Evaluation of respiratory functions in chest trauma patients treated with thoracic wall stabilization

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Received 22 September 2014; accepted 28 October 2014
Available online 24 November 2014

KEYWORDS
Blood gas;
Pulmonary function test;
Chest wall stabilization

Abstract  Background: Surgical stabilization may provide an early restoration of chest wall contour and lead to decrease in the duration of ventilatory support. Long-term postoperative pulmonary function seems to be better preserved after surgical stabilization.

Objective: To evaluate pulmonary function tests and oxygenation in patients with thoracic wall surgical stabilization for flail chest.

Materials and methods: Forty patients (30 men, 10 women; mean age 42.6 years) with anterolateral flail chest (≥4 ribs fractured at ≥2 sites) fulfilled the inclusion criteria and underwent surgical stabilization using metallic reconstruction plates under general anesthesia using lung protective ventilation strategy. Clinical assessment, pulmonary function testing and blood gas analysis were performed before surgery, and after 3 months following surgery. Ten patients could not perform pulmonary function because of either instability or non-cooperation.

Results: Indications for surgical fixation were as follows: ten patients required thoracotomy because of associated thoracic injuries; fifteen non-intubated patients had anterolateral flail chest; fifteen patients without pulmonary contusion presenting with impaired respiratory functions required early surgical stabilization.

A satisfactory stabilization of the chest wall was obtained in all surgically treated patients. There were statistically significant differences in PaO2 (62.2 ± 8.3 and 97.6 ± 6.4), PaCO2 (38.1 ± 9.3 and 32.4 ± 8.4) and SpO2 (89.2% ± 1.4 and 98.4 ± 1.6) with a P value <0.001, respectively.

Improvement of the pulmonary function test was significant in FVC (69.28 ± 5.9 and 78.55 ± 5.5), FEV1 (68.07 ± 4.7 and 78.97 ± 3.9) and PEF (72.68 ± 4.7 and 80.23 ± 4.1) with a P value 0.001. There was no 30-day and 3 month mortality for the surgically treated patients. The median intensive care unit stay was 4.5 days. Infectious complications occurred in 5% (2/40 patients).

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Peer review under responsibility of The Egyptian Society of Chest Diseases and Tuberculosis.

http://dx.doi.org/10.1016/j.ejcdt.2014.10.005
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Conclusion: Surgical stabilization of flail chest with metallic plates is a safe and effective therapy in properly selected patients. These patients had a significantly smoother course during the intensive care unit and hospital stays, had improved respiratory functions and decreased rate of complications.

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Introduction

Trauma mostly affect young males in the productive period of age [1], and even more younger patients from the Middle East region [2] compared to studies from developed countries. Blunt trauma is more frequent than penetrating trauma in many series [3]. Traffic accidents are the leading cause of chest trauma in most cases [4]. However violence was the leading cause in others [1].

Rib fractures were the most common type of injury due to blunt trauma. The number of fractured ribs indicates the severity of trauma and closely correlates with morbidity and mortality [5]. Additional rib fracture could increase the risk of mortality, pneumonia, Acute Respiratory Distress. Flail chest injuries carried bad prognosis before the recent medical interventions. In the past, management of these severe thoracic injuries was mainly non-operative such as external strapping, patient positioning and traction by way of towel clips attached to the flail segment [6,7]. These techniques reduced paradoxical motion at the fracture site but often led to more serious complications due to prolonged recumbency.

Internal fixation techniques of flail chest appeared in the 1950s. At that time common surgical techniques included simple wire suture fixation and rush rod fixation of the flail segment [8,9]. In the late 1950s positive pressure ventilation was used as ‘internal splinting’ of flail segments [6]. This resulted in improved patient outcomes relative to early non-operative and operative fixation [6]. However, prolonged ventilation usually results in secondary chest infections and high mortality rates.

Primary internal fixation of severe flail chest injury is associated with generally improved results relative to nonsurgical historical techniques with low long-term morbidity and pain [10]. The indications for internal fixation of flail chest remain controversial because of a lack of adequate studies comparing operative and non-operative treatments. Surgical stabilization may provide an early restoration of chest wall contour and result in a significant reduction in the duration of ventilatory support. Long-term postoperative pulmonary function seems to be better preserved after surgical stabilization.

Materials and methods

The study was conducted from March 2011 through April 2012 at Qena University Hospital, South Valley University, Egypt. The study was approved by ethics medical committee of our faculty. Fifty patients were admitted to our hospital with chest trauma. Ten patients were excluded from the study on the following grounds: requiring endotracheal intubation immediately on admission due to severe respiratory distress, hemodynamic instability, encephalopathy, and emergency surgery following admission; non-cooperative patients unable to use face mask; severe acidosis; patients who could not perform pulmonary function test.

All participants or informants gave their written informed consent. Forty patients fulfilled the inclusion criteria which includes: (a) five or more rib fractures in a row, or three or more segmental (two fractures in one rib) rib fractures on plain chest X-ray or CT chest and confirmed by the presence of a flail segment; (b) patients with marked dyspnea with respiratory rate (RR) > 25 cycles/min; (c) oxygen saturation (SpO2) 90% or more while breathing 6 L oxygen/min (c) ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO2/FiO2) 300 while receiving FiO2 > 0.5 in the ICU.

All patients underwent surgical stabilization using metallic reconstruction plates 3.5 mm fixed with a cortical screw 3.5 mm. The plate was placed in position without thoracotomy except in the case of patients in whom thoracotomy was needed because of associated thoracic injuries. In cases of lateral flail chest the approach for surgical stabilization was a lateral or posterolateral incision. In cases of anterior or antero-lateral flail chest, a vertical midline incision was used.

All patients received general anesthesia induced without premedication by I.V. propofol 1%; 1–2 mg/kg and tracheal intubation was facilitated using I.V. atracurium 0.4–0.6 mg/kg and maintained with isoflurane. An arterial I.V. catheter in the right or left radial artery was inserted for withdrawal of blood samples for blood gas analysis. A central line was also inserted in the right or left internal jugular vein for fluid administration and CVP measurement.

We used lung protective ventilation strategy for these potentially acutely injured lung patients with a tidal volume of 4–6 ml/kg and a positive end expiratory pressure of 5–10 cm H2O, respiratory rate was adjusted to keep normocapnia, the inspiratory to expiratory time ratio (I:E ratio) was 1:2, peak inspiratory airway pressure was adjusted not to cause hypotension, Recruitment Maneuver (RM) was done (to expand atelectatic lung regions) just after intubation and just before extubation in the form of raising airway pressure to 35–40 cm H2O with sustained inflation of the lungs for 5–10 min with respiratory rate 6–7 cycles/min and I:E ratio 1:3 provided that the patient is hemodynamically stable.

Patients were monitored for non-invasive blood pressure, ECG, heart rate, end tidal CO2, SpO2, core and peripheral temperatures. We used conservative fluid therapy in the form of 10–12 ml/kg/h crystalloid solution or as appropriate for keeping normal hemodynamic state and guided by urine output and CVP. Pain control was done by inserting thoracic paravertebral catheter for one sided chest injury or thoracic epidural catheter for bilateral chest injuries. Local anesthetic used was 5 mL lidocaine 1% ± 25–75 μg of fentanyl at regular time intervals (nurse-controlled analgesia). Rescue doses of...
I.V. meperidine were given for breakthrough pain and pain assessment was done using the visual analog scale (VAS).

Spirometry was performed in all patients before and after 3 months following surgery. It was done in sitting position with a standard medical international research calibrated machine. The following spirometric parameters were determined: forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, and maximal mid expiratory flow rate (FEF 25–75%). Pulmonary function test was performed using a bellows spirometer (Jaeger, Master screen PFT) according to the standards of the American Thoracic Society [11]. For arterial blood gas analyses, blood was drawn pre-operatively from the radial artery while the patients were breathing room air. Arterial oxygen tension, pH, carbon dioxide tensions and bicarbonate were analyzed with a blood gas analyzer (Roche OMNI_C, Roche Diagnostics, Germany).

Patients were given repeated intercostals nerve blocks or high segmental epidural analgesia, air and blood were removed from the pleural cavity, fluids were restricted, furosemide diuretics were given, methylprednisolone sodium succinate was given for a 24-h period early on, colloid infusion was given to maintain an adequate plasma oncotic pressure, oxygen was given by mask, and intensive chest physiotherapy was started. All the patients were closely monitored.

Statistical analysis was performed using the statistical package SPSS (version 10.0; SPSS, Chicago, IL, USA). Data are given as mean ± SD. Comparisons of normally distributed variables were performed with paired or unpaired t tests as appropriate, whereas the Mann–Whitney and Wilcoxon tests were used for other variables. Comparisons of two or more proportions were conducted with the chi-square test; the Fisher exact test was used for small frequencies. All tests were two-tailed and statistical significance was accepted at a P value less than 0.05.

Results

Characteristics of forty patients (30 men, 10 women; mean age 42.6 years) with antero-lateral flail chest (>4 ribs fractured at ≥2 sites and fractures rib on one side plus sternum fractures was 8 patients 20%) are presented in Tables 1 and 2.

A comparison of patients before and after surgical stabilization as regards pulmonary function tests revealed a significant improvement in all spirometric parameters except FEV1/FVC ratio. Blood gas parameters showed a significant P value in oxygen saturation, partial arterial oxygen and CO2 (Tables 3 and 4).

We found a statistically significant difference in onset and time to first analgesic request between thoracic epidural and paravertebral block as the onset of block was faster in paravertebral block but its duration of analgesia was shorter than in epidural block (Table 5).

Discussion

The integrity of the chest wall structure is essential for the physiological respiratory function. Rib fractures and lung contusion are the common cause of acute respiratory insufficiency in chest trauma. Flail segments due to multiple rib fractures are responsible for increasing morbidity and mortality [12]. Mal-union of old fractures can lead to severe pain which can

### Table 1 Patient characteristics (data are presented as mean ± SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients (No. = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>42.6 ± 9.68</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>30 (75%)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>10 (25%)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66 ± 6</td>
</tr>
<tr>
<td>ASA status I/II</td>
<td>28/12</td>
</tr>
<tr>
<td>Duration of surgery (min)</td>
<td>130 ± 6</td>
</tr>
</tbody>
</table>

### Table 2 Injuries in patients treated by surgical stabilization.

<table>
<thead>
<tr>
<th>Fractures</th>
<th>Lateral</th>
<th>Antero-lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Multiple ribs on one side</td>
<td>26</td>
<td>65</td>
</tr>
<tr>
<td>Ribs on one sides + sternum</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>70</td>
</tr>
</tbody>
</table>

### Table 3 Spirometry of studied cases.

<table>
<thead>
<tr>
<th>Clinical parameters</th>
<th>Pre stabilization</th>
<th>Post stabilization</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>69.28 ± 5.9</td>
<td>78.55 ± 5.5</td>
<td>0.001</td>
</tr>
<tr>
<td>FEV1</td>
<td>68.07 ± 4.7</td>
<td>78.97 ± 3.9</td>
<td>0.001</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>98.25 ± 9.3</td>
<td>100.53 ± 6.9</td>
<td>0.08</td>
</tr>
<tr>
<td>PEF</td>
<td>72.68 ± 4.7</td>
<td>80.23 ± 4.1</td>
<td>0.001</td>
</tr>
</tbody>
</table>
be avoided by rib fixation [13]. Usage of titanium bars, plates and screws has increased recently in the fixation of rib fractures. Rib fixation is indicated in flail chest, concomitant lung lesion, serious alterations of the chest shape and persistent chronic pain that affects quality of life [14]. Continued mechanical ventilation could be an alternative for rib fixation in flail chest especially when there are other indications for mechanical ventilation [15].

Fixation of fractured ribs in our study is a method of great value in the treatment of severe flail chest. Surgical stabilization of the paradoxical movement of the chest wall can avoid the use of ventilator; reduce pain intensity and total analgesia requirement. There was an improvement in pulmonary function test parameters and blood gas parameters in the studied patients and this is consistent with many studies which clearly support the use of surgical stabilization in the management of isolated multiple non-flail and painful rib fractures for improving patient outcomes [16–18]. The interest and benefit was shown not only in terms of pain (VAS score: Table 5) and respiratory function (forced vital capacity, forced expiratory volume in 1 s), but also in improved quality of life and reduced social disability.

We evaluated two methods of post-operative pain control namely the thoracic paravertebral block for one sided chest injuries and the thoracic epidural block for bilateral chest injuries and sternotomies with the results in favor of the thoracic epidural as it provides better analgesia with the same effect on the hemodynamics of the patient as paravertebral block. Hence, the current evidence shows surgical stabilization to be safe and effective method in selected patients. These patients had improved respiratory functions with a significant smoother course during the intensive care unit and a decreased rate of complications.

**Conflict of interest**

There is no conflict of interest.

**References**


Surgical stabilization of flail chest must be accompanied by adequate physiotherapy to assist in raising the sputum. We have obtained stabilization of flail chest in all cases with great tolerance even in patients with severe anterior paradoxical movement.

The excessive mobility of the flail segment creates pain and this affects chest wall movement as a whole, producing shallow breathing and decreased ventilation. Also, coughing is very difficult because the expulsive force of the cough tends to be dissipated in the paradoxical motion of the chest wall.

Respiratory failure may result from the combination of the instability of chest wall and the effect of pulmonary contusion, which leads to an alteration in the alveolar ventilation perfusion ratio, shunting and hypoxemia. This in accordance with our study as restoring hypoxemia was obtained in all our patients after surgical stabilization [19,20].

Pneumothorax or hemothorax is frequently associated with flail chest, and it is important to rapidly recognize and treat associated injuries. Out of 40 patients in this study 32 had an associated pneumothorax or hemothorax. Evacuation of air and blood from the pleural space by placement of chest tubes is important in improving the respiratory status of these patients. This is in agreement with Thomas et al. and Freedland et al. [21,22].

**Conclusion**

Surgical stabilization of flail chest with metallic plates is a safe and effective method in selected patients. These patients had improved respiratory functions with a significant smoother course during the intensive care unit and a decreased rate of complications.

**Table 5** Quality of post-operative pain control.

<table>
<thead>
<tr>
<th></th>
<th>Thoracic paravertebral (n = 12)</th>
<th>Thoracic epidural (n = 13)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset of analgesia</td>
<td>45 ± 12 s</td>
<td>79 ± 22 s</td>
<td>0.001*</td>
</tr>
<tr>
<td>Time to first analgesic requirement</td>
<td>75 ± minutes</td>
<td>102 ± 20 min</td>
<td>0.001*</td>
</tr>
<tr>
<td>Breakthrough pain attacks in 24 h</td>
<td>3</td>
<td>2</td>
<td>0.976</td>
</tr>
<tr>
<td>VAS before spirometry</td>
<td>6.44 (5.77–6.91)</td>
<td>6.32 (5.61–6.88)</td>
<td>0.858</td>
</tr>
</tbody>
</table>
Respiratory functions in chest trauma treated with surgical stabilization