulmonary complications ($p = 0.011$). Moderately contused patients were significantly more likely to experience pneumonia ($p = 0.005$), whereas severely contused patients were more likely to experience empyema ($p = 0.001$) when compared with patients with no contusions. Overall, there were no differences in the rates of hemothorax or pleural effusion between the N–BPC, M-BPC, and S–BPC groups.

Outcomes found to be significant in the initial analysis were adjusted for age, GCS, ISS, and number of ribs fractured, then compared between the N–BPC and M-BPC groups, as well as the N–BPC and S–BPC groups. After adjustment, patients with any BPC were more likely to be admitted to the ICU (M-BPC adjusted odds ratio [OR]: 1.55, 95% confidence interval [CI]: 1.10–2.19; S–BPC adjusted OR: 2.74, 95% CI: 1.41–5.32) when compared with N–BPC patients. Patients with moderate contusions had significantly increased rates of pneumonia (adjusted OR: 2.52, 95% CI: 1.43–4.90) compared with patients without contusions. Rates of empyema were significantly higher in the S–BPC group (adjusted OR: 4.80, 95% CI: 1.07–21.54) compared with the N–BPC group. No differences were seen in composite pulmonary complications. An additional analysis showed no difference between the M-BPC and S–BPC groups for mortality ($p = 0.840$), admission to the ICU ($p = 0.113$), need for ventilation ($p = 0.844$), composite pulmonary complications ($p = 0.808$), pneumonia ($p = 0.336$), pleural effusion ($p = 0.900$), or hemothorax ($p = 0.857$).

The average LOS for the rib fracture population at our institution was 9.59 days (95% CI: 9.031–10.159), and the average ICU LOS for the same population was 7.28 days (95% CI: 6.626–7.948). Patients without pulmonary contusions stayed in the hospital for an average of 9.09 days (standard error of the mean [SEM] ± 0.326) and in the ICU for 7.06 days (SEM ± 0.416), with 6.73 (SEM ± 0.556) days on a ventilator. M-BPC and S–BPC patients spent an average of 10.64 (SEM ± 0.685) and 13.48 (SEM ± 1.238) days in the hospital, which was not significantly longer than N–BPC patients after multivariate adjustment. M-BPC and S–BPC patients who were admitted to the ICU stayed for an average of 7.12 (±0.721) and 9.06 (±0.900) days,

Table 2
Demographic data.

Characteristics	N−BPC	Pulmonary Contusion		p value
		M-BPC	S−BPC	
n	1126	236	85	
Mean age (years)	58.0	49.3	38.8	**<0.001**
Male sex, (%, n)	67.58 (761)	70.34 (166)	81.18 (69)	0.029
Mean ISS (95% CI)	18.1 (17.56−18.59)	21.34 (20.29−22.40)	28.18 (25.65−30.58)	**<0.001**
Mean Chest IS (95% CI)	2.79 (2.74−2.83)	3.44 (3.27−3.59)	3.72 (3.49−3.95)	**<0.001**
Mean GCS score (95% CI)	13.81 (13.63−14.00)	13.35 (12.86−13.85)	10.08 (8.91−11.26)	**<0.001**
Flail chest (%, n)	2.75 (31)	5.08 (12)	16.47 (14)	**<0.001**
Mechanism of injury (%, n)				
Motor vehicle collision	39.70 (477)	51.69 (122)	58.82 (50)	**<0.001**
Motorcycle collision	14.83 (167)	16.95 (40)	25.88 (22)	
Assault	2.58 (29)	0.85 (2)	1.18 (1)	
Fall	36.94 (416)	25.00 (59)	12.94 (11)	
Pedestrian struck	3.82 (43)	2.12 (5)	1.18 (1)	
Struck by falling object	2.13 (24)	3.39 (8)	0	
Number of ribs fractured (%, n)				
1−3 ribs	44.67 (503)	31.36 (74)	25.88 (22)	**<0.001**
4−6 ribs	35.70 (402)	32.30 (76)	31.76 (27)	
7 + ribs	19.62 (221)	36.44 (86)	42.35 (36)	
Associated injuries (%, n)				
Closed head	19.80 (223)	17.80 (42)	28.24 (24)	0.114
Long bone	5.95 (67)	8.47 (20)	9.41 (8)	0.200
Abdominal	21.94 (247)	25.85 (61)	45.88 (39)	**<0.001**
Pelvic	14.39 (162)	17.80 (42)	17.56 (15)	0.331
Spine	2.22 (25)	2.97 (7)	10.59 (9)	**<0.001**

Note: p values listed in bold type are significant.
GCS, Glasgow Coma Scale; ISS, Injury Severity Score; M-BPC, moderate blunt pulmonary contusion; N−BPC, no blunt pulmonary contusion; S−BPC, severe blunt pulmonary contusion.

Table 3
Severity of blunt pulmonary contusion and the impact on mortality and complications.

Outcome	BPC category	Proportions with outcomes (%, n)	p value for OR	Adjusted OR (95% CI)	p value
Mortality	N−BPC	4.97 (56)	–	–	–
	M-BPC	4.24 (10)	0.632	–	–
	S−BPC	9.41 (8)	0.083	–	–
%ICU	N−BPC	36.94 (416)	–	1.00 (reference)	–
	M-BPC	52.12 (123)	**<0.001**	1.55 (1.10−2.19)	**0.013**
	S−BPC	77.65 (66)	**<0.001**	2.74 (1.41−5.32)	**0.003**
%Ventilator	N−BPC	19.63 (221)	–	1.00 (reference)	–
	M-BPC	27.97 (66)	**0.005**	1.32 (0.83−2.09)	0.242
	S−BPC	56.47 (48)	**<0.001**	1.56 (0.73−3.36)	0.251
Composite Pulmonary Complications	N−BPC	20.94 (236)	–	1.00 (reference)	–
	M-BPC	25.42 (60)	0.131	–	–
	S−BPC	32.94 (28)	**0.011**	1.31 (0.76−2.28)	0.333
Pneumonia	N−BPC	4.61 (52)	–	1.00 (reference)	–
	M-BPC	9.32 (22)	**0.005**	2.52 (1.43−4.90)	**0.001**
	S−BPC	7.06 (6)	0.313	–	–
Empyema	N−BPC	0.62 (7)	–	1.00 (reference)	–
	M-BPC	1.27 (3)	0.298	–	–
	S−BPC	4.71 (4)	**0.001**	4.80 (1.07−21.54)	**0.040**
Hemothorax	N−BPC	4.79 (54)	–	–	–
	M-BPC	3.39 (8)	0.349	–	–
	S−BPC	3.53 (3)	0.597	–	–
Pleural effusion	N−BPC	5.41 (61)	–	–	–
	M-BPC	5.08 (12)	0.837	–	–
	S−BPC	4.71 (4)	0.779	–	–

Note: p values listed in bold type are significant.
BPC, blunt pulmonary contusion; ICU, intensive care unit; M-BPC, moderate blunt pulmonary contusion; N−BPC, no blunt pulmonary contusion; OR, odds ratio; S−BPC, severe blunt pulmonary contusion.
*OR adjusted for age, GCS, ISS, and number of ribs fractured.

Table 4
Difference in days representing the effect of blunt pulmonary contusion on patient outcomes.

Outcome	BPC Category	Mean Days (±SEM)	P value	Adjusted OR (95% CI)	P value
Hospital Length of Stay	N–BPC	9.08 (±0.326)	–	1.00 (reference)	–
	M-BPC	10.64 (±0.685)	0.046	0.91 (−0.56–2.39)	0.224
	S–BPC	13.48 (±1.238)	**<0.001**	1.34 (−1.08–3.76)	0.278
ICU Length of Stay	N–BPC	7.06 (±0.416)	–	1.00 (reference)	–
	M-BPC	7.12 (±0.721)	**0.015**	0.29 (−1.32–1.90)	0.722
	S–BPC	9.06 (±0.900)	**<0.001**	1.64 (−0.53–3.82)	0.138
Ventilator Days	N–BPC	6.73 (±0.556)	–	1.00 (reference)	–
	M-BPC	6.47 (±0.874)	0.150	–	–
	S–BPC	8.21 (±1.05)	**<0.001**	0.92 (0.41–2.06)	0.844

Note: p values listed in bold type are significant.
BPC, blunt pulmonary contusion; ICU, intensive care unit; M-BPC, moderate blunt pulmonary contusion; N–BPC, no blunt pulmonary contusion; OR, odds ratio; S–BPC, severe blunt pulmonary contusion; SEM, standard error of the mean.
*OR adjusted for age, GCS, ISS, and number of ribs fractured.

respectively, which was not significant after multivariate adjustment. M-BPC and S–BPC patients who were placed on a ventilator spent an average of 6.47 (±0.874) and 8.21 (±1.05) days on a ventilator, respectively (Table 4).

Discussion

It is well established that patients who develop pulmonary contusions after BCT have higher rates of pneumonia, ARDS, and respiratory failure. Pulmonary contusions during the first 48 h evolve, along with its related mortality. The goal of the study was to determine if meaningful prognostication can be made based on the extent of pulmonary contusion present on initial imaging.

We found that patients with BPC on initial CT scan had higher rates of admission to the ICU, increased odds of requiring mechanical ventilation, and a trend toward increased mortality. These findings are consistent with current literature. de Moya et al. developed a simple scoring system to identify patients requiring mechanical ventilation using a combination of BPC assessment derived from BPC, GCS, and the number of rib fractures.[15] Miller et al. used a volumetric method to measure BPC, classifying BPC involving more than 20% of total lung volume as severe; they then showed a correlation between severe contusions and higher rates of pulmonary dysfunction.[13] Wagner et al. reported that patients who had greater than 28% of total lung contused required mechanical ventilation, whereas patients with less than 18% lung contusion did not require mechanical ventilation.[12]

The observed increased need for mechanical ventilation in patients with pulmonary contusions is likely related to poor gas exchange due to damage to the lung parenchyma, which leads to the extravasation of blood and fluid in the alveolar spaces. Traumatic blunt force to the chest compresses the thoracic volume, increases intrathoracic pressure, and compresses and damages the pulmonary parenchyma. This results in pulmonary edema and reduced lung compliance, which causes a ventilation and perfusion mismatch, hypercarbia, hypoxia, and increased work of breathing. An increase in mucus, infiltration of inflammatory cells, and impaired surfactant production can also act to increase pulmonary damage.[11] Additionally, significantly elevated levels of the inflammatory cytokines tumor necrosis factor-alpha, interleukin (IL)-6, and IL-10 have been seen in trauma patients with pulmonary contusions when compared with trauma patients without contusions for up to 1 week after the injury, which suggests that patients with BPC have a more robust inflammatory response.[16]

Whether mortality in patients with BPC is due to the contusions themselves is not clear. Evidence suggests that mortality in patients with BPC is mostly due to associated injuries, not to pulmonary insufficiency. Rodriguez et al. compared the outcomes of patients with isolated pulmonary contusions without other thoracic injuries versus patients with pulmonary contusions and additional injuries. The authors noted that patients with isolated BPC had mortality rates that were similar to patients with no pulmonary contusions, whereas mortality in patients with BPC and other thoracic injuries was higher.[17]

We found no differences in composite pulmonary complications across the groups. However, patients with moderate contusions were more likely to develop pneumonia, and patients with severe contusions were more likely to develop empyema. We attributed this increase in infectious pulmonary complications to higher rates of respiratory failure and ventilator days in patients with BPC, resulting in ventilator-associated pneumonia.

The difficulty in studying pulmonary contusions is due to the lack of universal methods for accurately determining the extent of contusions. Several existing scoring systems record pulmonary contusions as simply present or absent in each lobe, whereas others assign points based on perceived severity.[18–20] We feel that volumetric methods, although labor intensive, reflect the extent of pulmonary contusion more accurately.

Notably, most previous studies only reviewed patients with isolated chest trauma. We believe that the inclusion of polytrauma patients in our study greatly increases the generalizability of our results to any trauma patient who may present with pulmonary contusions on an initial CT scan. In our patient population, the majority of patients with severe contusions were injured via a motor vehicle or motorcycle collision, and almost half of the severely contused patients had concomitant abdominal injuries. The presence of associated injuries in contused patients further underscores that presence of BPC on initial imaging is a hallmark of serious injury. Our data also showed that patients who were more severely contused were younger, which is consistent with previous literature. This is likely related to greater compliance of the chest wall, as the costal cartilage and posterior costovertebral ligaments are more flexible in younger patients.[12,21]

Our study is limited by the retrospective nature of its design. Comorbidities and outcomes were collected from a trauma registry using ICD-9 codes, which could introduce errors in the data. Our data were collected from a single institution with unique management protocols, which may limit the generalizability of our results. Additionally, to quantify the amount of pulmonary contusions, the volume of nonfunctional lung was calculated from CT scans by two radiologists. Although predefined criteria were used to determine the percentage of pulmonary contusion present, there could be discrepancies in volume quantifications between the two radiologists. Fluid administration has been known to worsen BPC, and while we did not evaluate it in this study, it could be an important variable in future studies. Finally, 21.5% of our patient

population did not have a CT on admission; we chose to characterize those patients as N–BPC. Incorrect classification of patients with BPC but no CT could have skewed our results.

Our data suggest that patients with severe BPC on an initial CT scan should be admitted to a higher level of care. Therefore one could anticipate increased resource utilization, which is likely necessary to mitigate potential negative outcomes. Because blunt pulmonary contusion patients are less healthy overall, admittance to a higher level of care and more aggressive treatment likely improved their outcomes in our study. The presence of BPC on initial CT imaging should be included into prognostic scoring systems designed to stratify the risk of polytrauma patients with BCT.

Conclusions

Blunt pulmonary contusions are common injuries for patients who experience blunt trauma. Patients with severe BPC showed a trend toward increased mortality. We demonstrated that patients with pulmonary contusions were significantly more likely to be admitted to the ICU and had an increased risk of infectious pulmonary complications. The presence of pulmonary contusions on initial CT evaluation can provide an early clue to a patient's likely hospital course and can be used for outcomes prediction and management.

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References

1. Battle CE, Hutchings H, Lovett S, et al. Predicting outcomes after blunt chest wall trauma: development and external validation of a new prognostic model. *Crit Care*. 2014;18:R98. https://dx.doi.org/10.1186%2Fcc13873.
2. Dehghan N, de Mestral C, McKee MD, et al. Flail chest injuries: a review of outcomes and treatment practices from the National Trauma Data Base. *J Trauma Acute Care Surg*. 2014;76:462–468. https://doi.org/10.1097/TA.0000000000000086.
3. Alisha C, Gajanan G, Jyothi H. Risk factors affecting the prognosis in patients with pulmonary contusion following chest trauma. *J Clin Diagn Res*. 2015;9:OC17–OC19. https://doi.org/10.7860/JCDR/2015/13285.6375.
4. Allen GS, Coates NE. Pulmonary contusion: a collective review. *Am Surg*. 1996;62:895–900.
5. Sharma S, Mullins RJ, Trunkey DD. Ventilatory management of pulmonary contusion patients. *Am J Surg*. 1996;171:529–532. https://doi.org/10.1016/S0002-9610(96)00021-9.
6. Hoff SJ, Shotts SD, Eddy VA, Morris JA. Outcome of isolated pulmonary contusion in blunt trauma patients. *Am Surg*. 1994;60:138–142.
7. Antonelli M, Moro ML, Capelli O, et al. Risk factors for early onset pneumonia in trauma patients. *Chest*. 1994;105:224–228. https://doi.org/10.1378/chest.105.1.224.
8. Croce MA, Fabian TC, Davis KA, Gavin TJ. Early and late acute respiratory distress syndrome: two distinct clinical entities. *J Trauma*. 1999;46:366–368.
9. Ware LB, Mattahy MA. The acute respiratory distress syndrome. *N Engl J Med*. 2000;342:1334–1349. https://doi.org/10.1056/NEJM200005043421806.
10. Ganie FA, Lone H, Lone GN, et al. Lung contusion: a clinicopathological entity with unpredictable clinical course. *Bull Emerg Trauma*. 2013;1:7–16.
11. Cohn SM, Dubose JJ. Pulmonary contusion: an update on recent advances in clinical management. *World J Surg*. 2010;34:1959–1970. https://doi.org/10.1007/s00268-010-0599-9.
12. Wagner RB, Jamieson PM. Pulmonary contusion: evaluation and classification by computed tomography. *Surg Clin*. 1989;69:31–40. https://doi.org/10.1016/S0039-6109(16)44732-8.
13. Miller PR, Croce MA, Bee TK, et al. ARDS after pulmonary contusion: accurate measurement of contusion volume identifies high-risk patients. *J Trauma*. 2001;51:223–230.
14. Pape HC, Remmers D, Rice J, et al. Appraisal of early evaluation of blunt chest trauma: development of a standardized scoring system for initial clinical decision making. *J Trauma*. 2000;49:496–504.
15. de Moya MA, Manolakaki D, Chang Y, et al. Blunt pulmonary contusion: admission computed tomography scan predicts mechanical ventilation. *J Trauma*. 2011;71:1543–1547. https://doi.org/10.1097/TA.0b013e31822c4a8b.
16. Liu K, Liu J, Wu S. Association of dynamic changes in serum cytokine levels with the severity of injury in patients suffering from closed chest traumas complicated with pulmonary contusions. *Exp Ther Med*. 2011;2:563–567. https://doi.org/10.3892/etm.2011.241.
17. Rodriguez RM, Friedman B, Langdorf MI, et al. Pulmonary contusion in the pan-scan era. *Injury*. 2016;47:1031–1034. https://doi.org/10.1016/j.injury.2015.11.043.
18. 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;46:833–838.
19. Daurat A, Millet I, Roustan JP, et al. Thoracic Trauma Severity score on admission allows to determine the risk of delayed ARDS in trauma patients with pulmonary contusion. *Injury*. 2016;47:147–153. https://doi.org/10.1016/j.injury.2015.08.031.
20. Chen J, Jeremitsky E, Philip F, et al. A chest trauma scoring system to predict outcomes. *Surgery*. 2014;156:988–993. https://doi.org/10.1016/j.surg.2014.06.045.
21. O'Connor JV, Kufera JA, Kerns TJ, et al. Crash and occupant predictors of pulmonary contusion. *J Trauma*. 2009;66:1091–1095. https://doi.org/10.1097/TA.0b013e318164d097.