Prognostic factors in flail-chest patients

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Abstract

Objective: The records of 250 patients presenting with flail-chest injury in a level I trauma centre were reviewed and analysed in order to determine prognostic factors. Methods: There were 250 consecutive trauma patients with flail chest, 183 men (73.2%) and 67 women (26.8%) ranging in age from 18 to 91 years, admitted to our hospital. The leading cause of injury was road traffic accident. One hundred and six patients (42.4%) were conservatively treated, while 117 (46.8%) needed thoracic drainage. Ventilatory assistance was used in 28 cases (11.2%). Only 19 (7.6%) required thoracotomy and/or laparotomy. The mortality rate reached 8.8%. Patients were divided into three groups: group I consisted of 105 patients (70/35) with an isolated flail chest (Injury Severity Score (ISS): 16); group II included 58 cases (48/10) with extrathoracic fractures (ISS: 25—30); and group III comprised 87 patients (65/22) with injuries to the brain or to thoracic or abdominal organs requiring thoracotomy and/or laparotomy (ISS: >40). Parameters such as age, sex, ISS, presence of extrathoracic fractures, haemopneumothorax and head injury as well as the need for mechanical support in an intensive care unit (ICU) and mortality were evaluated. Results: The mortality rate in group III was higher compared to those of groups I and II (16% vs 3.8% and 6.9%, respectively) and the difference was found to be statistically significant. Laparotomy and thoracotomy affected mortality, while age, pneumothorax and head injury did not. Finally, mechanical support was used only in a few cases. Conclusions: (1) ISS is the strongest predictor of outcome associated with increased mortality; and (2) mechanical support was not considered a necessity for the treatment of flail chest.

1. Introduction

Thoracic trauma comprises 10—15% of trauma and is the cause of death in 25% of all fatalities due to trauma [1]. In blunt thoracic trauma, approximately one out of 13 patients with fractured ribs admitted to a hospital will have flail chest with reported mortality rates averaging 10—20% [2,3]. Flail chest is defined as fractures of more than two consecutive ribs at two separate sites. Since a segment of the rib cage becomes sufficiently disconnected from the rest of the thorax, this allows independent movement. Consequently, by inspiration, the contraction of the diaphragm and other respiratory muscles move the flail segment inwards and, by expiration, the flail segment is moved outwards, giving rise to the term ‘paradoxical respiration’ [2,4]. Contusion usually co-exists and, along with the pain, results in shallow tidal volumes, collapse of alveoli, arteriovenous shunting and hypoxaemia leading to respiratory insufficiency [5—7]. Despite the prevalence and recognised association of pulmonary contusion and flail chest as a combined, complex, injury pattern with inter-related pathophysiology, the mortality and short-term morbidity of this entity have not improved over the last three decades [7]. Advances in diagnostic imaging and critical care have also failed to impact upon outcome.

The records of 250 patients presenting with flail-chest injury during a 12-year period in our hospital, a level-I trauma centre, were reviewed and analysed in order to determine factors affecting mortality.

2. Material

Clinical charts, reports of medical visits and radiological images were reviewed retrospectively. There were 250 consecutive trauma patients with flail chest, 183 men (73.2%) and 67 women (26.8%) ranging in age from 18 to 91 years with a mean age of 58.3 ± 16.5 years, admitted to the General Hospital of Piraeus. Data were obtained on the aetiology of the trauma, pulmonary contusion, presence of haemopneumothorax requiring drainage, types of associated injuries and Injury Severity Score (ISS). These parameters were correlated with patient outcome including the incidence of ventilatory support and hospitalisation in the intensive care unit (ICU).
The leading cause of injury was road traffic accident followed by falls and assaults. The diagnosis of flail chest was clinically made by evidence of paradoxical motion of a portion of the chest on physical examination. Chest pain and dyspnoea were the most common symptoms, whereas sensitivity over the chest wall and bone crepitations were the most common findings at presentation. The anamnesis revealed concomitant chronic diseases in 24.4% of hospitalised patients ($n = 61$). A radiological confirmation followed with two or more segmental rib fractures (Fig. 1). The number of ribs broken in each patient ranged between three and eight. Computerised tomography (CT) scanning was conducted in order to diagnose pulmonary contusions or to exclude rupture of a great vessel.

The classification was done according to the ISS, which is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury allocated to one of six body regions was assigned an Abbreviated Injury Scale (AIS) score and the three most severely injured body regions have their score squared and added to produce the ISS score [8].

Fluid administration was carefully managed since it was assumed that everyone had a mild contusion, even if it was not apparent on the first CT scan.

The clinical approach towards these patients was based on arterial blood gas measurements. For the management of pain due to the fractures, narcotic and non-narcotic analgesics, intercostals nerve block, patient-controlled analgesia (PCA) and epidural analgesia were used. The degree of pain relief was assessed by the necessity of supplementary analgesics according to the capacity of mobilisation, cough and deep inspiratory effort.

Nasotracheal aspiration and fibreoptic bronchoscopy along with aggressive physiotherapy and humidification of inspired air were performed to clear secretions and to avoid atelectasis that could lead to infection. In 49 cases (19.6%), an early tracheostomy (after the third day of hospitalisation) was performed in order to facilitate the drainage of bronchial secretions, while in seven cases a continuous positive airway pressure (CPAP) mask was used. The frequency of bronchial toilet depended on the cooperation of a patient to cough always assisted by the physiotherapists and was used 2—4 times per day.

We divided our patients into three groups. Group I consisted of 105 patients (70/35) with an isolated flail chest (ISS: 16), group II included 58 cases (48/10) with extrathoracic fractures (ISS: 25—30) and group III comprised 87 patients (65/22) with injuries to the brain or the thoracic or abdominal organs requiring thoracotomy and/or laparotomy (ISS: $>40$; Table 1).

Thoracic and extrathoracic fractures are summarised in Tables 2 and 3, respectively, while the distribution of thoracic and extrathoracic injuries in the groups are shown in Tables 4 and 5.

Parameters such as age, sex, ISS, presence of thoracic and extrathoracic fractures, haemopneumothorax and head injury and also the need for mechanical support in the ICU...
were evaluated by using the unpaired t-test and $\chi^2$ test where appropriate. A second comparison took place concerning all the above-mentioned risk factors. These were entered into a Cox regression analysis to identify independent risk factors influencing mortality. A level of $p < 0.05$ was maintained to denote statistical significance in all comparisons.

3. Results

Pulmonary contusion was diagnosed in 195 patients (78%) and classified as mild in 68 (35%), moderate in 80 (41%) and severe in 47 cases (24.1%) with a similar incidence among the three groups. One hundred and six patients (42.4%) were conservatively treated, while 177 (46.8%) needed thoracic drainage. The presence of pneumothorax and/or hae-mothorax was almost equal in all three groups.

Twenty-eight patients (11.2%) were hospitalised in the ICU, while 22 of them (8.8%) developed acute respiratory insufficiency with hypoxaemia or hypercapnia (partial pressure of oxygen (arterial) (PO$_2$) < 60 mmHg, partial pressure of carbon dioxide (arterial) (PCO$_2$) > 45 mmHg) or hypovolaemic shock due to intrathoracic or intra-abdominal bleeding or suffered from severe head injury and required intermittent positive-pressure ventilation. The average number of days on the ventilator was 9.6. The rest stayed in the ward and were followed with evaluation of vital signs, complete blood count and chest X-ray daily. Only 19 (7.6%) required emergency thoracotomy and/or laparotomy. Synchronous operative stabilisation of the chest wall was performed only in six (2.4%) patients from among the 117 (46.8%) needed thoracic drainage. The presence of pneumothorax and/or hae-mothorax was almost equal in all three groups.

Flail chest is a consequence of an application of large forces to the chest, leading to severe trauma and is included to the major, often life-threatening, decelerational injuries along with aortic disruption, tracheobronchial disruption and sternal fracture serving as markers of significant intrathoracic injury [3,9]. It is generally agreed that the most common cause of injury is traffic accidents [1,8,10]. Multiple intra- and extrathoracic injuries are associated with development of flail chest.

It is also well known that factors such as the underlying lung contusion, mechanical instability of the thoracic cage, pain, limited thoracic movement and lung expansion contribute in variable degrees to the development of respiratory failure [10,11]. Pulmonary contusion is by far the most important single factor, present in the majority of cases, while paradoxical motion disrupts the mechanics of ventilation, leading to a decrease of total lung capacity (TLC) and functional residual capacity (FRC) [6,10].

Gyhra et al. [12], in an experimental study, proved the decrease of tidal volume, explained by the reduction of the intrathoracic volume, while, after oxygen administration, tidal volume values remained unchanged despite the increase of PaO$_2$ (PO$_2$ in alveoli). Consequently, the conclusion that flail chest is associated with hypoxia is not valid. Hypercapnia can be caused by a number of factors including ventilation/perfusion mismatch secondary to contusion, haematoma or alveolar collapse and inadequate tissue oxygen delivery (due to pneumothorax), but not by flail chest itself. Hypercarbia may also result in inadequate ventilation and decreased conscious levels, whereas metabolic acidosis is also a common finding that must not be overlooked.

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<th>Extrapulmonary injuries</th>
<th>Groups</th>
<th>Total</th>
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<td></td>
<td>I (n = 105)</td>
<td>II (n = 58)</td>
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<tr>
<td>Head injury</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
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<tr>
<td>Splenic rupture</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
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<tr>
<td>Liver rupture</td>
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<th>Table 6 Mortality of the three groups separately.</th>
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Table 5 Distribution of extrathoracic injuries into the three groups.
Mechanical ventilation is another point to debate. Potential indications for ventilation in patients with flail chest are shock, several associated injuries, severe head injuries and respiratory insufficiency usually attributed to an underlying pulmonary disease, such as chronic obstructive pulmonary disease (COPD), and to age [10]. In the 1970s, Trinkle [2] was the first to raise the possibility that obligatory mechanical ventilation was not necessary.

We do advocate selective ventilatory support as Shackford et al. [13] suggested, in order to correct abnormalities of gas exchange in cases where it is needed. In the majority of cases, as shown in our series (contrary to Velmahos et al. [14]), intubation was avoided, since worse survival has been demonstrated due to the complications of mechanical ventilation. The authors agree with the recommendations of the Eastern Association for the Surgery of Trauma [6] where it is stated that obligatory mechanical ventilation should be avoided, while independent lung ventilation may be considered in severe unilateral pulmonary contusion when shunt cannot be otherwise corrected. Contrary to other trauma centres, ours is not run by trauma surgeons but by thoracic surgeons who provide in-house round-the-clock coverage and participate in all major resuscitations and thoracic operations. In all isolated flail-chest cases, conservative therapy with aggressive chest physiotherapy (including bronchoscopy) and optimal pain control were offered. Among the 250 patients in our series, only 28 patients needed ventilatory support: nine (8.6%) from group I, 12 (20.7%) from II and, finally, seven (8.0%) from III. It seems patients needed ventilatory support: nine (8.6%) from group I, 12 (20.7%) from II and, finally, seven (8.0%) from III. It seems that hypovolaemic shock, injuries, such as extrathoracic fractures, and severe head injuries led the majority of patients to the ICU \( (n = 12 + 7, 7.6\% \text{ compared with } 3.6\% \text{ for group I}) \) and not the flail chest itself. Patients with extrathoracic fractures or those with associated shock tend to require ventilatory support, while patients with severe head injuries or those requiring either laparotomy or thoracotomy need early ventilatory support and are more prone to develop complications.

Tracheostomy was liberally performed in patients with secretions along with intensive physiotherapy, especially at the beginning of this study and proved to be lifesaving [15], while the CPAP mask proved to be very effective in a few co-operative patients as a non-invasive method discussed in prospective studies by Tanaka et al. [16] In another well-matched study by Gunduz et al. [17], CPAP proved to be very effective, leading to lower mortality and nosocomial infection rate. Fluid resuscitation in these patients should be carefully handled. Patients should not be excessively fluid restricted, but they should be resuscitated as necessary, especially with isotonic crystalloid or colloid solution to maintain signs of adequate perfusion [6]. It is well stated nowadays that mortality in patients with pulmonary contusion correlated with admission pulmonary function but not with the amount of intravenous fluid administered [4].

It is argued in some recent publications [5,16,18,19] that operative fixation lowers the morbidity and mortality rates; however, this argument is not widely agreed upon. Thoracic cage stabilisation has been proposed by some authors as a method of choice to decrease mechanical ventilator dependence and respiratory complications [16]. Ahmed and Mohyudin [5] documented that patients with internal fixation of their flail chest remained an average of 3.9 days on mechanical ventilation compared to 15 days for patients managed without internal fixation; and Voggenreiter et al. [19] reported significantly shorter periods of mechanical ventilation in patients with operative thoracosternum stabilisation. On the other hand, Borrelly et al. [20], by studying the pathophysiology of flail segment, suggested restoration of parietal mechanics by early surgical fixation since the antero-lateral and postero-lateral flail segments are rendered susceptible to secondary dislocation through a complex set of factors. Unfortunately, all the above-mentioned studies were either retrospective or used groups that were not well matched in terms of the extent of chest-wall injury and overall ISS.

The authors believe that such an operation could be meaningless, if it is done in order to improve lung air-volume reduction, since that is caused by the lung contusion and not by the thoracic deformity [21]. In another series [22—24], the authors found it reasonable to use operative fixation only in cases where thoracotomy was required for another indication, and so did these authors. Surgical solutions must be tailored to the individual case.

The surgical approach is mainly implied in view of huge thoracic deformity, of ensuing respiratory failure and as a ‘retreat indication’ where thoracotomy is mandatory because of threatened visceral lesions. Some authors advocate that the disability due to chest deformity impairs patients from returning to their prior active role in society. Unfortunately, there are no long-term prospective studies or follow-up studies of any sort in any group of trauma patients in the literature. However, the decision is based on the experience and judgement of the thoracic surgeon. The goal of minimising intubation time by operative fixation of fractured ribs has not been proved yet [25] and it is not in accordance with the practice management guideline for pulmonary contusion and flail chest by the Eastern Association for the Surgery of Trauma (EAST) group [6] published recently. Among the disadvantages of operative stabilisation is the required general anaesthesia which is inherently risky for patients who have sustained multiple and severe trauma, or the presence of associated severe injuries such as myocardial contusion. Techniques of stabilisation can be difficult, time consuming and the additional dissection required to accomplish these repairs may increase local tissue injury. Implanted foreign bodies can contribute to chronic osseous and soft tissue infections. The management of flail chest has been the subject of controversy for many years. An individualised approach putting into consideration the patient’s post-traumatic cardiopulmonary status and the extent of trauma to other organ systems is generally supported. There are many aspects to be clarified and prospective randomised trials are needed in order to compare conservative and surgical treatments.

In accordance with other studies [6,9,24,25], the majority of deaths in patients with flail chest are due to associated injuries. The mortality rate varies in different studies from 11% to 40% [9,13,25], while, in our series, it reached only 8.8%, which represents one of the lowest rates published. The mortality rate in group III (ISS > 40) was higher compared to those of groups I and II (16% vs 3.8% and 6.9%, respectively) and the difference was found to be statistically significant.
(p < 0.01), while the strongest predictor of outcome associated with increased mortality was found to be the ISS. The incidence of haemopneumothorax did not seem to influence either ICU hospitalisation or mortality, but it affected morbidity slightly. Finally, although in other studies [1,9] age had been correlated with prognosis, in the present series no statistical significance was found. Although there are limitations and biases, since the study is a retrospective one, to our knowledge it is the longest series of flail-chest patients conservatively treated that are analysed in the literature.

In conclusion, we emphasise that

1. Age, haemopneumothorax and mechanical support had no demonstrable impact on mortality.
2. ISS was found to be the only strong predictor on outcome concerning mortality rate.
3. Adequate oxygenation, carbon dioxide clearance and normal blood gases’ values without ventilatory support along with the maintenance of pulmonary and tracheal hygiene, systematic analgesia and the management of associated injuries improve the outcome.

References


Appendix A. Conference discussion

Dr D. Wood (Seattle, Washington, USA): I think it’s important to point out a couple of things. This is a heterogeneous group of patients, a wide range of associated trauma. Results, it appears, largely relate to the associated trauma rather than necessarily the flail chest alone.

Another thing that I think the audience should recognize is that one of the reasons that the good results are what they are is that in the trauma centre concerned, the thoracic surgeons are involved in these patients up front, at the initial stage of evaluation of chest trauma, as opposed to what commonly occurs — an initial evaluation by general or trauma surgeons with referral to thoracic surgery only when complications arise. So I think that your group is to be commended on that experience.

I have two questions for you. The first relates to your last point about ventilation. I’m wondering if there are any specific indications for ventilation regarding flail chest alone, not related to associated injuries. And you have made a point that it’s rarely necessary. Is it sometimes necessary, and, if so, when?

Dr Athanassiadi: I think it is necessary. Actually, it’s not my opinion. It comes from the guidelines of the Eastern Association for Trauma Surgery. The one case where ventilatory support is necessary is when you have severe contusion extending to the whole lung. You have to ventilate the patient because you have a huge shunt. It is difficult, even for the most co-operative patient, to make do only with the CPAP mask. In the literature, the majority of patients with isolated flail chest did not need ventilation, although there is a particular group of patients who are elderly patients with concomitant disease, COPD or myocardial infarction, that in my opinion can be better managed if ventilated. They are not co-operative patients, having a bronchial toilet sometimes even 3 times per day using bronchoscopy. Even if they have a tracheostomy, even if there is a physiotherapist around the clock and they have a nerve block of epidural anaesthesia or PCA for pain management, they are not going to recover easily. That’s my personal opinion.

Dr Wood: My second question is regarding chest wall stabilisation, which appears to be increasingly popular in many centres, and you rarely performed it, and that is our experience as well. So I’m wondering if you could give us your thoughts on the indications for surgical chest wall stabilisation in these patients.

Dr Athanassiadi: One indication for stabilisation that was already mentioned is severe dislocation of ribs, that sometimes they can also cause severe bleeding. The second indication is when it’s a huge deformity, in order to get this patient to his normal life really quickly, but you rarely see that. Among these 250 cases, we have seen that only in 6 cases, and we have a follow-up of at least 38 months.
Dr R. Milton (Leeds, United Kingdom): I just wondered if you could expand a bit more on the pulmonary contusion side of things. How do you grade between mild, moderate, and severe pulmonary contusion?

Dr Athanassiadi: There are guidelines according to CT. If it’s a segment, it’s mild; if it’s one lobe, it’s moderate; and if it’s the whole lung, it’s severe.

Dr Milton: And you mentioned that mortality was related to the injury severity score. I don’t know. Does that include pulmonary contusion and —

Dr Athanassiadi: As you know, the ISS score, you can include the contusion. The ISS score is practically a numerical score. You have AIS score. That means you judge all the anatomical parts. Then for the ISS score, you get the most severe and you square it. So if you have a severe contusion, you have to square it. It’s more than flail chest, which is numbered 4. Flail chest is still more in the ISS score than the moderate contusion or mild one.

Dr Milton: Finally, do you have any experience with extracorporeal support in people with respiratory failure and severe pulmonary contusion?

Dr Athanassiadi: I didn’t get the question. Sorry.

Dr Milton: Have you ever had to make use of extracorporeal membrane oxygenation or other ventilatory adjuncts, like the use of a Novalung, in people with severe pulmonary contusion and respiratory failure following trauma?

Dr Athanassiadi: No. I have experience with Novalung, but I do not have experience with Novalung in trauma. What would really worry me with Novalung in trauma is heparinization of the patient, although it’s a small amount of heparin. ECLA would probably be better, but I have never used it in trauma. In our country, it is also a matter of the patient’s insurance or the department’s budget.