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Unilateral Post-Traumatic Pulmonary Contusion: Findings of a Review

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Abstract
Purpose. There is still much controversy regarding the optimal treatment for pulmonary contusion. Therefore, we examined the variables affecting patient outcomes over a 10-year period.
Methods. We retrospectively reviewed 107 consecutive patients with a mean age of 28 years, who were treated for pulmonary contusion during a 10-year period. Pulmonary perfusion scans were obtained for 11 patients. We used a pulmonary contusion score (PCS) of one-third of a lung = 3 and the entire lung = 9.
Results. Overall mortality was 15%, which increased to 24.4% in patients with a PCS of 7–9. The time taken for contusions to resolve was longer based on scan results than chest X-rays (42.6 *vs* 15.5 days, respectively). Concomitant thoracic injures were present in 64.5% of patients, and 29% had a flail chest. The factors predictive of mortality were age ≥60 years, an injury severity score (ISS) ≥25, transfusion of ≥4 units of blood, a PaO_2/FIO_2 ratio of <300, concomitant flail chest, and a PCS of 7–9. The predictors for mechanical ventilation were age ≥60 years, concomitant flail chest, a PCS of 7–9, and an ISS ≥25. Mortality and the need for mechanical ventilation were higher in patients with nonisolated contusions than in those with isolated contusions.
Conclusions. Optimizing patient outcome requires prompt diagnosis, appropriate maintenance of fluid volume, and selective mechanical ventilation.

Key words Pulmonary contusion · Trauma

Introduction

Pulmonary contusion, which may lead to cardiopulmonary failure and complicated patient management, is present in about 17% of patients with multiple injures and an Injury Severity Score (ISS) >15,[1] and 30%–75% of all blunt lung injuries.[2] Pneumonia or adult respiratory distress syndrome (ARDS) associated with long-term respiratory dysfunction are common. Therefore, aggressive early intervention and therapy are essential.[2] Among the injures requiring hospitalization, pulmonary contusion is an incremental risk factor for an unfavorable outcome,[3] with mortality of 5%–25% in adults and 24%–43% in children.[4] Recent advances in pulmonary care and ventilator management have been responsible for improved outcomes; however, unacceptable morbidity and mortality rates continue to be reported.[5,6] There is much controversy regarding the optimal methods of treatment for this life-threatening condition.[7] Although the adverse effects of associated injuries and head trauma in patients with pulmonary contusions are well documented, it is less clear how other clinical findings contribute to the mortality.[8]

The purpose of this study was to identify the causes of morbidity and mortality as well as the variables affecting the outcomes of patients with post-traumatic pulmonary contusion. We also suggest an optimal management plan on our 10-year experience of treating this injury.

Patients and Methods

We retrospectively reviewed 107 patients treated consecutively for unilateral pulmonary contusion resulting from blunt trauma over a 10-year-period between 1991 and 2001. Nine patients with bilateral contusions were not included. Three patients with chest X-rays taken more than 48 h after injury were also excluded study

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because of the difficulty in differentiating contused areas from supervening pulmonary infiltrates. Two other patients were excluded after being lost to follow-up. The data collected from the patients records included age, sex, mechanism of injury, requirement for ventilatory support, length of stay in the intensive care unit (ICU) and the hospital, ISS, transfusion requirement in the first 48h after admission, resuscitation volume (total fluid volume received in the first 48h after admission), admission chest X-ray, and perfusion scan results. Pulmonary contusion was indicated by radiographic findings of nonsegmental areas of opacification resulting from a blow to the chest. Diagnosis was established by computed tomography (CT) scans within first 48h of admission. The radiographic extent of contusion was assessed by clinical review and successive chest X-rays taken during the first 48h of admission to properly gauge progression of the lesion. A pulmonary contusion score (PCS) was assigned to each chest X-ray by dividing the lung fields into upper, middle, and lower thirds and assigning a score of 1 to 3 to each region based on the extent of opacification.[9] A contusion encompassing one third of a lower lung field, accounting for one ninth of an entire lung, would receive a PCS of 1, whereas complete opacification of the lower third of one lung would receive a PCS of 3. If an entire lung was opacified, it would receive a PCS of 9.[9] Thus, a single chest X-ray could receive a PCS between 1 and 9. The patients were divided into three groups according to whether the score was 1–3, 4–6, or 7–9, and each group was evaluated and compared. Scans were obtained from contusion areas in 11 patients. In patients who underwent lung perfusion scans, a hypoperfused area seen in the same localization with the radiological lesion was accepted as a contusion area. Counters were obtained from scans of hypoperfused area and compared with counters from healthy areas of the lungs. Lung perfusion scans were taken four times, initially after a mean period of 1.4 days, then at intervals of 14.3 days after injury. Scans were obtained on an ambulatory basis after discharge. Written permission for lung scans was obtained from all patients. The ISS was calculated using the method of Baker et al.[10] and the 1990 Abbreviated Injury Scale.[11] Survivors and nonsurvivors were compared in terms of previously described variables using the one-way analysis of variance and chi-square test. To compare the means, Tukey's post hoc test was used. Statistical analysis was performed by SPSS 10.0 for Windows. A *P* value of less than 0.05 was considered significant.

All patients were given sufficient intravenous fluids only to support blood pressure, maintain urine output, and correct lactic acidosis if present. Corticosteroids were not given routinely. Fluids were restricted in all patients, except during resuscitation. Patients with major central nervous system trauma were treated with routine corticosteroids and strict fluid restriction. All patients received antibiotic therapy pre- and postoperatively. There was no standard protocol for antibiotics, but first-generation and second-generation cephalosporins were empirically used if no specific culture was available.

Indications for intubation and ventilation included clinical signs of respiratory deterioration and fatigue, a respiratory rate >40 or <8, $PaCO_2$ >45mmHg, PaO_2 <60mmHg, the need to establish or maintain a patent airway, or hemodynamic instability. It was adjusted to the minimum value necessary to ensure adequate oxygenation, which was usually 5–10cm H_2O. Tracheostomy was performed in patients needing intubation for longer than 5 days as well as those with failed extubation, persistent tracheal secretions, or severe head injury. Patients who were not intubated were monitored closely for hypoxia by continuous pulse oximetry or arterial blood gas analysis. Nasotracheal suction, chest physiotherapy, postural drainage, and blow bottles were used to minimize atelectasis and expel bronchial secretions. If patients were still unable adequately to clear their secretions, bronchoscopy was done.

Flail chest was defined as a chest wall segment consisting of three or more ribs broken in two locations, displaying subjective evidence of asynchronous movement with respect to the respiratory movement of the uninjured portion of the chest wall. Pneumonia was diagnosed in the presence of a pulmonary infiltrate on chest X-ray and if three of four clinical criteria existed, namely, fever, leukocytosis, purulent sputum, and new or progressive roentgenographic infiltrate, supported by the identification of a pathogen in either the endotracheal aspirate or bronchoalveolar lavage. Criteria for acute respiratory distress syndrome were acute, diffuse, bilateral pulmonary infiltrates demonstrated radiographically with the pulmonary capillary wedge pressure <18mmHg, and one of the following: an alveolar-arterial oxygen gradient >200, a PaO_2/FIO_2 ratio <150, and pulmonary shunt >20%.

Results

The patients ranged in age from 5 to 76 years (mean 28 years). There were 87 male patients and 20 female patients. The most frequently used ventilatory mode was positive end-expiratory pressure. Bronchoscopy was done in 29 patients, and mean 3.6 days after injury. The mechanisms of injury included motor-vehicle accidents in 62 (58%), falls in 35 (32.7%), assaults in 7 (6.5%), and other accidents in 3 (2.8%). Table 1 shows a comparison of contusion scores. Patients with a score of 7–

Table 1. Clinical features of patients according to contusion scores

Clinical features	1–3 (n = 18)	4–6 (n = 48)	7–9 (n = 41)
Nonsurvivors (n = 16)	11%	8.3%	24.4%
Mean ISS	17.3 ± 5.4	22.3 ± 4.2	30.2 ± 6.1
Flail chest (n = 31)	11%	16.6%	51.2%
Other thoracic injuries (n = 69)	27.7%	58.3%	87.8%
Intubation (n = 43)	5.5%	29%	56%
Transfusion requirement (units)	0.6 ± 1.2	2.4 ± 2.2	3.4 ± 3.2
Resuscitation volume (ml)	4204 ± 441	4142 ± 335	4987 ± 587
ICU stay (days)	1.3 ± 0.8	2.8 ± 1.7	6.5 ± 3.7
Hospital stay (days)	8.5 ± 2.8	13.4 ± 4.4	16.3 ± 6.3
Resolving time by chest X-ray (days)	16 ± 7.4	15 ± 4.5	15.6 ± 7.7
Resolving time by scans (days)	38.2 ± 4.4	41 ± 7.2	46 ± 6.8

ICU, intensive care unit; ISS, injury severity score

9 had a higher mortality ratio than those with scores of 4–6 or 1–3 (24.4% *vs* 11% and 8.3%, respectively; F [analysis of variance] = 5.19, P = *0.027*). There was no difference in mortality between the 1–3 and 4–6 score groups (F = 0.77, P = *0.249*). The mean ISS was higher in the 7–9 score group than in the 1–3 and 4–6 score groups (30.2 ± 6.1, F = 4.78, P = *0.041*), but there was not difference in the mean ISS between other two score groups (F = 2.41, P = *0.088*). Flail chest was more frequent in the 7–9 score group than in the 1–3 or 4–6 score groups (51.2% *vs* 11% and 16.6%, respectively; F = 10.2, P = *0.004*). Thoracic injures were most frequent in the score 7–9 group (87.8%, F = 9.88, P = *0.005*), then in the 4–6 score group (58.3%, F = 8.75, P = *0.008*), and least frequent in the 1–3 score group (27.7%, F = 9.88, P = *0.005*). Similarly, intubation was most frequent in the 7–9 score group (56%, F = 10.8, P = *0.003*), then in the 4–6 score group (29%, F = 9.78, P = *0.004*), and least frequent in the 1–3 score group (5.5%, F = 11.2, P = 0.02). Transfusion requirements were less in the 1–3 group than in the 4–6 and 7–9 score groups (F = 9.9, P = *0.004*). There was no difference in time of resuscitation among the three PCS groups (F = 0.99, P = *0.349*). The ICU stay was longer in the 7–9 group (6.5 ± 3.7 days, F = 7.48, P = *0.019*), but there was no difference between the other two groups (F = 0.79, P = *0.403*). The hospital stay was shortest in the 1–3 score group (8.5 ± 2.8 days, F = 6.46, P = *0.031*), but there was no difference between the 4–6 and 7–9 groups (F = 1.4, P = 0.093). The time taken for the pulmonary contusion to resolve on chest X-ray and scans did not differ among the three groups (F = 0.22, P = *0.548*). However, the time taken to resolve was longer according to scans than according to chest X-rays (15.5 *vs* 42.6 days, respectively; F = 15.7, P = *0.000*). The injury was caused by a motor-vehicle accident in 53 patients (49.5%), a fall in 37 (34.5%), and crushing in 17 (16%). The average ISS was 23 (range: 11–48). Thirty-four patients (31.7%) had a systolic blood pressure lower than 80 mm Hg on arrival and required resuscitation with blood and intravenous fluids.

Table 2. Associated injuries in patients with pulmonary contusion

Thoracic (n = 69)	
Hemothorax	35
Pneumothorax	15
Cardiac contusion	7
Open chest wound	4
Lung laceration	3
Tracheobronchial tear	1
Esophageal injury	1
Diaphragmatic hernia	1
Other	3
Extrathoracic (n = 77)	
Head/neck	23
Liver	10
Spleen	8
Soft-tissue injury	8
Upper extremity fracture or dislocation	8
Spinal bones or cord injury	6
Lower extremity fracture or dislocation	5
Pelvic fractures	3
Stomach	2
Vascular	2
Other	2

Concomitant thoracic injures were sustained by 69 (64.5%) patients, with hemothorax in 35 (32.7%), pneumothorax in 15 (14%), and cardiac contusion in 7 (6.5%). Extrathoracic associated injures were sustained by 77 (72%) patients, the most frequent being craniocerebral trauma, long bone and spine fractures, and liver and splenic lacerations. Table 2 shows the thoracic and extrathoracic injuries. Surgical intervention was necessary in 58 (84%) of the 69 patients with thoracic-associated injuries in the form of chest tube drainage in 52 (for hemothorax in 35, for pneumothorax in 15, and for an open chest wound in 2). The remaining 6 (8.7%) patients underwent thoracotomy for primary closure of airway tear, esophageal injury, and rupture of the diaphragm, in one each, and three underwent pneumorrhaphy for laceration. No lung resections were performed. None of the patients was lost to follow-up. Concomitant flail chest injury was present in 31 (29%) patients, accounting for 27.4% of the survivors and 37.5% of the nonsurvivors. Thirty-eight (35.5%) patients required intubation, including 38% of the survivors and all of the nonsurvivors. Of the total 107 patients, 24 had isolated contusion and 83 had nonisolated contusion. Only one patient with an isolated pulmonary contusion died, resulting in 4% mortality, whereas the mortality of patients with nonisolated contusions was 18% ($P < 0.05$). Only one patient with an isolated contusion required mechanical ventilation (4%), whereas 44% of the patients with nonisolated contusions were ventilated ($P < 0.05$). The most frequent complication of ventilatory treatment was pneumonia (35.5%).

Sixteen patients died, resulting in 15% overall mortality. The causes of death in these patients are summarized in Table 3. The mean survival period of the nonsurvivors was 7.4 days (range 1–19), but 5 of these 16 died within the first 24 h after injury, 3 of whom had a flail chest. Two patients survived for 18 and 19 days, before succumbing to multiple organ failure. Eleven of the 16 nonsurvivors died as a direct consequence of pulmonary failure or lung injury; 6 of acute respiratory failure, and 5 with acute respiratory distress syndrome associated with multiple organ failure. Seven factors were predictive of mortality: age ≥60 years old, severe head trauma, ISS ≥25, transfusion of blood ≥4 units, PaO_2/FIO_2 ratio <300, presence of concomitant flail chest, and a PCS of 7–9 (Table 4). The mean ISS of the survivors was 24.3 vs 39.3 for the nonsurvivors. The initial systolic blood pressure did not differ significantly between the survivors and nonsurvivors, indicating that mortality was not correlated with shock. A similar analysis was performed to predict the need for intubation. These predictors were: age ≥60 years old, concomitant flail chest, a PCS of 7–9, and an ISS ≥25 ($P < 0.05$). The mechanism of injury did not affect mortality. The period of antibiotic treatment to prevent pneumonia after lung contusion, which ranged from 3 to 23 days (mean 4.2 days), was adjusted according to clinical findings.

Table 3. Causes of death in patients with pulmonary contusion

Cause of death	No. of patients
Severe head injury	7
Multiple organ failure	3
Respiratory failure from flail chest	3
Acute respiratory distress	2
Multiple blunt injuries	1

Discussion

Pulmonary contusion is a parenchymal injury resulting in hemorrhage and interstitial edema, leading to alveolar collapse and lung consolidation. The basic injury involves parenchymal disruption, which may be due to tensile stress in the alveolar wall caused by the impact.[2]

Table 4. Facors analyzed as predictors of mortality in post-traumatic pulmonary contusion

Predictor	Survivors (n = 91)	Nonsurvivors (n = 16)	P value
Age < 60	78 (89.6%)	9 (10.4%)	<0.05
Age ≥ 60	13 (65%)	7 (35%)	
Severe head trauma	3 (50%)	3 (50%)	<0.05
Other	88 (87%)	13 (13%)	
ISS < 25	40 (95.2%)	2 (4.8%)	<0.05
ISS ≥ 25	51 (78.4%)	14 (21.6%)	
Blood < 4 units	74 (95%)	4 (5%)	<0.05
Blood ≥ 4 units	17 (58.6%)	12 (41.4%)	
PaO_2/FIO_2 < 300	52 (77.6%)	15 (22.4%)	<0.05
PaO_2/FIO_2 ≥ 300	39 (97.5%)	1 (2.5%)	
No flail chest	71 (93.4%)	5 (6.6%)	<0.05
Concomitant flail chest	20 (64.5%)	11 (35.5%)	
Contusion score 1–6	63 (95.5%)	3 (4.5%)	<0.05
Contusion score 7–9	28 (68.3%)	13 (32.7%)	
Systolic BP < 80 mmHg	27 (79.4%)	7 (20.6%)	NS
Systolic BP ≥ 80 mmHg	64 (87.7%)	9 (12.3%)	

BP, blood pressure; NS, not significant

The typical appearance on chest X-ray is a patchy infiltrate or opacification, generally adjacent to areas of chest pain, edema, or fractured ribs.[9] We observed agreement between chest X-ray and CT images of contusion. The importance of ventilation and perfusion abnormalities in producing hypoxemia[12] and decreased lung bacterial clearance suggesting that contused lungs are more susceptible to bacterial infections[13] has been reported. Atelectasis and infection become more important contributors to hypoxia 24–48 h postinjury.[14] We observed that clearing the lungs with bronchoscopy, expectorants, and prophylactic antibiotherapy were beneficial, especially to protect against infections and resolve atelectasis.

The most commonly reported specification of pulmonary contusion was that a higher ISS and lower oxygenation ratio 24 and 48 h after admission predicted higher mortality, morbidity, and ventilatory need.[12,15–17] Advanced patient age[14,17] and hypotension[5,6] have been inconsistently correlated with poor outcome, as have the requirements for and volume of transfusions or intravenous fluids. We found that patients older than 60 years were more susceptible to contusion. Moreover, the need for blood transfusion was significantly higher in the nonsurvivors than in the survivors. The volume of intravenous fluids in the first 48 h after admission did not significantly differ between the survivors and the nonsurvivors. Although the volume of resuscitation fluids was previously found to be a predictor of mortality,[8] there was no correlation between fluid volume and mortality in our series.[12] We restricted fluids to 1 500 ml/day chrystalloid solution for adults and 750 ml for children, but only in those who were hemodynamically stable. While resuscitating patients, no fluid restriction was enforced. A systolic blood pressure of less than 90 mmHg on admission was not correlated with mortality.[12] Furthermore, mortality was not highr in patients with a systolic blood pressure lower than 80 mmHg on admission. Previous studies found that flail chest does not contribute to mortality,[12] in contrast with our findings that concomitant flail chest was not only associated with a greater chance of intubation, but also with higher mortality. Flail chest is well known to be a mortality factor in the thoracic trauma patient.[7,16] We now use a selective approach to treat flail chest according to the aforementioned indications, with 60% of flail chest patients treated by mechanical ventilation.

In this study, the 41 patients with a PCS of 7–9 had a higher mortality rate (24.4% vs 11%) and tended to need ventilatory assistance more frequently (69% vs 35.9%, $P < 0.05$). Pulmonary contusions may not be radiographically apparent up to 48 h after injury.[18] Since repeat chest X-rays are not performed until the following day, a window is possible for unanticipated patient deterioration. Moreover, the size of the lesion can be underestimated in up to 60% of cases.[2] All of these factors might have caused us to underestimate the effect of contusion on mortality. We observed clearer contusion regions as hypoperfusion on lung scans than on chest X-rays. Ventilation of the injured area may decrease by as much as 44%.[2] Chest X-rays provided limited information in identifying contusions in the immediate and early post-trauma period, whereas pulmonary perfusion scintigraphy showed not only the hypoperfused lung but also a more accurate estimation of the size of the lesion. Chest CT is an attractive alternative to chest X-ray, its chief advantage being its accuracy in detecting lesions immediately after injury. Estimating the total volume of the injured lung may also predict the need for ventilatory support. We found pulmonary contusions and lacerations at thoracotomy in some patients who had been diagnosed as having intrathoracic hematoma by CT. However, while CT scans can effectively detect pulmonary contusion, they are costly.

There are few reports on the scintigraphic study of pulmonary contusion. One study performed to differentiated pulmonary contusion from pulmonary embolism concluded that a pulmonary arteriogram may be necessary for differentiation. Although there may be some doubt about old reports on patients diagnosed with pulmonary contusion by chest X-ray, further studies are necessary to differentiated embolism from contusion. We also emphasize that scintigraphic images showing hypoperfusion in a trauma victim surely indicate contusion unless hypoxia improves and the hypoperfused lung area diminishes in time.

The mortality associated with pulmonary contusion is difficult to define with coexistent injuries, but it is generally thought to range from 10% to 25%.[2] Although isolated contusion is a less dangerous injury for the patient with minimal risk of mortality, who is unlikely to need ventilatory support (4% each), pulmonary contusion with thoracic or extrathoracic injuries resulted in mortality rates of 64.5% and 72%, respectively. In fact, these associated injuries were responsible for most of the deaths, especially severe head injuries, as in most reports.

In conclusion, pulmonary perfusion scans effectively show the perfusion defect and size in patients with pulmonary contusion. According to these scans, perfusion of the contused lung area improves later than that according to radiologic appearance. Mortality and morbidity are higher in patients with a large contusion area. Flail chest is also an important mortality and morbidity factor. Although isolated pulmonary contusion is a relatively benign condition, special maintenance therapy is a more appropriate treatment than routine trauma management.

References

1. Cohn SM. Pulmonary contusion: review of the clinical entity. J Trauma 1997;42:973–9.
2. Allen GS, Coates N. Pulmonary contusion: a collective review. Am Surg 1996;62:895–900.
3. Trunkey DD. Torso trauma. Curr Probl Surg 1987;24:212–65.
4. Hoff SJ, Shotts SD, Eddy VA, Morris JA. Outcome of isolated pulmonary contusion in blunt trauma patients. Am Surg 1994;60: 138–42.
5. Pinella JC. Acute respiratory failure in severe blunt chest trauma. J Trauma 1982;22:221–6.
6. Richardson JD, Adams L, Flint LM. Selective management of flail chest and pulmonary contusion. Ann Surg 1982;196:481–7.
7. Clark GC, Schecter WP, Trunkey DD. Variables affecting outcome in blunt chest trauma: flail chest vs. pulmonary contusion. J Trauma 1988;28:298–304.
8. Kollmorgen DR, Murray KA, Sullvian JJ, Mone MC, Barton RG. Predictors of mortality in pulmonary contusion. Am J Surg 1994; 168:659–64.
9. 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;46:833–8.
10. Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluation of emergency care. J Trauma 1974;14:187–96.
11. Committee on Injury Scaling. The Abbreviated Injury Scale, 1990 revision. Des Plaines, IL: Association for Advancement of Automotive Medicine; 1990.
12. Johnson JJ, Cogbill TH, Winga ER. Determinants of outcome after pulmonary contusion. J Trauma 1986;26:695–7.
13. Richardson JD, Woods D, Johnson WG Jr, Trinkle JK. Lung bacterial clearance following pulmonary contusion. Surgery 1979;86:730–5.
14. Fulton RL, Peter ET. The progressive nature of pulmonary contusion. Surgery 1970;67:499–506.
15. Matsumoto K, Noguchi T, Ishikawa R, Mikami H, Mukai H, Fujisawa T. The surgical treatment of lung lacerations and major bronchial disruptions caused by blunt thoracic trauma. Surg Today 1998;28:162–6.
16. Tanaka H, Tajimi K, Endoh Y, Kobayashi K. Pneumatic stabilization for flail chest injury: an 11-year study. Surg Today 2001;31: 12–7.
17. Stellin G. Survival in trauma victims with pulmonary contusion. Am Surg 1991;57:780–4.
18. Pepe PE. Acute post-traumatic respiratory physiology and insufficiency. Surg Clin North Am 1989;69:157–73.