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ORIGINAL ARTICLE

Continuous positive airway pressure ventilation versus Bi-level positive airway pressure ventilation in patients with blunt chest trauma

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Abstract   *Introduction:* The use of positive pressure ventilation has decreased the overall morbidity and mortality associated with blunt chest trauma, but invasive mechanical ventilation (IMV) is associated with many complications. The role of noninvasive ventilation (NIV) for the management of patients with blunt chest trauma has not been well established. The aim of this study was to compare the efficiency of CPAP versus BiPAP in avoiding IMV.

Patients and method: This study was carried out in the period between April 2011 and April 2103, on 40 patients admitted to ICU with blunt chest trauma with acute respiratory distress that had deteriorated despite aggressive medical management. Patients were randomly assigned to receive either continuous positive airway pressure ventilation (CPAP) (group 1) $n = 15$, Bi-level positive airway pressure ventilation (BiPAP) (group 2) $n = 15$ or IMV (group 3) $n = 10$.

Results: Improvement in gas exchange and relieve of respiratory distress was noticed in the three studied groups after the start of assisted ventilation. Four patients in group 1 (26.7%) and three patients in group 2 (20%) required endotracheal intubation. There was no significant difference in the length of stay in ICU between the three groups (10 ± 5 days in group 1, 11 ± 4 in group 2 and 10 ± 6 in group 3. Pneumonia developed in one patient in group 1 (6.6%) and in 2 patients in group 2 (13.3%) and in 3 patients in group 3 (30.3%). Pneumothorax developed in one patient in group 1 (6.6%) and in no patients in group 2 (0%) and in one patient in group 3 (10%). As regards mortality no mortalities were observed in groups 1 and 2 but one patient in group 3 (10%) died.

Conclusion: Both CPAP and BiPAP are safe and efficient techniques in managing respiratory failure and reducing the incidence of intubation in patients with blunt chest trauma.

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Introduction

Chest trauma is one important factor for total morbidity and mortality in traumatized emergency patients. The lethality of isolated chest traumas is about 5–8%. Up to 25% of all deaths caused by trauma are related to chest injuries [1], and mortality dramatically increases as a function of increased chest trauma force [2].

Chest injuries often occur in combination with other severe injuries, such as extremity, head, brain and abdominal injuries [1]. The impact of a blunt trauma is typically conducted to many different intrathoracic structures; hence nearly all organs of the thoracic cavity can be involved in chest trauma. The most common types of damage that result from chest trauma include injuries to the ribs, lung contusion, hematoma of the chest wall, pleural effusion, pneumothorax and haemothorax [3].

Pathophysiological aspects

Respiratory impairment: damage to the osseous structure of the thorax by rib and sternum fractures destabilizes the rib cage and impairs spontaneous breathing mechanics substantially; this condition is amplified by pain, which further reduces breathing function. Direct traumatic damage to the lung leads to an extravasation of protein-rich fluid with an altered surfactant composition [4]. Disturbance of diffusion, the reduction of compliance and functional residual capacity, ventilation–perfusion mismatch and intrapulmonary shunt develop with subsequent reduced oxygenation and elevated $PaCO_2$ levels [5,6]. After severe chest trauma, intrapulmonary shunting can also be caused by a disruption of pulmonary capillaries and extravasation into the alveolar spaces. Aspiration of blood and/or gastric contents, fat embolism to the lung due to long bone fractures and systemic inflammatory response syndrome may additionally exacerbate respiratory deficits and may lead to acute respiratory distress syndrome (ARDS) [7].

Cardiovascular impairment: a reduction in normal intraventricular filling by tension pneumothorax, pericardial tamponade or massive hemorrhage may result in a life-threatening reduction in cardiac output. Moreover, intracardiac structural damage or heart contusions with concomitant arrhythmias are additional contributors to reduced cardiac output [6].

Management of patients with blunt chest trauma focuses on interventions such as the stabilization of fractures, pulmonary toilet, effective physiotherapy, and early and adequate pain control [8,9]. These patients are at high risk for developing respiratory failure [10] with reports of up to 20% of patients with blunt chest trauma developing acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) [8]. Intubation rates range from 23% to 75% and depend on the severity of the trauma, the degree of the underlying lung disease, and the intensity of initial management and monitoring [8,11]. The use of positive pressure ventilation has decreased the overall morbidity and mortality associated with blunt chest trauma, but endotracheal intubation and mechanical ventilation are associated with a high risk of nosocomial pneumonia and prolonged mechanical ventilation [12].The role of noninvasive ventilation (NIV) for the management of patients with blunt chest trauma has not been well established [13]. The aim of this study was to compare NIV (CPAP and BiPAP) with invasive mechanical ventilation (IMV) in management of patients with blunt chest trauma and to compare efficiency of CPAP versus BiPAP in avoiding intubation and IMV.

Patients and method

This clinical study was carried out on 40 patients admitted to intensive care unit with blunt chest trauma (either isolated chest trauma or as a part of polytrauma) in the period between April 2011 and April 2013. The inclusion criteria were acute respiratory distress that had deteriorated despite aggressive medical management, including severe dyspnea at rest, a respiratory rate greater than 35 breaths per minute; and the partial pressure of arterial oxygen (PaO_2) less 60 mmHg while the patient was breathing oxygen through a Venturi mask with FiO_2 up to 60%; and active contraction of the accessory muscles of respiration or paradoxical abdominal motion.

Patients with any of the following were excluded: tracheal intubation indicated for any other reason, contraindication for non-invasive ventilation (active gastro-intestinal hemorrhage, low level of consciousness, multiorgan failure, airway control problems, hemodynamic instability), traumatic brain injury, facial trauma, skull base fracture, orbit base fracture, cervical injury with specific treatment contraindicating a facial mask [10].

All patients were subjected to

- Complete medical history.
- Clinical examination.
- Laboratory investigations (renal and hepatic function tests, serum electrolytes, blood sugar ,complete blood count, arterial blood gas analysis, and microbiological investigations when pneumonia was suspected).
- Radiological investigations (plain X ray and computed tomography on the chest for all patients and for other body parts as indicated).
- The Injury Severity Scale (ISS): was evaluated as the measure of anatomic injury for six body regions: (1) the head-neck, (2) the face, (3) the thorax, (4) the abdomen-pelvis, (5) the extremities and (6) the external. The ISS was calculated as the sum of the squares of the highest abbreviated injury scale grade in each of the three most severely injured body regions [14].
- Simplified acute physiologic score (SAPS) was calculated, this score takes into account 14 variables (age, heart rate, systolic blood pressure, body temperature, respiratory rate or need for ventilatory support, urinary output, white-cell count, hematocrit, Glasgow coma score, and serum glucose, potassium, sodium, bicarbonate, and urea nitrogen concentrations). A range of 0–4 is assigned for each variable (range of possible scores, 0–56). Higher scores indicate a higher risk of death [15].

Patients were randomized to receive CPAP (group 1) $n = 15$ (11 males, 4 females with mean age 31.8 ± 13.8), BiPAP (group 2) $n = 15$ (10 males, 5 females with mean age 31.8 ± 13.1), and patients who met inclusion criteria but did not show cooperation received IMV (group 3) $n = 10$ (7 males, 3 females with mean age 30.6 ± 12.7).

Methods of mechanical ventilation

BiPAP

The patients were connected to a ventilator (BiPAP Vision, Respironics Inc., Murrysville, Pa., USA). Initial ventilator settings were: inspiratory positive airway pressure (IPAP) was set at 8 cm H_2O, positive end-expiratory pressure at 5 cm H_2O and FiO_2 at 100%. Then, IPAP and EPAP were titrated to reach the clinical targets of respiratory rate (RR) less than 25 breaths/min and tidal volume greater than or equal to 8 mL/kg for IPAP and Spo_2 greater than or equal to 90% on FiO_2 < 60% for EPAP titration, while minimizing patients' intolerance and leaks around the mask [10].

NIV in the CPAP mode

Using Tranquility, Healthdyne, USA, pressure was initially set to 3 cm H_2O for 5 min then titrated according to patient's tolerance and comfort and clinical monitoring [10].

Conventional invasive ventilation

Patients were intubated and connected to ventilators (Puritan Bennett 7200 (Puritan Bennett, Overland Park, Kans.) and the Servo 900 C (Siemens Elema, Uppsala, Sweden). Strategy of protective mechanical ventilation was applied by limiting peak lung distension and preventing end-expiratory collapse with low tidal volumes (Tidal volumes of 6 mL/kg of predicted body weight), limited plateau pressure < 30 cm H_2O) and optimal PEEP to optimize oxygenation [10].

The criteria for NIV failure included: failure to maintain a PaO_2 above 60 mmHg with FiO_2 less than 0.6, a greater than 10-mmHg increase in $PaCO_2$ from baseline, evidence for exhaustion, such as active contraction of the accessory muscles with thoracic-abdominal paradoxical movement or respiratory alternans, hemodynamic instability and respiratory or cardiac arrest. Improvement in gas exchange was evaluated within 1 h after study entry (initial improvement) and over time (sustained improvement). When patients tolerated $FiO_2 \leqslant 0.5$ with EPAP $\leqslant 8$ cm H_2O and IPAP $\leqslant 14$ cm H_2O for > 6 consecutive hours, withdrawal from NIV was attempted daily in 30-min spontaneous breathing trials. Predefined criteria for failure of the spontaneous breathing trial were: Spo_2 < 90% or PaO_2 < 60 mmHg with FiO_2 > 0.6, RR > 30 breaths/min, or activation of the accessory respiratory muscles [10].

Statistical analysis

Results are given as means ± SD. Demographic and physiologic characteristics of the two groups were compared with use of Student's t-test for continuous data and chi-square test for categorical data. The SPSS package (SPSS, Chicago) was used for all analyses. P < 0.05 was considered as statistically significant.

Results

This study was carried out between April 2011 and April 2013 , on 40 patients admitted to the intensive care unit (ICU) due to blunt chest trauma (either isolated chest trauma or as a part of polytrauma) .The patients were randomly assigned to receive either CPAP (group 1) $n = 15$ (11 male, 4 females with mean age 31.8 ± 13.8), BiPAP (group 2) $n = 15$ (10 male, 5 females with mean age 31.8 ± 13.1), and patients who met inclusion criteria but did not show cooperation received IPPV(group 3) $n = 10$ (7 male, 3 females with mean age 30.6 ± 12.7).

Table 1 shows the base-line characteristics of the studied three patient groups: the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO_2:FiO_2), arterial Ph., partial pressure of carbon dioxide ($PaCO_2$), respiratory rate(RR), heart rate(HR), injury severity score (ISS) and simplified acute physiological score (SAPS), all showed non-significant differences.

Fig. 1 shows improvement of the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO_2:FiO_2) after 1 h of mechanical ventilation in the three groups.

After one hour of mechanical ventilation there was a decrease in $PaCO_2$ and the RR and HR (Figs. 2–4) from the base line in the three groups.

Table 2 shows a significant increase in mean PaO_2:FiO_2 and decrease in RR, and HR after MV in the three groups.

Table 3 shows non-significant difference in mean change of PaO_2:FiO_2 among the three groups.

As regards the patient outcomes in the three studied groups as shown in (Table 4): four patients in group 1 (26.7%) and three patients in group 2 (20%) required endotracheal intubation with no significant difference P > .05. The reasons for intubation in these patient groups are shown in Table 5, the failure of noninvasive ventilation to maintain the PaO_2 above

Table 1 Baseline characteristics of the studied patient groups.

	Group 1 ($N = 15$)	Group 2 ($N = 15$)	Group 3 ($N = 10$)	P
Age (years)	31.8 ± 13.8	31.8 ± 13.1	30.6 ± 12.7	0.97
Male/female	11:4	10:5	7:3	0.92
Arterial Ph.	7.4 ± 0.066	7.4 ± 0.065	7.4 ± 0.07	0.93
$PaCO_2$ (mmHg)	39.6 ± 8.09	39.6 ± 7.7	38.8 ± 7.9	0.95
PaO_2:FiO_2	216.9 ± 32.9	217.1 ± 38.2	221.7 ± 33.2	0.93
RR (breath/min)	34.2 ± 2.37	34.3 ± 2.34	34.2 ± 2.1	0.99
HR (beat/min)	119 ± 2.4	118.8 ± 2.4	118.1 ± 2	0.63
Mean blood pressure (mmHg)	75 ± 6.3	76.2 ± 5.2	74.8 ± 4.7	0.9
ISS	42.9 ± 2.1	42.3 ± 1.4	43.2 ± 2.2	0.51
SAPS	15.6 ± 1.3	15.4 ± 1.1	15.2 ± 1.4	0.82

ISS: injury severity score.
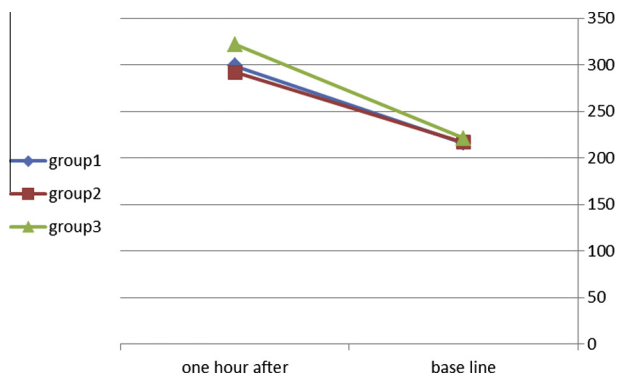SAPS: simplified acute physiological score.

Figure 1 Ratio of partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO_2:FiO_2) at the base line and after 1 h of mechanical ventilation in the studied patient groups.
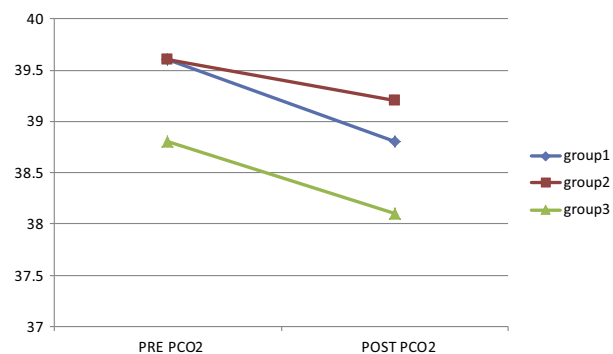

Figure 2 Partial pressure of arterial carbon dioxide at the base line and after 1 h of mechanical ventilation in the studied patient groups.
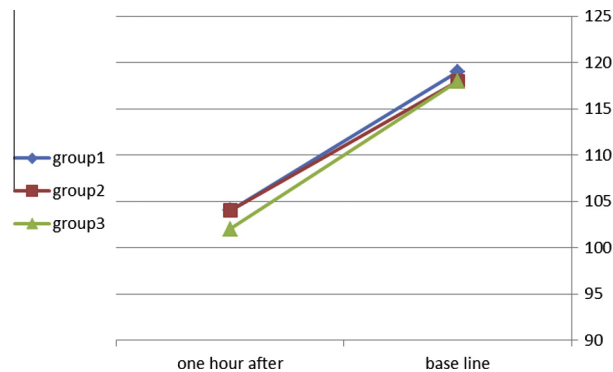

Figure 3 Heart rate at the base line and after 1 h of mechanical ventilation in the studied patient groups.

60 mmHg (2 patients in group 1 and 2 patients in group 2, inability to correct dyspnea (one patient in group 1 and one patient in group 2), and hemodynamic instability (one patient in group 1).

There was no significant difference in the length of stay in the intensive care unit between the three groups (10 ± 5 days in group 1, 11 ± 4 in group 2 and 10 ± 6 in group 3) ($p = .8$).

Pneumonia developed in one patient in group 1 (6.6%) and in 2 patients in group 2 (13.3%) and in 3 patients in group 3 (30.3%).
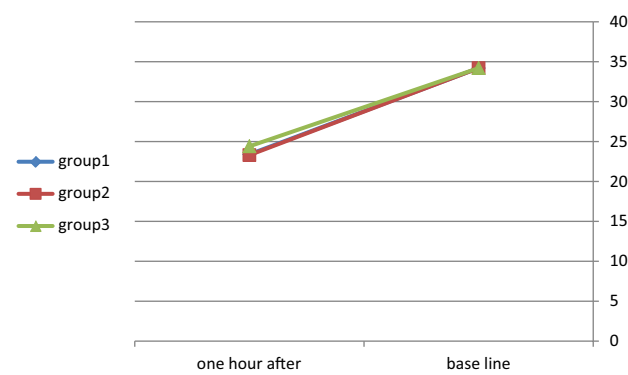

Figure 4 Respiratory rate at the base line and after 1 h of mechanical ventilation in the studied patient groups.

Pneumothorax developed in one patient in group 1 (6.6%) and in no patients in group 2 (0%) and in one patient in group 3 (10%), with no significant difference between the three groups $P = .08$. As regards mortality one patient in group 3 died due to septic shock while there was no mortality in groups 1 and 2.

Discussion

A general optimal ventilatory strategy that is applicable to all patients after chest trauma does not exist. Understanding the pathophysiology of individual patients, with their specific kinds of lung damage after trauma, and accordingly implementing ventilation strategies may support the respiratory system and prevent further ventilator-associated lung injury (VALI). VALI has the potential to induce acute lung injury (ALI) or ARDS, as well as multiple organ failure [16,17]. Clinicians can select between two different strategies to apply mechanical ventilation: noninvasive ventilation and invasive mechanical ventilation. The advantages of noninvasive ventilation are the avoidance of complications related to endotracheal intubation, avoidance of sedation and paralysis and the easy removal and reinstitution of NIV, if needed. However, tracheal intubation should never be delayed if the respiratory status worsens under noninvasive ventilation [12].

The role of noninvasive ventilation for the management of patients with blunt chest trauma has not been well established [12]. Although the safety of NIV has been assessed in a number of observational studies in patients with blunt thoracic injuries [8,13], the evidence regarding the use of NIV in this setting is inconsistent [12]. The aim of this study was to compare noninvasive ventilation (CPAP and BiPAP) with invasive mechanical ventilation in management of patients with blunt chest trauma and compare the efficiency of CPAP versus BiPAP in avoiding intubation and IMV.

This study included 40 patients: 15 patients received CPAP, 15 patients received BiPAP and 10 patients were intubated and received conventional invasive mechanical ventilation .The patients who received invasive mechanical ventilation, met the criteria of NIV but they were uncooperative, this together with the similarity of ISS and SAPS between the present study groups made comparison possible as in some previous studies [18,19] which compared invasive with noninvasive ventilation and there were significant differences between patient groups

Table 2 Change in mean PaO$_2$:FiO$_2$, RR, HR before and after MV in each group.

		Before	After	Paired t	P
Group 1	Mean PaO$_2$:FiO$_2$	216.9 ± 32.9	299 ± 50.2	−5.9	0.00
	RR	34.2 ± 2.3	23.4 ± 1.8	17.2	0.00
	HR	119 ± 2.4	104.6 ± 4.7	14.4	0.00
Group 2	Mean PaO$_2$:FiO$_2$	217.1 ± 38.2	292 ± 58.9	−4.5	0.00
	RR	34.3 ± 2.3	23.3 ± 2.5	21.7	0.00
	HR	118.8 ± 2.4	104 ± 4.3	20.2	0.00
Group 3	Mean PaO$_2$:FiO$_2$	221.7 ± 33.2	322 ± 23.4	−11.7	0.00
	RR	34.2 ± 2.1	24.4 ± 2.4	25.2	0.00
	HR	118.1 ± 2	102.1 ± 3.1	21	0.00

Table 3 Mean PaO$_2$:FiO$_2$ change among the studied groups.

	Mean PaO$_2$:FiO$_2$ change	F	P
Group 1	86.87 ± 42.8	0.58	0.5
Group 2	82.0 ± 48.1		
Group 3	100.3 ± 27.07		

as regards the ISS and the severity of underlying condition as the invasive group involved patients with absolute indication of IMV like coma and hemodynamic instability.

In this study CPAP and BiPAP like conventional invasive mechanical ventilation were efficient in improving gas exchange and relieving respiratory distress (Figs. 1–4).

Four patients in the CPAP-ventilation group (26.7%) and three patients in the BiPAP group (20%) required endotracheal intubation, so the success rate to avoid intubation was 73.3% in the CPAP group and 80% in the BiPAP group (Table 4), this agrees with the finding of Duggal et al. 2013 [20]. The reasons for intubation (Table 5) were failure of non-invasive ventilation to maintain the PaO$_2$ above 60 mmHg (four patients), its inability to correct dyspnea (two patients) and hemo-dynamic instability (one patient).

Nosocomial pneumonia and pneumo-thorax were the most commonly reported adverse events associated with NIV use in previous studies, and the rate ranged from 8% to 13.8% [20,21]. The rate of pneumothorax reported in two studies

ranged from 5.5% to 24% [21,22]. In this study pneumonia developed in one patient in group 1 (6.6%) and in 2 patients in group 2 (13.3%) and in 3 patients in group 3 (30.3%) and pneumothorax developed in one patient in group 1 (6.6%) and in no patients in group 2 (0%) and in one patient in group 3 (10%), with no significant difference between the three groups $P = .08$.

This study showed non-significant differences as regards the length of stay in the intensive care unit between the CPAP, BiPAP and the conventional invasive ventilation groups (10 ± 5, 11 ± 4 days and. 10 ± 6) (Table 4), this finding did not agree with that of a previous study which showed that the length of stay in ICU was lower in patients with NIV use compared to invasive mechanical ventilation [12]. This can be explained by that in this previous study the conventional invasive patient group included patients with more severe underlying condition who were excluded from the present study patient group on invasive ventilation (like comatosed patients).

In this study no patients in the noninvasive-ventilation group and one patient in the conventional-ventilation group died in the intensive care unit. The observed low mortality in these study patients may be explained by that patients with severe central nervous system damage and a low Glasgow coma scale score were excluded; studies have shown that central nervous system damage is an independent predictor of mortality in polytrauma patients [20].

Table 4 Outcome of MV in the studied patient groups.

Outcome	Group 1	Group 2	Group 3	Sig.
Nosocomial pneumonia	1 (6.6%)	2 (13.3%)	3 (30.3%)	0.000008
Development of pneumothorax	1 (6.6%	0 (0%)	1 (10%)	0.08
Need for invasive ventilation (failure of NIV)	4 (26.7%)	3 (20%)		0.3
Length of hospital stay(dayes)	10 ± 5	11 ± 4	10 ± 6	0.8
Mortality	0 (0.0%)	0 (0.0%)	1 (10%)	0.00004

Table 5 Reasons for the NIV failure.

Reason of failure	Group 1 (4/15)	Group 2 (3/15)	P
Failure to maintain the PaO$_2$ above 60 mmHg	2 Patients	2 Patients	0.11
Inability to correct dyspnea	1 Patient	1 Patient	0.2
Hemodynamic instability.	1 Patient	0	0.02
Total failure	4	3	0.28

Conclusion

Both CPAP and BiPAP are safe and efficient techniques in managing respiratory failure and reducing the incidence of intubation in patients with blunt chest trauma and they are associated with few serious complications, a short stay at the intensive care unit, so early identification of at-risk patients with early institution of CPAP or BiPAP in appropriate patients may be of a great benefit.

Conflict of interest

We have no conflict of interest to declare.

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