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The Management of Flail Chest Injury: Factors Affecting Outcome

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The records of 57 patients presenting with flail chest injury from 1981 through 1987 were reviewed to determine factors affecting morbidity and mortality. Fifteen patients (26%) had 8+ rib fractures with a unilateral flail and seven (12%) had multiple rib fractures with a bilateral flail. Thirty-two (56%) had moderate-severe pulmonary contusions and 44 (77%) required chest tubes for hemo-pneumothorax.

Ventilatory assistance was used in 36 (63%). The major factors determining the need for ventilatory assistance were: an ISS ≥ 23, blood transfusions in the first 24 hours, moderate-severe associated injuries (fractures, head injuries or truncal organs requiring operation), and shock on admission ($p < 0.001$).

An adverse outcome occurred in 15 (28%); nine required ventilatory assistance ≥14 days and six died of sepsis with pneumonia. The main factors associated with an adverse outcome were: an ISS ≥ 31 ($p < 0.001$), moderate-severe associated injuries ($p < 0.001$), and blood transfusions ($p < 0.005$). Although the primary determinants of an adverse outcome were the associated injuries and blood loss, a bilateral flail ($p < 0.01$) and age ≥50 years ($p < 0.02$) were contributing factors.

Flail chest continues to be an important injury with significant complications. Approximately one out of every 13 patients with fractured ribs admitted to a hospital will have flail chest (2), with reported mortality rates averaging 10 to 20% (4, 7, 9, 11, 15).

Before 1956 the treatment of severe flail chest was primarily external chest wall stabilization. From 1956 to 1975, early intubation and ventilatory support were increasingly emphasized. Since Trinkle's classic study in 1975 (15), there has been an increasing effort to treat selected flail chest patients supportively without ventilatory assistance. However, controversy continues to exist concerning the results of such treatment, partly due to disagreement about the major factors which determine outcome. In an effort to evaluate our treatment of flail chest and the factors affecting results, we reviewed our most recent experience with this problem.

MATERIALS AND METHODS

The records of 57 patients admitted to Detroit Receiving Hospital from 1981 through 1987 with a diagnosis of flail chest due to blunt trauma were reviewed. The flail chest injuries occurred in 25 (44%) drivers or passengers in cars, 11 (19%) pedestrians, and three (5%) motorcyclists. The other causes of flail chest were falls from various heights in 12 (21%), altercations in four (7%), and crushing industrial accidents in two (4%).

Forty-four (77%) of the patients were male. The age range was 13 to 86 years, with a mean of 43 ± 18 years. Ten (18%) of the patients were 60 years of age or older.

Flail chest was diagnosed clinically by evidence of paradoxical motion of a portion of the chest wall on physical examination. This was confirmed by radiographic evidence of fractures of the sternum (two patients) and/or three or more segmental rib fractures. The 57 patients were divided into four groups according to the number of rib fractures: a) three to five rib fractures (19 patients); b) six or seven rib fractures (16 patients); c) eight or more rib fractures with a unilateral flail (15 patients); and d) eight or more rib fractures with a bilateral flail (seven patients).

Pulmonary contusion was diagnosed in 46 (81%) of the patients because of an acute infiltrate on the admission chest radiograph. An initial infiltrate involving less than a segment was considered mild, more than a segment but less than a lobe was considered moderate, and an infiltrate involving more than a lobe was considered severe The incidences of mild, moderate, and severe pulmonary contusions were 25%, 26%, and 30%, respectively. Patients with pulmonary contusion without clinical evidence of flail were excluded from this study.

Chest tubes were inserted in 44 (77%) of the patients because of an associated pneumothorax or hemothorax. In eight of these patients, bilateral chest tubes were required.

Endotracheal intubation to provide ventilatory support or protect the airway was performed at or soon after admission, either in the emergency department or in the operating room, in 36 (63%) of the patients. This was primarily a clinical decision because only six (11%) of the patients had hypoxemia

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(PO_2 <60 mm Hg) in spite of oxygen administration and the one patient with hypercarbia had severe chronic obstructive lung disease. There were no further intubations for flail chest after 24 hours.

Patients were placed into one of three clinical groups based on the types of associated injuries present. Group I included 20 patients with either an isolated flail chest or only associated soft-tissue injuries. Group II included 15 patients with extrathoracic fractures, usually of the long bones of the lower extremities. Group III included 22 patients with either associated severe injuries to the brain or to thoracic or abdominal organs requiring laparotomy or thoracotomy.

Data were obtained on the etiology of the trauma, extent of chest wall injury and pulmonary contusion, presence of hemopneumothorax requiring chest tubes, types of associated injuries, ISS score, presence of shock on admission, and number of blood transfusions in the first 24 hours. These were correlated with patient outcome including the incidence of ventilatory support, pneumonia, prolonged ventilatory support (≥14 days), and later septic deaths associated with pneumonia.

Shock on admission was diagnosed in 16 (28%) of the patients on the basis of a systolic BP less than 80 mm Hg with evidence of poor tissue perfusion. Blood transfusions of 1 to 4 units were given during the first 24 hours to 35 (61%) of the patients; 18 (32%) of the patients required 5 or more units of blood during that period. Pneumonia was diagnosed by positive sputum culture, a rectal temperature greater than 101.4°F, and a new infiltrate on the chest radiograph.

Data were recorded as mean ± standard deviation. Statistical analyses for comparison of means were performed using the two-tailed Student's t-test. Chi-square analysis was used to compare ratios. A p-value less than 0.05 was considered significant.

RESULTS

CLINICAL OUTCOME

Two patients died from massive intra-abdominal hemorrhage within 24 hours of admission, and two died of head injuries on the first and third days of admission. These four patients were excluded when attempting to determine which factors were associated with a later adverse outcome.

The remaining 53 patients were divided into five outcome groups. There were 21 patients (37%) who did not require ventilatory support; these patients had no pulmonary complications. Seven (13%) patients required 1 to 13 days of ventilatory support but did not develop pneumonia. Ten (19%) required less than 14 days of ventilatory support but developed pneumonia. Nine patients (17%) required 14 or more days of ventilatory support and survived; all of these patients developed pneumonia. Six patients (11%) required ventilatory support and died from sepsis associated with pneumonia. Thus, of the 57 patients, 36 (63%) had ventilatory support. Of the 53 who did not die rapidly of other injuries, 25 (47%) developed pneumonia, 15 (25%) had an adverse outcome (ventilatory support ≥14 days and/or septic death), and six (11%) died with pulmonary sepsis. Septic deaths associated with pneumonia occurred at 6, 8, 30, 56, 70, and 197 days.

FACTORS AFFECTING CLINICAL OUTCOMES

1. **Etiology of Injury.** Of the four early nonseptic deaths, two occurred in MVA drivers or passengers and two occurred in pedestrians. Of the remaining 53 patients, the 24 with motorcycle accidents (MCA), pedestrian accidents (Peds), or falls had the worst prognosis. Nineteen (79%) of the MCA-Peds-falls group required ventilatory support compared to 13 (45%) in the other 29 patients ($p < 0.02$) (Table I). In addition, five of the six later septic deaths and six of the nine survivors requiring ventilator assistance ≥14 days were in the MCA-Peds-Falls group.

2. **Age.** There was a tendency for patients more than 50 years of age to have a poorer prognosis. Of the 32 patients less than 50 years of age, five (16%) had an adverse outcome (two died of sepsis and three required 14 or more days of ventilator support). In contrast, of 21 patients aged 50 years or older, ten (48%) had an adverse outcome (four died of sepsis and six required more than 14 days of ventilator support) ($p < 0.05$). Of the ten patients who were 60 years of age or older, three (30%) died with pulmonary sepsis; the septic death rate in the younger patients was only 12% (3/43) ($p < 0.05$).

3. **Chest Wall Injury.** All seven patients with bilateral flail chest required ventilatory assistance; six (86%) of these patients developed pneumonia, and three (43%) died with pulmonary sepsis (Table II). The mean time on the ventilator in survivors with a bilateral flail chest was 15 ± 10 days. Of the other 46 patients surviving more than three days, 21 (46%) did not require ventilator assistance. Of the 25 patients who had ventilator assistance, three (12%) died of pneumonia, and their average ventilator time was 12 ± 12 days. In the 50 patients with a unilateral flail chest, the number of rib fractures made no difference in the incidence of ventilator support, pneumonia, or prolonged ventilation.

4. **Pulmonary Contusion** (Table III). There was a slight nonsignificant correlation between the extent of the chest wall injury and the presence of pulmonary contusions. Of the 35 patients with less than eight rib fractures, 26 (74%) had pulmonary contusions. Of the 22 with eight or more rib fractures, 20 (91%) had pulmonary contusions ($p < 0.15$).

The 32 patients with moderate-severe pulmonary contusion required ventilatory support more frequently (75%) than the 25 who had no or only mild contusions (48%) ($p < 0.04$). The patients with moderate-severe contusions also had a higher incidence of pneumonia (60%) than the other patients (30%) ($p < 0.04$).

5. **Hemo/Pneumothorax.** The presence of a hemothorax or pneumothorax on admission requiring a chest tube was associated with a tendency to an increased (68%) incidence of ventilatory support; of the 13 patients not requiring a chest tube, six (46%) required ventilatory assistance ($p < 0.16$) (Table IV). The 55% (23/42) incidence of pneumonia in patients requiring chest tubes

TABLE I
Etiology of trauma correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

Etiology of Trauma	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
Motorcycle Pedestrian Fall	26**	(21) [a] 81%	(17) [c] 71%	(11) [e] 46%	(5) [g] 21%
Assault MVA Industrial	31**	(15) [b] 48%	(8) [d] 28%	(4) [f] 14%	(1) [h] 3%
Totals	57****	(36) 63%	(25) 47%	(15) 28%	(6) 11%

Each * indicates a patient who died before 72 hours. These patients are excluded when calculating the incidence of pneumonia, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a vs. b: $p < 0.02$. e vs. f: $p < 0.02$.
c vs. d: $p < 0.005$. g vs. h: $p < 0.05$.

TABLE II
Chest wall injury correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

Number of Fractured Ribs	Flail	Number of Patients	Outcome			
			Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
3–5	Unilateral	19***	(14) [a] 74%	(9) [e] 56%	(5) [i] 31%	(3) [m] 19%
6–7	Unilateral	16	(6) [b] 38%	(5) [f] 31%	(3) [j] 19%	[n] —
8+	Unilateral	15*	(9) [c] 60%	(5) [g] 36%	(2) [k] 14%	[o] —
8+	Bilateral	7	(7) [d] 100%	(6) [h] 86%	(5) [l] 71%	(3) [p] 43%
Totals		57****	(36) 63%	(25) 47%	(15) 28%	(6) 11%

Each * indicates a patient who died before 72 hours. These patients are excluded when calculating the incidence of pneumonia, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a + b + c vs. d: $p < 0.04$. i + j + k vs. l: $p < 0.01$.
e + f + g vs. h: $p < 0.03$. m + n + o vs. p: $p < 0.005$.

was significantly higher than in those not requiring them (18%) ($p < 0.05$).

6. **Associated Injuries.** The three clinical groups determined by associated injuries had statistically significant differences in mean ISS scores (19 ± 2, 28 ± 7, and 41 ± 10). The incidence of shock, five or more blood transfusions in the first 24 hours, and moderate-severe pulmonary contusions was higher in Group II (with fractures) and Group III (with head or truncal organ injuries) (Table V).

The incidence of ventilatory assistance (60%) and pneumonia (47%) was greater for Group II (extrathoracic fractures) than for Group I ($p < 0.004$). Group III (head or truncal organ injuries) in turn, had a significantly higher incidence of ventilatory assistance (100%), pneumonia (100%), and prolonged ventilation or septic death (67%) than Group II (Table VI). All ten deaths (septic and nonseptic) occurred in Group III.

7. **ISS.** Grouping the patients according to their ISS (16–22, 23–30, and 31 or more) could be correlated with significant increases in the incidence of ventilatory assistance, pneumonia, and adverse outcome (ventilator assistance ≥14 days and/or septic death) (Table VII). The mean ISS score for the four patients who died within 72 hours was 55 ± 9. The mean ISS score in the six patients who died later with pneumonia was 39 ± 10 ($p < 0.05$).

8. **Shock on Admission.** All 16 patients who had

TABLE III
Extent of pulmonary contusion correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

Extent of Pulmonary Contusion	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
None	11**	(6) [a] 55%	(3) [e] 38%	(2) 22%	(1) 11%
Mild	14	(6) [b] 43%	(4) [f] 29%	(4) 29%	(3) 21%
Moderate	15*	(13) [c] 87%	(9) [g] 64%	(3) 21%	(1) 7%
Severe	17*	(11) [d] 65%	(9) [h] 56%	(6) 38%	(1) 6%
Totals	57****	(36) 63%	(25) 47%	(15) 28%	(6) 11%

Each * indicates a patient who died before 72 hours. These patients are excluded when calculating the incidence of pneumonia, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a + b vs. c + d: $p < 0.04$.
e + f vs. g + h: $p < 0.04$.

TABLE IV
Chest tubes for hemopneumothorax correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

Chest Tubes	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
0	13**	(6) [a] 46%	(2) [d] 18%	(2) 18%	(1) 9%
1	35**	(22) [b] 63%	(17) [e] 52%	(9) 27%	(4) 12%
2	9	(8) [c] 89%	(6) [f] 67%	(4) 44%	(1) 11%
Totals	57****	(36) 63%	(25) 47%	(15) 28%	(6) 11%

Each * indicates a patient who died before 72 hours. These patients excluded when calculating the incidence of pneumonia, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a vs. c: $p < 0.04$.
a vs. b + c: $p < 0.07$.
a + b vs. c: $p < 0.08$.
d vs. e + f: $p < 0.03$.

shock and a flail chest on admission were intubated and given ventilatory support. In the remaining 41 patients, only 49% (20/41) were placed on a ventilator ($p \leq 0.005$). The incidence of pneumonia (92% vs. 33%) was also significantly increased in those with shock on admission ($p < 0.001$).

9. **Blood Transfusions.** Seventeen (30%) of the patients required 1–4 units of blood and 18 (32%) required five or more units of blood within the first 24 hours of admission. The transfusions were required primarily for extrathoracic injuries. The need for blood was associated with an increased need for ventilatory assistance (85% vs. 27%) ($p < 0.001$), increased incidence of pneumonia (63% vs. 14%) ($p < 0.001$), and increased incidence of a prolonged ventilation and/or septic death (45% vs. 5%) ($p < 0.001$) (Table VIII).

10. **Ventilatory Support.** All 21 patients who were treated without ventilatory support had an uncomplicated recovery. None of them developed pneumonia. In contrast, the incidence of pneumonia was 56% in those ventilated for 1–7 days and 100% in those requiring ventilatory support for more than 7 days.

FACTORS INCREASING THE NEED FOR VENTILATORY ASSISTANCE OR PNEUMONIA

The four most significant factors associated with an increased incidence of ventilatory assistance included an

TABLE V

Incidence of morbidity factors correlated with the clinical groups

Associated Injuries	Number of Patients	ISS	Shock	5+ Units Blood	Mod./Severe Pulmonary Contusion
Group I Soft Tissue	20	[a] 19.2 ± 2.0	[d] 0	[g] 0	[j] 45% (9)
Group II Fractures	15	[b] 27.8 ± 6.5	[e] 7% (1)	[h] 27% (4)	[k] 47% (7)
Group III Head/Organs	22	[c] 40.7 ± 10.0	68% (15)	[i] 68% (15)	[l] 73% (16)

a vs. b: $p < 0.001$.
b vs. c: $p < 0.001$.
d + e vs. f: $p < 0.001$.
g + h vs. i: $p < 0.001$.
j + k vs. l: $p < 0.05$.

TABLE VI

Associated injuries correlated with incidence of ventilator pneumonia, prolonged ventilation, and septic death

Group Associated Injuries	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
I Soft Tissue	20	[a] 25% (5)	[d] —	[g] —	[j] —
II Fractures	15	[b] 60% (9)	[e] 47% (7)	[h] 20% (3)	[k] —
III Head or Truncal Organ	22****	[c] 100% (22)	[f] 100% (18)	[i] 67% (12)	[l] 33% (6)
Totals	57***	63% (36)	47% (25)	28% (15)	11% (6)

* Four of these patients died within 3 days of nonpulmonary problems and are excluded from calculations determining the incidence of pneumonia, prolonged ventilation, and septic deaths.

( ) indicates the number of patients in each group.

a vs. b: $p < 0.004$.
b vs. c: $p < 0.005$.
d vs. e: $p < 0.001$.
e vs. f: $p < 0.001$.
g + h vs. i: $p < 0.001$.
h vs. i: $p < 0.01$.
j + k vs. l: $p < 0.005$.
k vs. l: $p < 0.02$.

ISS of 23 or more, associated fractures or injuries to the head or truncal organs, blood transfusions in the first 24 hours, and shock on admission (Table IX). The same factors also significantly ($p < 0.001$) increased the incidence of pneumonia. Bilateral chest tubes also tended to increase the need for assisted ventilation, but age ≥60 years did not.

FACTORS INCREASING THE INCIDENCE OF PROLONGED VENTILATORY ASSISTANCE OR SEPTIC DEATH

The three main factors increasing the incidence of prolonged (14+ days) ventilatory support and/or septic death were: an ISS of 31+, associated fractures or head or truncal injuries, and blood transfusions ($p < 0.005$) (Table X). Factors associated with a septic death were an ISS of 31+ ($p < 0.001$) or bilateral flail chest ($p < 0.005$). Although the primary determinants of an adverse outcome were the associated injuries and blood loss, a bilateral flail ($p < 0.001$) and age ≥50 years ($p < 0.02$) were contributing factors.

DISCUSSION

Despite obvious advances in overall trauma care and marked improvements in ventilatory support, the mortality rate for flail chest injury has not changed appreciably in certain centers over the past several decades (13). Although some centers emphasize the value of routine endotracheal intubation and positive end-expir-

TABLE VII
ISS correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

ISS	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
16–22	24	^{a}25% (6)	^{d}4% (1)	^{g}4% (1)	^{j}— (0)
23–30	9	^{b}78% (7)	^{e}56% (5)	^{h}22% (2)	^{k}— (0)
31+	24****	^{c}96%	^{f}95%	^{i}60%	^{l}30%
Totals	57****	63%	47%	28%	11%

Each * indicates a patient who died before 72 hours. These patients are excluded when calculating the incidence of pneumonia, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a vs. b: $p < 0.025$.
a vs. b + c: $p < 0.001$.
d vs. e: $p < 0.001$.
e vs. f: $p < 0.01$.
h vs. i: $p < 0.06$.
g + h vs. i: $p < 0.01$.
i + j vs. k: $p < 0.001$.

TABLE VIII
Number of blood transfusions correlated with the incidence of ventilatory assistance, pneumonia, prolonged ventilation, and septic death

Units of Blood in First 24 hrs	Number of Patients	Outcome			
		Ventilatory Assistance	Pneumonia	Prolonged Vent. or Septic Death	Septic Death
None	22	^{a}27% (6)	^{d}14% (3)	^{g}5% (1)	5% (1)
1–4	17*	^{b}76% (13)	^{e}50% (8)	^{h}38% (6)	13% (2)
5+	18***	^{c}94% (17)	^{f}93% (14)	^{i}53% (8)	20% (3)
Totals	57****	63% (36)	47% (25)	28% (15)	11% (6)

Each * indicates a patient who died before 72 hours. These patients are excluded when calculating the incidence of pneunomina, prolonged ventilation, and septic death.
( ) indicates the number of patients in each group.

a vs. b + c: $p < 0.001$.
a + b vs. c: $p < 0.001$.
d vs. e + f: $p < 0.001$.
d + e vs. f: $p < 0.001$.
g vs. h + i: $p < 0.005$.
g + h vs. i: $p < 0.03$.

atory pressure (PEEP) in an attempt to improve gas exchange and allow for earlier recovery of the lung (14), others emphasize techniques for avoiding ventilatory support because of the inherent risks associated with such therapy (15).

In 1859 Malgaigne described strapping the chest wall to provide mechanical support (9). The importance of mechanical support was further emphasized by Bauer in 1909 when he postulated the pendelluft theory, attributing inefficient ventilation and hypoxemia to a pendulum-like movement of air from one lung to the other during inspiration and expiration (9).

In 1956, Avery et al. introduced mechanical ventilation to treat flail chest (1). Although this technique was thought to provide internal pneumatic stabilization to the flail segment, it did not significantly reduce mortality, and many patients still died of pulmonary failure. It became increasingly apparent that flail chest is usually associated with some contusion of the underlying lung which alters alveolar ventilation:perfusion (V/Q) ratios and produces pulmonary arteriovenous shunting with hypoxemia.

In the mid-1970s, Trinkle and associates emphasized the concept of selective management of flail chest (15). They viewed the underlying pulmonary contusion as the primary pathophysiologic problem, the effects of which could be ameliorated by certain supportive measures. Intravascular fluid volume was strictly limited because this had been found to uniformly reduce the size of the contusion in experimental studies. Local pain relief,

TABLE IX
Factors affecting the incidence of ventilatory support

Factor	Per Cent Requiring Ventilatory Support		Chi-square Value	*P*-value
	In Presence of Factor	In Absence of Factor		
ISS = 23+	(30/33) 91%	(6/24) 25%	25.940	<0.001
Blood transfusions first 24 hours	(30/35) 86%	(6/22) 27%	19.828	<0.001
Assoc. injury, bone, head, or truncal organs	(31/37) 84%	(5/20) 25%	19.280	<0.001
Shock on admission	(15/16) 94%	(21/41) 51%	8.947	<0.005
Motorcycle Pedestrian Fall	(21/26) 81%	(15/31) 48%	6.372	<0.02
Bilateral flail	(7/7) 100%	(29/50) 58%	4.655	<0.04
Mod-severe pulmonary contusion	(24/32) 75%	(12/25) 48%	4.397	<0.04
Bilateral chest tubes	(8–9) 89%	(28/48) 58%	3.041	<0.09 NS
Age of 60+ years	(6/10) 60%	(30/47) 64%	−0.052	NS

chest physiotherapy, and aggressive removal of pulmonary secretions also helped patients with flail chest to be managed safely without ventilatory support.

Hypoxemia is frequently mentioned as a problem in flail chest (3, 6, 7). In this series the initial blood gases, done after the patients were receiving O_2 and/or ventilatory support, were not helpful in predicting outcome. Only six patients who lived beyond 72 hours had an initial arterial PO_2 less than 60 mm Hg on O_2 and only one had a PCO_2 >50 mm Hg. Three of these seven patients were treated without a ventilator and none died. The other four patients required a ventilator for 1, 6, 7, and 21 days and lived.

Since its introduction more than 35 years ago, the epidural block has become one of the most frequently used techniques for regional analgesia. The efficacy of epidural analgesia in rib fracture patients has been noted by several investigators (8), including Rankin and Comber, who reported effective analgesia with epidural bupivacaine and morphine in 80% of patients (10). Although about one third of patients may show no improvement of ventilation with epidural analgesia, paradoxical movement of the flail frequently is diminished or may even cease completely (8). This is probably best explained by the pain relief reducing the effort of breathing. Most of our early patients were tested with intercostal nerve blocks. Some of our later patients were treated with epidural analgesia if the patient could be watched for apnea in an ICU. Pain relief was improved with the epidural analgesia, but no difference in outcome has been apparent.

If it appears that ventilatory assistance for flail chest will be required, early implementation is best, particularly if there are moderate-severe associated injuries. We have previously found that if a patient with a flail chest was hypotensive and he was not given ventilator assistance until clinical evidence of hypoxia and/or inadequate ventilation developed for more than 24 hours, the mortality rate exceeded 90% (12). It was also noted that early institution of ventilatory assistance in patients with moderate-severe associated injuries resulted in a mortality rate of only 6%. In similar individuals in whom ventilator assistance was delayed for more than 24 hours, the mortality rate was 50% (12).

Minimal ventilation time is an important objective of care. Cullen et al. (5) were able to reduce the time on the ventilator from 19 ± 4 days to 5 ± 5 days using IMV and positive end-expiratory pressure (PEEP). Although only some of our staff surgeons routinely used IMV and PEEP, no difference in results was apparent. Nevertheless, all of our patients requiring 8 or more days of ventilatory support developed pneumonia.

TABLE X
Factors affecting the incidence of prolonged ventilatory support (>14 days) or septic death

Factor	Per Cent Requiring Ventilatory Support		Chi-square Value	*P*-value
	In Presence of Factor	In Absence of Factor		
ISS 31+	60% (12/20)	9% (3/33)	15.905	<0.001
Assoc. injury, bone, head, or truncal organs	45% (15/33)	0% (0/20)	12.679	<0.001
Blood transfusion first 24 hours	45% (14/31)	5% (1/23)	10.461	<0.005
Bilateral flail	71% (5/7)	22% (10/46)	7.392	<0.01
Age 50+ years	48% (10/21)	16% (5/23)	6.396	<0.01
Motorcycle Pedestrian Fall	46% (11/24)	14% (4/29)	5.410	<0.02
Shock on admission	46% (6/13)	23% (9/40)	2.705	<0.10 NS
2 chest tubes	44% (4/9)	25% (11/44)	1.392	<0.20 NS
Mod.-severe pulmonary contusion	30% (9/30)	26% (6/23)	0.312	NS

The majority of the deaths in patients with flail chest are due to associated injuries. In a previous series from Detroit Receiving Hospital, the mortality rates were 39% without and 100% with associated head injuries (12). Of 19 patients with three or more associated injuries, 11 (58%) died; of 81 patients with fewer associated injuries, only 13 (16%) died. In a more recent series of patients with flail chest reported by Richardson et al. the mortality rate for their entire group of patients was 6.5%, but only a fifth of these deaths were due to pulmonary injury (11).

Because of the profound effect that associated injuries have on the mortality rate in patients with flail chest, a true comparison of different series is almost impossible without an objective measure of injury such as the Injury Severity Score (ISS). In one series (4) there were no deaths with flail chest injury if the ISS was less than 30, while in patients with an ISS of 46 or more, the mortality rate was 67%. These data were almost identical to our current series. None of our 32 patients with an ISS less than 30 died, but of the patients with an ISS of 46 or more, 76% (5/7) died.

Although the ISS may not be entirely apparent to the physicians caring for the patient initially, the types of associated injury can help one decide if a given patient should have early ventilatory assistance. From this and other studies it appears that patients with isolated flail chest injuries do not require ventilatory support unless the flail is bilateral. Patients with associated extrathoracic fractures tend to require ventilatory support for severe fractures (AIS $\geq$ 4) or if there is associated shock or blood loss requiring blood transfusions. Patients who have a flail chest plus severe head injuries or truncal injuries requiring a laparotomy or thoracotomy need early ventilatory support and are more likely than the other groups to develop complications.

It is generally felt that elderly patients with flail chest do less well than younger patients. However, some authors have noted that elderly patients frequently sustain a flail chest from less severe trauma, and therefore often have a less severe pulmonary contusion. In this series, the only significant changes with older age were a tendency to prolonged ventilator assistance and/or septic death in patients $\geq$50 and 60 years of age, respectively.

Patients with pulmonary contusion often have a higher incidence and duration of assisted ventilation as well as longer ICU and hospital stays (4). This was also true in our patients when we compared those who had minimal or no contusion with those who had moderate-severe contusions.

Although the incidence of associated hemothorax or pneumothorax is often mentioned, its effects on outcome are seldom noted. The incidence of an associated pneumothorax or hemothorax in our series (77%) was similar to the incidence (85%) noted elsewhere (12). Although the need for a chest tube did not increase the mortality rate in our series, there was a tendency for the patients with chest tubes to need ventilatory support more frequently (68% vs. 46%) ($p < 0.16$). More important, the incidence of pneumonia in this series increased significantly in those with a hemothorax or pneumothorax (55% vs. 18%) ($p < 0.05$).

The reported incidence of pneumonia with flail chest has been as high as 60% (1). In our series, the incidence of pneumonia was 47%, and it was directly related to the duration of the ventilatory assistance. In patients requiring ventilator support for less than 1 week, the incidence of pneumonia was 56%, whereas in patients requiring 8 or more days of ventilatory support, it was 100%.

Thus it is clear that more work must be done to reduce the incidence of pneumonia, possibly by decreasing the frequency and duration of ventilatory support. More frequent use of early fixation of extremity fractures may be helpful in this regard. This may help not only to reduce our mortality rates, but also to alleviate, at least partially, our current severe ICU nurse shortage. Earlier and more frequent use of epidural analgesia may also be helpful, especially if this modality can be provided safely outside an ICU.

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