A comparative study of continuous positive airway pressure (CPAP) and intermittent positive pressure ventilation (IPPV) in patients with flail chest

M Gunduz, H Unlugenc, M Ozalevli, K Inanoglu, H Akman

Introduction: The role of non-invasive positive pressure ventilation delivered through a face mask in patients with flail chest is uncertain. We conducted a prospective, randomised study of continuous positive airway pressure (CPAP) given via a face mask to spontaneously breathing patients compared with intermittent positive pressure ventilation (IPPV) with endotracheal intubation (ETI) in 52 patients with flail chest who required mechanical ventilation.

Method: The 52 mechanically ventilated patients were randomly divided into two treatment groups: the ET group (n = 27) received mechanical ventilation with ETI, whereas patients in the CPAP group (n = 25) received CPAP via a face mask with patient controlled analgesia (PCA). Major complications, arterial blood gas levels, length of intensive care unit (ICU) stay and ICU survival rate were recorded.

Results: Nosocomial infection was diagnosed in 10 of 21 patients in the ET group, but only in 4 of 22 in the CPAP group (p = 0.001). Mean PO2 was significantly higher in the ET group in the first 2 days (p < 0.05). There were no significant differences in length of ICU stay between groups. Twenty CPAP patients survived, but only 14 of 21 intubated patients who received IPPV (p < 0.01).

Conclusion: Non-invasive CPAP with PCA led to lower mortality and a lower nosocomial infection rate, but similar oxygenation and length of ICU stay. The study supports the application of CPAP at least as a first line of treatment for flail chest caused by blunt thoracic trauma.

Materials and Methods
The ethics committee of the Faculty of Medicine of Cukurova University approved the study protocol, and each patient or their next of kin gave informed consent. In total, 52 patients, between the ages of 23 and 49 years, were admitted to our hospital with thoracic trauma between 1 January 2000, and 1 April 2004. Computed lung tomography (CLT) and plain chest x rays were taken routinely on admission, to evaluate patients with multiple traumas. Patients included in the study demonstrated: (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 CLT and confirmed by the presence of a flail segment—that is, paradoxical motion of the chest wall; (b) acute respiratory distress and severe dyspnoea with respiratory rate (RR) >25/min; (c) peripheral oxygen saturation (SpO2) <90% while breathing 10 l/min oxygen in the emergency room; and (c) a 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.

As mortality is associated with the degree and extent of accompanying injuries, all patients with flail chest were also assessed using the 25 point Thoracic Trauma Severity Score (TTSS) during the first 2 hours of admission (table 1).

Patients were excluded from the study on the following grounds: requiring ETI immediately on admission due to severe respiratory distress, haemodynamic instability, encephalopathy, respiratory failure caused by neurological disease or asthma attack; emergency surgery following admission; non-cooperative patients unable to use the face mask; coma or confusion; inability to protect the airway; severe acidosis,

Abbreviations: CLT, computed lung tomography; CPAP, continuous positive airway pressure; ETI, endotracheal intubation; ETMV, endotracheal intubation and mechanical ventilation; ICU, intensive care unit; IPPV, intermittent positive pressure ventilation; NPPV, non-invasive positive pressure ventilation; PCA, patient controlled analgesia; PEEP, positive end expiratory pressure; RR, respiratory rate; TTSS, Thoracic Trauma Severity Score
significant co-morbidity; vomiting; obstructed bowel; or haemodynamic instability.

Of the 52 patients, 43 (83%), having a TTSS between 5 and 15 were consecutively randomised to one of two ventilation treatment groups: the ET group (n = 21) received mechanical ventilation with ETI, and the CPAP group (n = 22) received CPAP via a face mask. The protocol allowed for CPAP patients to be intubated if symptoms or signs of respiratory distress continued or progressed (respiratory rate (RR)>25 breaths/min; SpO2 <90% while breathing 10 l/min oxygen and PaO2/FiO2 ≤200 while receiving FiO2 = 1.

Mechanical ventilation

Following ETI, IPPV with positive end expiratory pressure (PEEP) (50–100 mmH2O) was controlled with a tidal volume of 6–10 ml/kg, RR 10 l/min, to produce an end tidal carbon dioxide partial pressure in the range of 4.2–5 kPa; hypercapnia was not allowed. Peak inspiratory pressure was limited to 200–300 mmH2O. End expiratory pressure was increased in increments of 20–30 mmH2O up to 100 mmH2O until the required FiO2 was ≤0.6. Mechanical ventilation was administered with a Drager Evita 4 ventilator.

Following improvement in the clinical condition and blood gas and the ventilatory parameters (RR, SpO2, gas exchange values), when spontaneous breathing reappeared, ventilator settings were changed to intermittent mandatory ventilation (rate 4–7 breaths/min) for weaning from mechanical ventilation. Pressure support (140 to 200 mmH2O) was adjusted to achieve a spontaneous tidal volume of 8 to 10 ml/kg/min and a respiratory rate of <25 breaths/min, with accessory muscle activity absent. All patients were weaned from the ventilator by reducing the level of pressure support by 40 mmH2O twice and then decreasing the ventilatory rate by two breaths/min at 2 hour intervals, as tolerated. Patients who tolerated an intermittent mandatory ventilation rate of 0.5 breaths/min, a pressure support level of 80 mmH2O, and an FiO2 of ≤0.5 then underwent a 2 hour T piece trial, followed by extubation if respiratory rate remained <25 breaths/min and PaO2 >75 mm Hg.

As the clinical condition and blood gas and the ventilatory parameters (RR, SpO2, gas exchange values) improved, ventilation support was tapered off by progressively reducing the number of daily trials, or was stopped if the improvement remained stable (SpO2 >90%, RR <25 breaths/min).

Continuous positive pressure ventilation

Patients in the CPAP group were instructed in the use of the facemask, through which CPAP was delivered by a Drager Evita 4 ventilator. CPAP was increased in increments of 20–30 mmH2O repeatedly up to 80–150 mmH2O until the FiO2 requirement was ≤0.6. The CPAP level was adjusted on the basis of continuous oximetry and measurements of arterial blood gases.

CPAP was stopped if the respiratory rate was <25 breaths/ min; PaO2 >75 mm Hg with a FiO2 of 0.5, without ventilatory support, and if PaO2/FiO2 exceeded 200 for 24 hours. Therapy was considered successful if intubation was avoided and the patient could be transferred out of the ICU. Patients received CPAP for at least 6 hours each day, depending on their ability to tolerate it. Each day, however, patients were allowed to breathe spontaneously, with oxygen but without assistance, for 2 hours. The overall duration of CPAP ventilation was determined on the basis of clinical criteria and arterial blood gas levels; in each case, the decision was made by the physician in charge.

Monitoring

Monitoring of patients in the ICU included lead II electrocardiogram, pulse oximetry, invasive blood pressure, central venous pressure, end tidal CO2 pressure, core temperature, urine output, and ventilator settings (including tidal volume, respiratory rate, lung compliance, airway resistance, peak inspiratory pressure). Ventilator settings were adjusted on the basis of continuous pulse oximetry and measurements of arterial blood gases.

Sedation and analgesia

In the ET group patients, ETI was facilitated by an intravenous bolus of vecuronium (0.1–0.2 mg/kg). A propofol (2–3 mg/kg/h) plus fentanyl (0.002 pg/kg/min) combination was infused continuously. Thereafter no neuromuscular blocking agent was used.

In the CPAP group, patients were sedated with an intravenous midazolam infusion (0.015 mg/kg/h) and received morphine sulphate patient controlled analgesia. When the patient was breathing spontaneously on admission, and stable vital signs and breathing were maintained under oxygen therapy, a standardised (0.05 mg/kg) loading dose of morphine was given. Patients were then allowed to use bolus doses of morphine (0.0125 mg/kg every 30 minutes without time limit) with a PCA device (Abbott Pain Management Provider, class II, type CF; Abbott, Chicago, IL, USA). Verbal rating scores were measured at 6 hour intervals for 7 days and recorded daily as means (SD), and morphine consumption was recorded daily for 7 days in the CPAP group. Additionally, ondansetron 4 mg intravenously was prescribed every 12 hours on request as the rescue antiemetic therapy. In all patients, chest physiotherapy (percussion and vibration) was initiated following pain control.

Measurements

All patients with flail chest were assessed on admission using the APACHE III scoring system, and daily thereafter. TTSS and blood count were obtained at the start of the study and chest x rays daily.10 Patients were monitored for the development of infections or other complications. Those

<table>
<thead>
<tr>
<th>Grade</th>
<th>PaO2/FiO2</th>
<th>Rib fracture</th>
<th>Contusion</th>
<th>Pleural involvement</th>
<th>Age</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&gt;400</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>&lt;30</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>300–400</td>
<td>1–3</td>
<td>1 lobe, unilateral</td>
<td>PT</td>
<td>30–41</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>200–300</td>
<td>3–6</td>
<td>1 lobe bilateral or 2 lobes unilateral</td>
<td>H/H or HT</td>
<td>42–54</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>150–200</td>
<td>&gt;3</td>
<td>&lt;2 lobe bilateral</td>
<td>H/H or HT</td>
<td>55–70</td>
<td>3</td>
</tr>
<tr>
<td>IV</td>
<td>&lt;150</td>
<td>Flail chest</td>
<td>&lt;2 lobe bilateral</td>
<td>TPT</td>
<td>&gt;70</td>
<td>5</td>
</tr>
</tbody>
</table>

PT, pneumothorax; HT, haemothorax; HPT, haemopneumothorax; TPT, tension pneumothorax. For calculation of the total score, all categories were summed. A minimum value of 0 points and a maximum value of 25 points can be achieved.
developing manifestations of pneumonia, including radiographic evidence of persistent pulmonary infiltrates, hyperthermia or hypothermia, purulent tracheobronchial secretions, a high white cell count, and worsening of pulmonary gas exchange, underwent bronchoscopy with bronchoalveolar lavage. Pneumonia was diagnosed when at least 100 000 colony forming units of bacteria/ml were measured in bronchoalveolar lavage fluids.

TTSS was calculated according to Pape and Remmers. Arterial blood gas levels were determined at baseline and at 2 h intervals thereafter for 7 days. Finally, length of ICU stay, ICU survival rate, and the development of major complications associated with IPPV (pneumothorax, nosocomial infections assessed by positive blood culture) or CPAP (pneumothorax, gastric distension) were also recorded.

End points
In this study, the primary end point was the ICU mortality. Secondary end points included complications associated with IPPV or CPAP as above, oxygenation, and length of ICU stay.

Statistical analysis
Statistical analyses were performed using the statistical package SPSS (version 10.0; SPSS, Chicago, IL, USA). Results are given as means (SD). Demographic and physiological characteristics of the two groups were compared with Student’s t test. Categorical data were analysed by using the χ² test. Statistical significance was set at p<0.05.

RESULTS
Of the original 52 patients, nine were excluded from the study: seven required emergency endotracheal intubation because of severe respiratory distress (RR >25 breaths/min, SpO₂ <90% while breathing 10 l/min oxygen, and PaO₂/FiO₂ <200 while receiving an FiO₂ ≥1), and deterioration in neurological status (Glasgow Coma Scale score of 8 or less) immediately after admission to the intensive care unit, while the other two patients were haemodynamically unstable. The remaining 43 patients were enrolled (n = 21 in the ET group and n = 22 in the CPAP group) in this study.

There were no differences in age, sex, and weight between the two groups. APACHE III scores were similar between two groups. Age (years) 38 (10) 40 (9) APACHE III 30 (5) 32 (7) Weight (kg) 71 (5) 70 (3) pO₂ (mm Hg) 78 (15) 106 (40) pCO₂ (mm Hg) 39 (3) 32 (6) pO₂/FiO₂ 200 (50) 190 (40) Length of ICU stay (day) 16 (3) 15 (4) Chest wall injuries (n)(%) 2–3 ribs 8 (38%) 7 (31.8%) c–3 ribs 13 (62%) 15 (68.2%) HT 4 (19%) 4 (19%) PT 9 (42.8%) 11 (50%) HPT 3 (14.2%) 2 (9.1%) TPT 1 (4.7%) 0 (0)

Figure 1 The PO₂ in both groups during treatment. In the first two days, PO₂ was significantly greater in the ET group (squares). There were no differences in PCO₂ between the two groups.

Table 2 Clinical and physiological characteristics on admission to the intensive care unit

<table>
<thead>
<tr>
<th>Variable</th>
<th>ET group (n = 21)</th>
<th>CPAP group (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M/F)</td>
<td>7/14</td>
<td>9/13</td>
</tr>
<tr>
<td>Age (years)</td>
<td>38 (10)</td>
<td>40 (9)</td>
</tr>
<tr>
<td>APACHE III</td>
<td>30 (5)</td>
<td>32 (7)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71 (5)</td>
<td>70 (3)</td>
</tr>
<tr>
<td>pO₂ (mmHg)</td>
<td>78 (15)</td>
<td>106 (40)</td>
</tr>
<tr>
<td>pCO₂ (mmHg)</td>
<td>39 (3)</td>
<td>32 (6)</td>
</tr>
<tr>
<td>pO₂/FiO₂</td>
<td>200 (50)</td>
<td>190 (40)</td>
</tr>
<tr>
<td>Length of ICU stay</td>
<td>16 (3)</td>
<td>15 (4)</td>
</tr>
</tbody>
</table>

Chest wall injuries (n)(%)

2–3 ribs 8 (38%) 7 (31.8%)
c–3 ribs 13 (62%) 15 (68.2%)
HT 4 (19%) 4 (19%)
PT 9 (42.8%) 11 (50%)
HPT 3 (14.2%) 2 (9.1%)
TPT 1 (4.7%) 0 (0)

DISCUSSION
This is the first study to evaluate use of CPAP for the treatment of flail chest caused by blunt thoracic trauma. Many other therapeutic approaches, including surgical, have been previously reported. In the past, especially in cases of severe lung contusion and prolonged mechanical ventilation, surgery has been recommended for external stabilisation of the chest wall. The first modern approach to flail chest...
was that of Avery et al, who reported that continued mechanical ventilation was required to achieve the internal stabilisation of the chest wall.14 Cullen et al recommended IMV for stabilisation in the treatment of flail chest injury.15 Antonelli et al, however, reported that the mechanical ventilation procedure should be more selective and showed that application of the two different ventilatory techniques (invasive with non-invasive ventilatory treatment) in hypoxaemic respiratory failure resulted in similar short term improvements in arterial blood gases, while non-invasive mechanical ventilation was associated with fewer serious complications and a shorter stay in the ICU compared with conventional mechanical ventilation.16

The effectiveness of non-invasive positive pressure ventilation (NPPV) in decreasing mortality and endotracheal intubation rates in patients with hypoxaemic respiratory failure has been demonstrated in meta-analyses,17 while the data to support the use of NPPV in these patients with hypoxaemic respiratory failure is inconclusive at present. Several prospective randomised trials have demonstrated that non-invasive ventilation reduces both the need for ETI and the complication rate, and also shortens the length of ICU stay, and improves survival in patients with chronic obstructive pulmonary disease.18 19 A recent study evaluated whether facemask CPAP is physiologically beneficial, and reduces the need for endotracheal intubation and mechanical ventilation (ETMV) in patients with acute lung injury.20

Despite an early favourable physiological response to CPAP in terms of comfort and oxygenation, there were no differences in the need for ETV, in hospital mortality, or length of ICU stay. However, in a retrospective study, Tanaka et al reported that CPAP with pressure support during spontaneous breathing reduced both complications and the duration of mechanical ventilation.21 One randomised controlled trial22 and two case series23 24 support the use of CPAP and regional analgesia were compared with immediate intubation followed by IPPV with PEEP. CPAP resulted in 7.3), fewer mean ICU days (14.6). Kasai et al25 reported that mechanical ventilation of more than 48 hours’ duration is the most important risk factor for ventilator related complications. Our pneumoaria in the ET group was 48% (n = 10), but only 9% (n = 2) in the CPAP group (p < 0.001), which is probably related to the lower nosocomial infection rate with CPAP. These findings agree with those of uncontrolled studies using CPAP or IPPV,26 27 however, in a multiple logistic regression model, failure to improve with mask CPAP was an independent predictor of death.28

CPAP was less effective in improving PO2 in the first 2 days than IPPV, possibly because of difficulty in adaptation to the CPAP mask. Thereafter, PO2 levels in the CPAP and IPPV groups were similar. Poor oxygenation in patients receiving CPAP is thought to be related to severe pain, analgesia being an important part of the treatment of flail chest. However, as it was difficult for patients with flail chest injury on admission to assume the lateral position for regional analgesic techniques, PCA is an acceptable alternative.

In conclusion, non-invasive CPAP with PCA led to lower mortality and nosocomial infection rate. Oxygenation and length of ICU stay were similar. The findings suggest that CPAP should be tried as a first step in the treatment of flail chest caused by blunt thoracic trauma. Further studies and larger groups are needed to draw firm conclusions and to establish the importance of this protocol in the treatment of flail chest injury.

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### REFERENCES

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