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Research Article

A comparative study of volume control ventilation versus pressure control ventilation in patients of trauma

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ABSTRACT

Background: Trauma patients may require mechanical ventilation secondary to the respiratory centre depression or acute respiratory distress syndrome (ARDS). It has become increasingly accepted that mechanical ventilation, although often life-saving, can contribute to lung injury. This concept has led to implementation of lung protective ventilation strategies.
Methods: This is a prospective, double blind, comparative study in which sixty patients of intubated trauma patients on mechanical ventilation expected at least for five days are included. They were divided in group V where patients were put on volume control ventilation for four days and group-P where patients were put on volume control for two days and pressure control for next two days, after initial stabilization. Each patient was evaluated for ventilation parameters (partial pressure of oxygen, partial pressure of carbon dioxide, peak inspiratory pressure), chest X ray findings and outcome of the patient, keeping the hemodynamic stability and medications same in all patients of both groups.
Results: The demographic data like age, weight, and sex were comparable in both volume and pressure control groups.. Baseline ventilation parameters were compared between the groups at every eight hours. During the study we found that there was significant and better oxygenation in pressure control ventilation than volume, less increase in peak inspiratory pressure in pressure controlled ventilation than volume controlled. Other parameters like partial pressure of carbon dioxide also showed less increase in pressure control ventilation. Chest X ray finding showed that the data is comparable and statistically not significant in both the groups. The outcomes of the patients were good in pressure control mode of ventilation than volume control mode and the data was statistically significant.
Conclusions: We conclude a better compliance of patients and good respiratory outcome on pressure control than volume. It has better lung compliance with respect to partial pressures of O_2 and CO_2 and peak inspiratory pressures than the volume control.

Keywords: Volume control mode, Pressure control mode, Mechanical ventilation, Trauma

INTRODUCTION

The primary goal in early management of a severely-injured patient is the provision of sufficient oxygen to the tissues to avoid organ failure and secondary central nervous system damage.[1] The first priority is to establish and maintain a patent airway. Head injury with impaired consciousness and reduced pharyngeal tone is the commonest trauma-related cause of airway obstruction. The airway may also be soiled with blood or regurgitated matter. Blunt or penetrating injuries that obstruct the airway include maxillary, mandibular and laryngotracheal fractures and large anterior neck hematomas. Respiratory centre depression or acute respiratory distress syndrome (ARDS) may necessitate mechanical ventilation. It is necessary for practitioner to have a good understanding of techniques to optimize mechanical ventilation and minimize complications. Development of our understanding of pressure volume curves and the recent demonstration of microscopic shear stress lung injury have changed the whole concept of safe lung with pressure and volume approach in mechanical ventilation.[2] The traditional approach of using large tidal volume in volume control ventilation in the trauma patients with central nervous system trauma injury or abdominal trauma injury causes cardiovascular embarrassment, risk of peak inspiratory pressure and plateau pressure without significant improvement in the arterial oxygenation.[3] More over high tidal volume causes excessive stretch of non dependant lung region and promotes alveolar rupture, leading to the volume trauma of the lungs.[4]

On the contrary, the decelerating inspiratory flow used during pressure control ventilation generates high flow rate causing more rapid alveolar inflation. The mechanical effect of pressure control ventilation allows a homogenous distribution of ventilation leading to better ventilation and perfusion matching, at the same time pressure limit and uniform distribution of forces within the lungs reduces the risk of volume and barotrauma.[2]

For patients who are critically injured, acute respiratory distress syndrome (ARDS) represents the first step on the final common pathway to death. The lung compromised from a variety of direct and secondary stressors, exhibits a pathophysiology that is uniform and classic.[5]

The aim of our study was to compare pressure control ventilation mode with conventional volume control mode in trauma patients with respect to improvement in the respiratory mechanics and outcome of staying length in trauma ICU.

METHODS

After taking approval from the institutional ethics committee, written informed valid consent was taken from patients' relatives after explaining the study protocol. We enrolled 60 patients of either sex, aged 10-70 years, having trauma to any part of the body except chest trauma and who are hemodynamically stable. Computer generated table of random numbers was prepared allotting equal number of patients in both groups.

Group V-These patients were kept on volume control ventilation for four days with tidal volume of 10 ml/kg, positive end expiratory pressure of 5, inspiratory: expiratory ratio of 1:2 and Fio2 of 50%.

Group P-These patients were kept on volume control group for two days with same ventilator setting as above and for next two days, pressure control mode was used with airway pressures in the range to maintain tidal volume of 6-8 ml/kg not to exceed maximum airway pressure of 35 cm of H_2O.

Patients with history of asthma or chronic respiratory disease, hemodynamically unstable patient, patients having extremely low haemoglobin (HB <7), patients who are on Inotropic support like dopamine and adrenaline were excluded from the study. Relative's refusal was also one exclusion criteria.

After following protocol of advanced trauma life support, patients who were not maintaining oxygen saturation (SpO2 <90%), glasgow coma scale <8, head injury patient with altered consciousness were intubated with appropriate number cuffed endotracheal tube and were put on volume controlled mode on ventilator support. After stabilizing patient for twenty four hours detailed history was taken, inclusion and exclusion criteria was followed. In patients who fitted in the inclusion criteria, consent was obtained from the relatives. Same IV sedation and medication was used in both the groups and patients were put on volume controlled mode and monitoring was by arterial blood gas analysis at interval of eight hour and PaO_2, PCO_2, peak airway pressure and chest X-ray were monitored for forty eight hours. After this for next two days, group V patients was continued on same sttings and group P was put on the pressure control ventilation. For both groups plateau inspiratory pressure was limited to <35 cm of H_2O and I/E ratio was allowed to be 1:2. If in time being any patient who was shifted to pressure control ventilation deteriorated was shifted to volume control ventilation.

Pressure control ventilation

In pressure control, a pressure limited breath is delivered at a set rate. The tidal volume is determined by the preset pressure limit. This is a peak pressure rather than a plateau pressure limit (easier to measure). The inspiratory time is also set by the operator. The combination of decelerating flow and maintenance of airway pressure over time means that stiff, noncompliant lung units (long time constants) which are difficult to aerate are more likely to be inflated. It is known that decelerating flow patterns improve the distribution of ventilation in a lung with heterogeneous mechanical properties (as in acute lung injury).[6]

Volume control ventilation

Volume-controlled mechanical ventilation is delivered with a constant inspiratory flow, resulting in increasing airway pressure through inspiration. To maintain this fixed rate of gas flow the pressure must rise through inspiration. The actual preset tidal volume remains constant as lung compliance and resistance change. High inspiratory flow during volume-controlled ventilation has detrimental effects on lung ventilation. Therefore, low inspiratory flow rates should be used to keep the peak ventilator pressure as low as possible. This ensures more homogeneous ventilation.[7]

Statistical analysis

Demographic data was analyzed by Pearson's chi-square test. Changes in the partial pressure of oxygen, partial pressure of carbon dioxide, peak inspiratory pressure and chest x-ray finding were analyzed using unpaired' test. 'P' value less than 0.05 was considered significant.

RESULTS

Thirty patients each were recruited in the two groups.

At day 1, mean partial pressure of oxygen of Group V was comparable with that of group P and the difference was not significant. At day 2, mean partial pressure of oxygen gradually went on increasing with pressure control mode as compared to volume control mode and was significant statistically. At day 3 and day 4, there was considerable difference in the mean partial pressure of oxygen between two groups. On 4th day, it was 94.60 in Group V, which was significantly less as compared to 144.60 in Group P. After 16 hours, mean partial pressure of oxygen was 93.80 in Group V, which was significantly less as compared to 178.33 in group P (Figure 1).

At day 1, mean partial pressure of carbon dioxide was 37.87 in group V, which was significantly more as compare to 34.70 in group P. At day 2, mean partial pressure of carbon dioxide continued to remain significantly higher in volume control mode as compared to that pressure control mode. At day 3 and day 4, the same trend continues. At the end of 4th day, mean partial pressure of carbon dioxide was 41.47 in group V, which was significantly more as compared to 35.43 in group P (Figure 2).

At day 1, baseline mean peak inspiratory pressure was 28.20 in group V, which was comparable with 28.13 in group P and the difference was comparable. On day 1 and 2 the peak pressures remained comparable in both groups. From day 3, there was a rising trend in the peak inspiratory pressure of group V as compared to group P. At day 4, mean peak inspiratory pressure was 27.50 group V, which was significantly more as compared to 24.10 group P (Figure 3).

In the group V, 14 (46%) were male; mean age was 39.37years (±9.07) and mean weight 61.57 kg (±10.01). In the group P, 12 (40%) were male; mean age was 40.70 years (±8.53) and mean weight was 59.67 kg (±9.45). All parameters were comparable and difference was not significant (Table 1).

In 80.0% of the cases in group V, chest X-ray was normal, which was less as compared to 93.3% of the cases in group P. The difference was not statistically significant, but it was clinically significant (Table 2).

In our study we found that 60.0% of the cases had good outcome among volume control mode, which was significantly less as compared to 83.3% of the cases among pressure control mode.

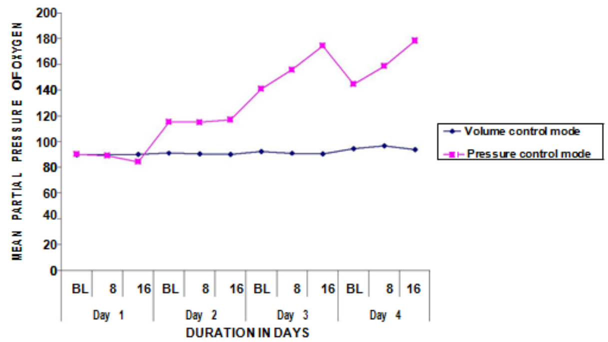

Figure 1: Comparison of change in mean partial pressure of oxygen between two groups.

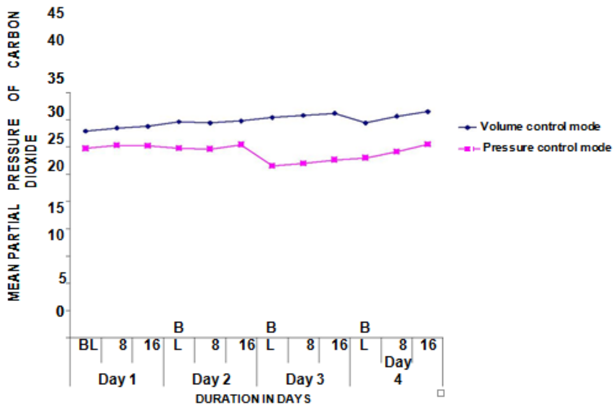

Figure 2: Comparison of change in mean partial pressure of carbondioxide between two groups.

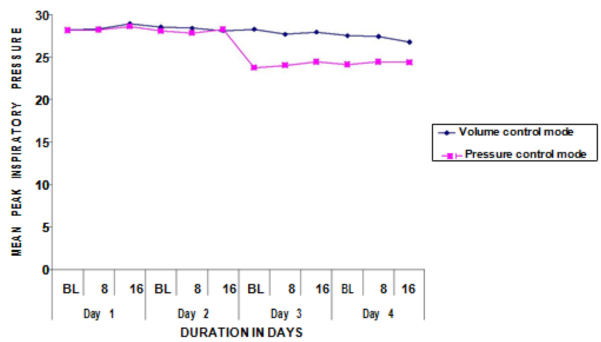

Figure 3: Comparison of change in mean peak inspiratory pressure between two groups.

Table 1: Demographical data.

Parameters	Volume control mode (N=30)	Pressure control mode (N=30)
Age (years)	39.37±9.07	40.70±8.53
Weight (kg)	61.57±10.01	59.67±9.45
Sex (M/F)	14/16	12/18

Table 2: Profile of chest x-ray finding.

Chest X-ray finding	Volume control mode		Pressure control mode	
		(N=30)		(N=30)
	No.	%	No.	%
Normal	24	80.0	28	93.3
ADRS	06	20.0	02	06.7
By chi-square test	P=0.389		Not significant	

DISCUSSION

Pulmonary dysfunction is a common complication of head trauma and spinal cord injury. Abnormal breathing pattern reflect the influence of altered neural integration. Early arterial hypoxemia can result from ventilation and perfusion mismatching, microatelactasis, aspiration, fat embolism or the development of ARDS. Significant changes in lung volume, ventilation and gas exchange can occur in spinal cord injury as a result of the loss of diaphragmatic or intercostal muscle function.[8]

Airway management is of prime importance in neurological trauma patient. The use of low or moderate positive expiratory pressure levels apparently improves oxygenation without worsening of the intracranial pressure. Ventilator management should be closely monitored and adjusted to hemodynamics, respiratory status to achieve a good outcome. A number of issues should be considered related to mechanical ventilation of patients like type of injury eg inhalation injury, Burn injury, blunt or penetrating chest trauma with lung contusion etc.[9-11] Ventilator setting should be selected with consideration of the potential effects on cerebral perfusion pressure in head injury.[12]

Joo WJ et al in the year 2010 did a clinical study to compare volume control mode and pressure control mode using laryngeal mask airway in gynaecological laproscopic procedures.[13] They demonstrated that PCV using a LMA is a rational method of ventilation during gynaecologic laparoscopy to ensure proper oxygenation and to eliminate CO_2 while minimizing the increases of the peak airway pressure after CO_2 insufflation. ($P < 0.05$).

We conducted prospective, randomized, double blind, clinical trial and recruited sixty patients of trauma (abdominal trauma, head injury, spine injury) expected to have ventilator support for more than four days. After stabilization, these patients were divided into group V on volume control mode for four days and group P on volume control mode for two days and pressure control mode for next two days. Other parameters like drugs for sedation, medications remained the same in both the groups.

All the patients were comparable with respect to the demographic parameters: age, sex and weight. Gupta S et al concluded in their study that pressure control mode improves oxygenation and decreases chances of lung injury.[14] In our study we also found that oxygenation is better in pressure control mode than volume control mode. Comparison of volume control and pressure control ventilation using a tidal volume of 10 ml/kg, respiratory frequency to maintain a pH >7.30 and $PaCO_2$ <50 mmHg, and positive end-expiratory pressure, (PEEP) set to maintain PaO_2 > 70 mmHg or SaO_2 > 93% with an $FiO_2 \leq 0.50$ was done by Davis K Jr et al and they concluded that both pressure controlled ventilation and volume controlled ventilation with a decelerating flow waveform provided better oxygenation at a lower peak inspiratory pressure and higher mean airway pressure compared to volume controlled ventilation with a square flow waveform.[15] The results were similar to our study with better oxygenation and lower peak inspiratoy pressures in pressure controlled ventilation than volume controlled ventilation. In a study on laparoscopic gastric banding surgeries for obesity by Cadi P et al, pressure controlled ventilation improved oxygenation as compared to volume controlled in morbidly obese patients.[16] We have also found similar results with the pressure controlled mode of ventilation.

Joo WJ et al did a clinical study on ventilation in laproscopic gynaecologic surgeries and concluded that in the PCV group increase of the arterial partial pressure of carbon dioxide was lower compared to that of the VCV group ($P<0.05$).[13] Comparison of the VCV and PCV modes did not reveal any significant differences in oxygenation. In our study on ventilation in trauma patients we found arterial partial pressure of carbon dioxide were lower in pressure controlled ventilation than volume controlled ventilation. Prella M et al did a clinical study on the effect of the short term pressure controlled ventilation on gas exchange, airway pressure and gas distribution in patients with acute lung injury/ARDS in comparison with volume controlled ventilation.[17] Their study concluded that pressure controlled ventilation allows the generation of lower P peaks through the precise titration of the lung distending pressure, peak airway pressure (P-peak) was significantly lower in pressure controlled ventilation compared with volume controlled ventilation. Choietal EM et al did a comparative study of VCV and PCV in steep Trendelenburg position for robot assisted laparoscopic radical prostatectomy. They found that PCV offered greater dynamic compliance and lower peak airway pressure than VCV, but no advantages over VCV in respiratory mechanics or hemodynamics.[18] Ogurlu M et al in a study done on sixty women undergoing laparoscopic gynaecologic surgeries, concluded that VCV was associated with a significant increase in peak airway pressure, plateau pressure and airway resistance.[19] Results were similar to our study in term of peak inspiratory pressure and lung compliance.

Othman MM et al did a clinical study on the hemodynamic effects of volume-controlled ventilation((VCV) versus pressure-controlled ventilation (PCV) in head trauma patients.[20] They concluded that VCV was associated with significant higher peak airway pressure in comparison with PCV after 4, 8, and 12 hours. The oxygenation values and other lung mechanics were not significantly changed. Guldager H et al and Unzueta MC et al have also found better oxygenation and lower peak inspiratory pressure in pressure control mode than volume controlled mode.[21,22] Our study also showed better oxygenation and lower p-peak in pressure controlled ventilation than volume controlled ventilation.

As per results 80.0% of the cases were normal in volume control group, which was less as compare to 93.3% of the cases in pressure control group but the difference was not statistically significant, but it is clinically significant. Andrews PL et al compared early airway pressure release ventilation with conventional ventilation and found lower incidence of acute lung injury and acute respiratory distress syndrome mortality in trauma patients on airway pressure release ventilation.[23] We also found less incidence of ARDS in our study in pressure control ventilation than conventional volume control ventilation which was not statistically significant, but clinically significant.

In our study we found that 60.0% of the cases had good outcome among volume control mode, which was significantly less as compared to 83.3% of the cases among pressure control mode. But there may be other contributing factors influencing the outcome.

CONCLUSION

We conclude that Pressure control mode of ventilation has better lung compliance with respect to partial pressures of O_2 and CO_2 and peak inspiratory pressures than the volume control mode of ventilation. Pressure-controlled ventilation also decrease incidence of complications in chronic mechanical ventilated patients.

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