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Original Article

Breathing comfort associated with different modes of ventilation: A comparative study in non-intubated healthy Nepalese volunteers

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Abstract
Objective: To compare subjective experience of comfort associated with various commonly used supportive modes of mechanical ventilation for weaning in the intensive care unit (ICU).
Subjects and Methods: The study was carried out in general ICU of a community-based teaching hospital in 30 healthy adult Nepalese volunteers of either sex and 19-37 years of age. The subjects were randomly made to experience breathing via anatomical facemask through ventilator circuit with synchronized intermittent mandatory ventilation (SIMV), assisted spontaneous breathing (ASB), biphasic positive airway pressure (BiPAP), and continuous positive airway pressure (CPAP) modes of ventilation with parameters set at intermediate level of respiratory support. Subjective comfort of breathing was noted using a 10cm visual analogue scale (VAS) with no discomfort at one end and maximum imaginable discomfort at the other. Inspiratory and expiratory experience of discomfort was also noted using a four point ranking scale (0-no discomfort, 1-mild discomfort, 2-moderate discomfort and 3-severe discomfort). In addition, presence or absence of feeling of breathlessness and inflation was also noted.
Results: BiPAP was the most comfortable mode of ventilation ($p<0.01$) on visual analogue scale. SIMV and CPAP modes were associated with higher discomfort than other modes during inspiratory and expiratory phases respectively. Breathlessness and inflation were least felt in BiPAP and SIMV modes respectively.
Conclusion: Perception of breathing comfort can vary widely with various supportive modes of ventilation in the ICU. Hence, no single supportive mode should be used in all patients during weaning from mechanical ventilation.

Key words: assisted spontaneous breathing; biphasic positive airway pressure; breathing comfort; continuous positive airway pressure; mechanical ventilation; supportive modes synchronized intermittent mandatory ventilation; weaning

Maximizing patient comfort and minimizing adverse patient-ventilator interactions and timely weaning from ventilator are common objectives of any ventilatory strategy. However, comfort and acceptability are subjective experiences and are difficult to assess in critically ill patients[1]. Many disturbing variables other than the ventilators (disturbed sleep, invasive monitoring and various procedures) are present in the intensive care environment that can confound the comfort associated with a particular ventilatory mode[2]. Conducting controlled studies in critical care setting is not only difficult but can also create ethical problems. Keeping these facts in mind, this study was designed and conducted to compare the comfort and acceptability associated with four different modes of partial ventilatory support used for weaning viz. synchronized intermittent mandatory ventilation (SIMV), assisted spontaneous breathing (ASB)- a type of pressure support ventilation, biphasic positive airway pressure (BiPAP) and continuous positive airway pressure (CPAP) in healthy Nepalese volunteers.

Subjects and Methods

This randomized double-blinded crossover study, involving 30 healthy Nepalese volunteers between the ages of 19-37 years belonging to both sexes, was carried out in the intensive care unit of the BP Koirala Institute of Health Sciences, Dharan, Nepal. Ethical approval was obtained from the institute's research committee and written informed consent was taken from each subject prior to the study.

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The purpose and the procedure of the study was explained to all the subjects and trial of spontaneous breathing was given through the Magill's breathing system with tight-fitting anaesthesia mask (size 3 or 4) using continuous flow anaesthesia machine to familiarize them to artificial breathing circuits and build confidence for the subsequent study with similar artificial breathing circuits.
Tight fitting anaesthesia masks (size 3 or 4) and sterile breathing system were used in all the subjects. The ventilator used was Drager Evita II^{TM} (Drager werk Aktiengesellschaft, Germany) [3]. The subjects as well as the principal investigators were blinded to ventilatory settings and its sequence and a second investigator introduced one of the ventilatory modes in a randomized manner according to computer generated random number codes.

Each mode was maintained for a period of 2 minutes after which a 10cm visual analogue scale (VAS) was used to measure the level of discomfort with one end representing no discomfort and the other end representing greatest imaginable discomfort. The breathing experience on ventilator during inspiratory and expiratory phases were ranked on a 4-point, 0-3 scale (0-no discomfort, 1-mild discomfort, 2-moderate discomfort and 3-severe discomfort). The subjects were also asked about whether they felt breathless and inflated or not. Each breathing mode was followed by a rest period of 10 minutes. None of the volunteers had any previous direct experience with ventilation or ventilators. The subjects were free to withdraw from the trial at any stage.

The ventilatory parameters used in SIMV mode were, tidal volume 6ml/kg, frequency 6 breaths/min, gas flow 60 liters/min, flow sensitivity 2 liters/min, FIO_2 0.3 and a square wave flow pattern. In ASB mode, an inspiratory pressure level of 10cm of water was used whereas in CPAP mode, 10cm water pressure was used. In the BiPAP mode, 5 and 10 cm water pressure were selected as the lower and higher levels respectively.
Volunteers' vital parameters were monitored using Lifescope12^{TM} (Nihon Kohden, Japan) every minute by a nurse to ensure safety.

Data were analyzed using SPSS version 10. Continuous data were expressed as mean± standard deviation whereas categorical data were expressed as percentage. Breathing comfort associated with various modes of ventilation were compared using paired Student's t-Test and Wilcoxon Signed Rank Test. Categorical data were analyzed using Chi-Square test. A p-value of less than 0.05 was considered significant.

Observation and Results
The demographic characteristics of the volunteers are given in table 1.
BiPAP was the most comfortable mode of ventilation with mean comfort VAS±SD of 3.0±1.2. ASB, SIMV and CPAP were associated with significantly higher VAS score compared to BiPAP ($p<0.01$) (Table: 2). SIMV and CPAP were ranked as the most difficult modes during inspiratory and expiratory phases respectively (Table: 3&4).
BiPAP was associated with significantly less feeling of breathlessness than other modes of ventilation ($p<0.05$) (Table: 5). The incidence of feeling of inflation was highest with the CPAP mode (Table: 6). All the subjects completed trial of all four modes of ventilation uneventfully.

Table 1: Demographic characteristic of the volunteers (n=30)

Parameter	Value
Age (years) Mean ±SD Range	 25.1±4.2 19-37
Sex ratio (M:F)	15:15
Height (cm) Mean ±SD Range	 159.6±11.3 140-183
Weight (Kg) Mean ±SD Range	 58.3±12.4 35-82
BMI Mean ±SD Range	 24.6±2.6 20.5-29.0

Table 2: VAS of discomfort associated with different modes of ventilation (n=30)

Mode	Mean ±SD	p-value
ASB	4.1±1.2	0.197 (vs. CPAP) 0.893 (vs. SIMV) **0.002** (vs. BiPAP)
CPAP	4.4±1.5	0.249 (vs. SIMV) **<0.001** (vs. BiPAP)
SIMV	4.0±1.2	**0.001** (vs. BiPAP)
BiPAP	3.0±1.2	

ASB: Assisted Spontaneous Breathing, CPAP: Continuous Positive Airway Pressure, SIMV: Synchronized Intermittent Mandatory Ventilation, BiPAP: Biphasic Positive Airway Pressure

Table 3: Breathing discomfort during inspiration in 4-point (0-3) ranking scale (n=30)

Mode	Mean±SD	p-value
ASB	0.93±0.73	0.214 (vs. CPAP) 0.078 (vs. SIMV) 0.175 (vs. BiPAP)
CPAP	1.20±0.96	0.687 (vs. SIMV) **0.014** (vs. BiPAP)
SIMV	1.33±0.84	**0.003** (vs. BiPAP)
BiPAP	0.70±0.46	

ASB: Assisted Spontaneous Breathing, CPAP: Continuous Positive Airway Pressure, SIMV: Synchronized Intermittent Mandatory Ventilation, BiPAP: Biphasic Positive Airway Pressure

Table 4: Breathing discomfort during expiration in 4-point (0-3) ranking scale (n=30)

Mode	Mean±SD	p-value
ASB	0.76±0.81	**0.035** (vs. CPAP) 0.399 (vs. SIMV) 0.313 (vs. BiPAP)
CPAP	1.30±1.02	0.085 (vs. SIMV) **0.006** (vs. BiPAP)
SIMV	0.90±0.88	0.106 (vs. BiPAP)
BiPAP	0.53±0.68	

ASB: Assisted Spontaneous Breathing, CPAP: Continuous Positive Airway Pressure, SIMV: Synchronized Intermittent Mandatory Ventilation, BiPAP: Biphasic Positive Airway Pressure

Table 5: Incidence of feeling of breathlessness during different modes of ventilation (n=30)

Mode	Number of subjects (%)	p-value
ASB	12 (40.0)	1.00 (vs. CPAP) 0.592 (vs. SIMV) **0.007** (vs. BiPAP)
CPAP	12 (40.0)	0.592 (vs. SIMV) **0.007** (vs. BiPAP)
SIMV	10 (33.3)	**0.028** (vs. BiPAP)
BiPAP	3 (10.0)	

ASB: Assisted Spontaneous Breathing, CPAP: Continuous Positive Airway Pressure, SIMV: Synchronized Intermittent Mandatory Ventilation, BiPAP: Biphasic Positive Airway Pressure

Table 6: Incidence of feeling of inflation during different modes of ventilation (n=30)

Mode	Number of subjects (%)	p-value
ASB	12 (40.0%)	0.196 (vs. CPAP) 0.165 (vs. SIMV) 0.790 (vs. BiPAP)
CPAP	17 (56.7%)	**0.008** (vs. SIMV) 0.120 (vs. BiPAP)
SIMV	7 (23.3%)	0.259 (vs. BiPAP)
BiPAP	11 (36.7%)	

ASB: Assisted Spontaneous Breathing, CPAP: Continuous Positive Airway Pressure, SIMV: Synchronized Intermittent Mandatory Ventilation, BiPAP: Biphasic Positive Airway Pressure

Discussion

The subjective feeling of discomfort becomes important particularly during the period of weaning from mechanical ventilation, as successful weaning is more likely with either an awake or a partially sedated patient[1]. Failure to maintain proper ventilator-patient interaction during this period can lead to inappropriate use of sedative drugs and thereby hampering the process of weaning. Difficulty in assessing actual subjective comfort due to various confounding factors in actual patients prompted us to carry out this study in healthy Nepalese volunteers.

We chose most commonly used modes for partial respiratory support for comparison in our study. Besides, these modes are available in most modern ventilators available in our set up. The parameters we have chosen can be considered as intermediate level respiratory support in the context of volunteers with normal chest compliance. To improve ventilator patient synchrony[4], we used flow triggering in SIMV mode. We also kept 10cm H_2O CPAP as one of the study arm as CPAP is used extensively and is considered comfortable method of respiratory support by many of us.

We found BiPAP to be the most comfortable among all the modes used in our study. This finding is in contrast to the finding by Russell and Greer[5] who found ASB to be the most comfortable mode among ASB, BiPAP and SIMV. This could be due to variation in perception of subjects. Moreover, shorter duration for each mode and use of anatomical mask in our study (unlike mouth piece in their study) may have contributed to the difference in our findings. The finding of the ranking scale has further supported our VAS scores although subjects' ability to decide their own respiratory rate and pattern without difficulty in initiating a breath has been attributed to better comfort in ASB mode[6]. But tendency to hyper-inflate lungs has been reported as an adverse effect of ASB[7] that may have contributed to our findings. Less number of subjects reported feeling of breathlessness and inflation with BiPAP mode than ASB mode in our study. Mols G and colleagues[8] have shown better comfort with automatic tube compensation than pressure support ventilation but it was not a part of our study.

We found SIMV to be associated with higher discomfort (both in VAS and ranking scale) than ASB and BiPAP, which is consistent with the findings of Russell and Greer[5]. Against our expectation, we found that CPAP of 10cmH_2O was associated with higher discomfort in VAS scale compared to other modes. It was associated with significantly higher discomfort in four-point scale both during inspiration and expiration. Further, it was associated with higher reporting of feeling of breathlessness and inflation. It is difficult to explain but need to exhale against constant pressure of 10cm H_2O, and individual variations in perception may be the contributing factors. However, studies in obstructive sleep apnoea patients have shown long term CPAP use (with comparable pressure to what we used) to be well tolerated and acceptable.[9, 10]

Conclusion

Our study showed wide difference in perception of breathing comfort with various available modes of respiratory support. Although these findings may not be generalized to all level and type of respiratory support, BiPAP is the most comfortable followed by ASB, SIMV and CPAP when used with intermediate support level parameters. This indicates that comfortable mode for one patient may not be comfortable for another patient. We recommend that no single supportive mode should be used in all patients during weaning from mechanical ventilation and trial of different available options should be undertaken to find out the most comfortable one on individual basis.

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