Original Article

Pressure Support Ventilation in Neonates – Is It Safe?

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Abstract

Introduction: Pressure support ventilation (PSV) is a common weaning mode in adults, but it is less familiar among the neonatal population due to lack of awareness and safety concerns associated with leaks around uncuffed endotracheal tube. There is limited evidence addressing this issue in the literature. Therefore, the study focuses on the safety of PSV among neonates. **Subjects and Methods:** The prospective observational study was done among 57 neonates (gestational age from 26 to 37 weeks) requiring mechanical ventilation. PSV mode was used 30 min before extubation and assessed for any changes in hemodynamic and ventilator parameters for two time points, during the initiation of PSV, and the end of 30 min of the trial. The incidence of reintubation within 72 h was also noted. **Results:** There were no wide variations in hemodynamic and ventilator parameters during the trial. The average heart rate, respiratory rate, and saturation of oxygen were noted to be 146 bpm, 54/min, and 95%, respectively. The average mean airway pressure was found to be 7.2 cm H_2O during PSV. The reintubation rate was found to be 8.2%, with a mortality rate of 5.2%. **Conclusion:** The current study findings conclude that PSV in neonates can be used safely as an independent mode during weaning.

Keywords: Neonatal ventilation, pressure support, respiratory severity score, spontaneous breathing trial

Introduction

Mechanical Ventilation (V̇e) is a lifesaving therapy in managing critically ill neonates, but its prolonged use can cause severe complications such as bronchopulmonary dysplasia, ventilator-associated pneumonia, and barotrauma. Therefore, it is necessary to wean from the ventilator as early as possible. Although weaning strategies are well established and practiced in the adult population, the evidence-based weaning in neonates is still lacking. Several studies showed that 3-min spontaneous breathing trial (SBT) would benefit in the smooth transition from mechanical V̇e to noninvasive support in neonates.[1,2] A 2–3-min continuous positive airway pressure (CPAP) is the commonest SBT trial used in neonates. The major drawback during CPAP trial is the unaccounted endotracheal tube resistance, which may further worsen or reduce the functional residual capacity and cause weaning failure.

Pressure support ventilation (PSV) is a commonly used weaning mode in adults and pediatrics. PSV assists spontaneously breathing with inspiratory pressure support along with baseline pressure, which helps in overcoming the endotracheal tube resistance.[3] Additionally, PSV assists the respiratory muscle, improves the efficacy of patient effort, and reduces the work of breathing (WOB).[4-6] Proper titration of pressure support level is essential since a higher or lower level of pressure can result in hyperinflation or hypoventilation.[7]

The use of PSV is limited among the neonatal population. The use of an uncuffed endotracheal tube is a unique challenge causing leak around the endotracheal tube, which can mimic as a spontaneous breath and cause serious complications such as air-leak syndromes and significant hemodynamic instability. The neonatal weaning approach should be gradual with frequent small changes made at regular interval that allows the neonates to progressively assume greater responsibility of gas exchange while reducing ventilator support.[1] Premature ventilator discontinuation can cause respiratory muscle

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fatigue and gas exchange failure leading to invasive ventilator support. Three-minute CPAP trial predicts extubation failure but does not provide ample transition time from invasive V̇e. Longer duration in a lower level of invasive support will help in assessing the extubation readiness as well as provide a smooth transition from invasive V̇e. Furthermore, lower level of ventilator support can help in easy transition to spontaneous breathing than from a higher level of support.[8]

Recent advancements in microprocessor technology and the introduction of dedicated flow sensors help in overcoming the trigger dyssynchrony associated with tube leak. The present-day neonatal ventilators are convenient to use with its leak compensation technique, which adjusts the delivered tidal volume (VT) for the endotracheal tube leak and automatically adapts to the trigger sensitivity.[9,10]

Subjects and Methods

The current prospective observational study was done at a multispecialty tertiary care center and teaching institute in South India after the approval from the Institutional Review Board and Institution Ethical Committee on April 2018. Neonates were screened based on the inclusion and exclusion criteria of the study. Written consent was taken from the parents/guardian of the neonates prior to recruiting the study (May 2018–March 2019). The neonates with gestational age from 26 to 37 weeks who required invasive V̇e were included in the study. Neonates with multiple congenital anomalies, air-leak syndrome, severe hemodynamic instability, and without informed consent were excluded. The predetermined sample size was not calculated in the current study. Subjects who met the study criteria were enrolled. A total of 57 neonates were eligible for the study.

The existing unit protocol used CPAP trial for an extended duration (3–5-min CPAP trial) under close monitoring to assess the extubation readiness. PSV trial is also given for neonates requiring prolonged duration of mechanical V̇e. Neonates <36 weeks of gestation also receive a dose of caffeine (20 mg/kg) 30 min prior to extubation. Postextubation, neonates are initiated on any of the noninvasive support (nasal CPAP, nasal synchronized intermittent mandatory ventilation [SIMV], and heated humidified high flow nasal cannula) accordingly. If the neonate presents with any hemodynamic instability, the mode is switched over to conventional V̇e.

The primary mode of V̇e was set based on our neonatal intensive care unit (NICU) protocol, started on either SIMV with pressure control or volume guarantee (SIMV-PC or VG) mode of V̇e, inspired oxygen concentration (FiO_2) (0.25–1), pressure control (targeting the VT of 4–6 ml/kg), positive end-expiratory pressure (PEEP) (5–6 cmH_2O), and respiratory rate of 45 bpm. The criteria to switch over from SIMV to PSV were FiO_2 (0.25), peak inspiratory pressure (PIP/14 cmH_2O), PEEP (5 cmH_2O), respiratory rate (f/30 bpm), inspiratory time (Ti/0.5 s), and inspiratory flow (7 L/min). The neonates were ventilated on PSV mode for 30 min before extubation. Initial settings on PSV were FiO_2 (21%–40%), targeting SpO_2 (88%–99%), PS (targeting a VT of 4–6 ml/kg), PEEP (5–6 cmH_2O), backup rate (20–25/min), and inspiratory time (Ti) – 50% more than spontaneous Ti. After 30 min of V̇e on PSV, the neonates were extubated onto noninvasive ventilator support with the permission from an attending physician [Figure 1].[11, 12-17]

Pressure support ventilation failure

It is defined as hemodynamic instability with more than 60% endotracheal tube leak, high variation between set and measured VT, and presence of clinical signs of distress. If neonates presented with any of these, they were switched back to the previous mode, and further care was decided based on the attending physician.

The primary outcome was to assess the changes in hemodynamic and ventilator parameters at 0 min and 30 min of PSV. The secondary outcome was to determine any incidence of air leak immediately post-PSV trial, the incidence of reintubation, the total duration of invasive V̇e, and noninvasive support.

Tools and equipment used included Philips Intellivue MP20 for monitoring vitals and Philips M11193A for pulse oximetry monitoring. Dräger Babylog® 8000 plus ventilator was used for infants between 26 and 34 weeks of gestation and SLE5000 (version 5.0) (SLE5000 infant ventilator-version5.0(SLE Limited,South Croydon,UK))or SLE6000 infant ventilator (version 2.0) software (SLE6000 infant ventilator-version2.0(SLE Limited,South Croydon,UK)) for infants of higher gestation 35–37 weeks.

The data were collected using an expert, validated pro forma. It included demographic data such as mode of birth, gestational age, gender, and birth weight. The ventilator parameters and vitals were recorded during the PSV trial. The set ventilator parameter includes (FiO_2, PS, PEEP, and flow),measured parameters[(Minute ventilation) minute V̇e, PIP, mean airway pressure (Paw), VT, compliance (C), and compliance at the last 20 s of breath cycle to total lung compliance (C20/C)],calculated parameters[Respiratory severity score (RSS) = Paw × FiO_2 with a cutoff value 1.26 and 2.6 [Pediatr Neonatal. 2017 December and SpO_2/FiO_2) and vitals[Heart rate,respiratory rate and SpO_2].

Statistical analysis

Data were analyzed using IBM (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, version 20.0. Armonk, NY, USA: IBM Corp). Continuous variables (duration of invasive V̇e, noninvasive V̇e, and hospital days); ventilator and hemodynamic parameters were expressed in mean and standard deviation. Categorical variables (gender and mode of delivery) expressed as *n* (%). Paired *t*-test was used to compare the ventilator parameters and hemodynamic parameters at two time points of PSV trial. P =0.05 or less was considered statistically significant.

Results

A total of 187 subjects required respiratory support during

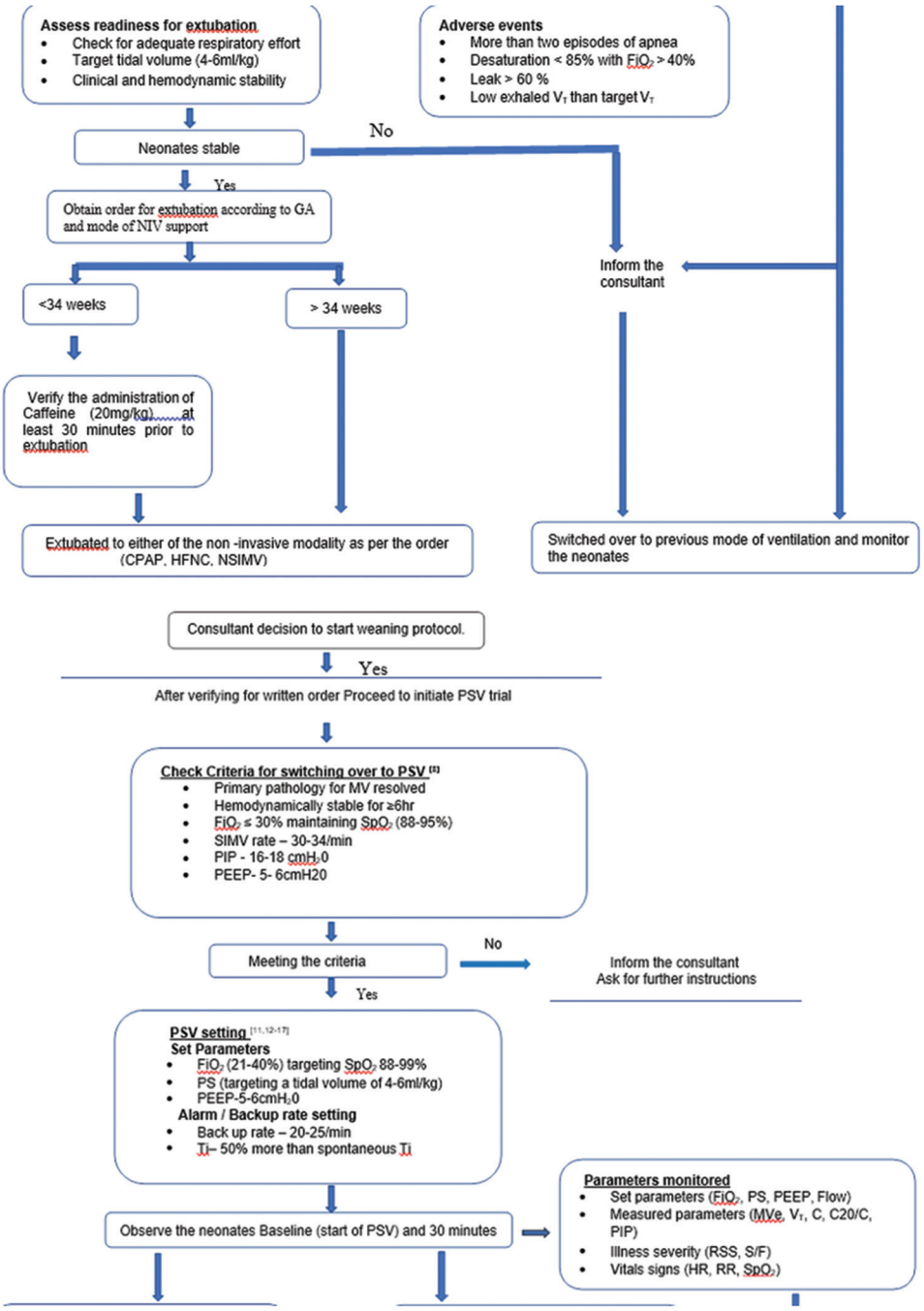

Figure 1: Pressure support ventilation weaning protocol

the hospital stay, 57 of whom were enrolled in the study as per the inclusion criteria [Figure 2]. Table 1 represents the demographical data of the enrolled subjects. Respiratory distress syndrome was the primary reason requiring ventilator assistance (54%). Meconium aspiration syndrome, postsurgical cases, sepsis, and asphyxia constituted 44%. Hemodynamic and ventilator parameters during PSV are represented in median and interquartile range [Table 2]. There was no significant difference observed in these parameters, comparing the two time points.

There was no incidence of air leak post-PSV trial. Two neonates were switched from PSV to the previous mode due to severe hypoxemia (PSV failure) and were successfully extubated following the second PSV attempt.

Five neonates needed reintubation. Two got reintubated due to severe hypoxemia (within 72 h) and the remaining three due to inadequate secretion clearance and severe bleeding associated with surgery (after 72 h). The duration of mechanical $\dot{V}e$ was expressed in median and interquartile range as 48 (24–72) h, and duration of noninvasive $\dot{V}e$ was 72 (48–120) h. The neonates

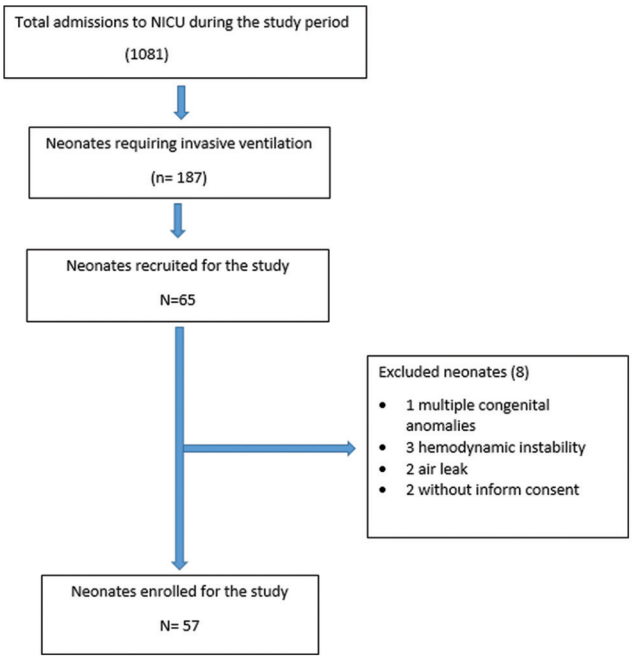

Figure 2: Neonates admitted and intubated during the study period

were extubated to either nasal CPAP (49%), high flow nasal cannula (47%), or nasal SIMV (4%). The average NICU stay and hospital stay were 15 ± 13.05 and 19 ± 15.02 days, respectively. The total mortality rate was 5.2%.

Discussion

The current study focused on assessing the safety of PSV as a stand-alone mode for weaning. During the investigation, no significant change in hemodynamic or measured ventilator parameters during the 30-min trial was observed. PSV did not result in any adverse effects. PSV resulted in a smooth transition from invasive V̇e to noninvasive V̇e.

Thirty-minute PSV was found to be safe in ventilating neonates without any hemodynamic instability or clinical deterioration in our study. Perren *et al*.[18] had concluded that an SBT trial for 30 min identified patients ready for extubation and the results were in accordance with the results obtained by 2-h SBT trial, with no difference in extubation failure among pediatric group. PSV was also used to assess patient–ventilator synchrony among neonates with congenital cardiac disorders where they had used pressure levels of 5 cmH_2O and 10 cmH_2O, respectively. Each pressure level was kept for 30 min, and they observed that PSV can augment spontaneous breathing effort with patient–ventilator synchrony.[19] Hence, 30 min of PSV trial was chosen to assess its safety in ventilating neonates.

Miqliori and Cavazza[20] compared SIMV with PSV, where they observed an increase in minute ventilation ($\dot{V}_E$), V^T, and a reduction in respiratory rate on PSV compared to SIMV. Similarly, Gupta *et al*.[21] also observed an increase in $\dot{V}_E$ when SIMV combined with PS than SIMV alone. The addition of PS resulted in improvement in $\dot{V}_E$. In both studies however, they did not observe these changes for PSV mode alone which was in contradiction to Nayeri *et al*.[11] in which they did not find any differences in VT, PIP, and incidence of pneumothorax between SIMV and PSV mode, but with PSV, the duration of mechanical V̇e was found to be less than SIMV.

In our study, as per the protocol, pressure support was set to achieve a target VT of 4–6 ml/kg, which remained in the target range throughout the study. Furthermore, $\dot{V}_E$ also remained the same without any increase in the respiratory rate, which may indicate less WOB during the trial.

In the Miqliori and Cavazza[20] study, they did not find any difference in the HR or saturation of oxygen and did not require any titration of FiO_2 in PSV group. Similarly, in our study, we did not find any significant difference in hemodynamics. Instead of PaO_2/FiO_2, we used noninvasive indicator SpO_2/FiO_2 (SF ratio) since blood gas analysis was not performed routinely.

Table 1: Demographic data of the enrolled subjects

Demographics	Category	Values, *n* (%)
Birth weight (g), mean±SD	Preterm	1492.5±618.6
	Term	2820.1±597.3
Gestational age (weeks), mean±SD	26-34	31 (54.3)
	35-37	26 (45.6)
Gender	Male	36 (63)
	Female	21 (36.8)
Mode of birth	LSCS	34 (60)
	NVD	22 (39)
	AVD	1 (1)

SD: Standard deviation, AVD: Assisted ventilator device, LSCS: Lower-segment cesarean section, NVD: Normal vaginal delivery

Table 2: Ventilator parameters, illness severity, and vital signs at initiation and at 30-min pressure support ventilation trial

Parameters	Baseline		*P*
	0 min	30 min	
Measured parameters			
Minute ventilation (L/min)	0.93±2.2	0.90±1.9	0.59
PIP (cm H_2O)	12.15±1.5	12.17±1.5	0.84
VT (ml)	9.13±5.4	9.38±5.5	0.26
Compliance (ml/mbar)	2.44±4.8	2.42±4.6	0.84
C20/C	1.47±0.9	1.46±0.86	0.89
Illness severity			
RSS	1.89±0.4	1.88±0.48	0.57
SpO_2/FiO_2 ratio	3.82±0.6	3.75±0.8	0.30
Vital signs			
HR (bpm)	146.5±11.8	146.5±11.3	0.95
Respiratory rate (bpm)	55.1±7.6	54.6±7.0	0.08
SpO_2	0.95±0.02	0.95±0.03	0.07

C20/C: Compliance the last 20 s of breath cycle to total lung compliance, PIP: Peak inspiratory pressure, HR: Heart rate, SpO_2: Oxygen saturation, FiO_2: Fraction of inspired oxygen, RSS: Respiratory severity score, VT: Tidal volume

The previous literature on PSV did not observe the C20/C index (a calculation of the compliance of the last 20% of a breath in relation to the compliance of the entire breath) and calculated parameters (RSS and S/F ratio) during the PSV trial. Fisher *et al*.[22] studied lung overdistension associated with mechanical V̇e in neonates, and they have used C_{20}/C to determine lung overdistension. They had concluded that C_{20}/C <0.8 had overdistension on the flow-volume loop, and C_{20}/C >1 was with a normal flow-volume loop. In the current study, we measured C_{20}/C, which is an index of lung distention, and the average C_{20}/C observed at 0 min and 30 min was 1.36 and 1.47, respectively. No graphical correlation of values was done.

Farhadi *et al*.[23] used PSV as a stand-alone mode with two different pressure levels (10 cmH_2O and 14 cmH_2O). They observed the statistical significance of higher Paw ($P < 0.025$) with pressure support of 14 cmH_2O, which can be related to the high-pressure level used between the groups. In this current study, the pressure support range of 10–14 cmH_2O with a Paw range of 5.1–10 was observed. Subjective approach of setting PS (as per the VT target of 4–6 ml/kg) resulted in a lower Paw which might have helped in smooth transition from invasive V̇e.

In 2013, a systematic review[24] on defining extubation success stated that apt window time for monitoring for reintubation following extubation depends on the study population. Neonates with BW <1000 g, a monitoring time for more than 1 week, will be required. We had observed a total of five reintubations. Among them, two were within 72 h and three after 72 h of extubation. One of these had a birth weight <1000 g and was reintubated after 72 h due to apnea of prematurity. Others were reintubated due to deterioration of underlying lung pathology and critical illness.

Mhanna *et al*.[25] observed that RSS, a multiple of Paw and FiO_2, could be criteria for predicting extubation readiness, with a minimum cutoff value of 1.26 and a maximum cutoff value of 2.6. They observed a higher RSS score among the extubation failures (reintubation within 48 h) among 45/147 neonates, which was contradictory to the present study. There was not much variation in Paw or FiO_2 which could change the RSS value during the trial. Even though the study population and reintubation rate were comparatively less, there were no observed changes in RSS value. The RSS score among the neonates requiring re-intubation(n=5) ranged from 1.47- 2.80 and among non-intubated cases the RSS score ranged from 1.50-3.50. Neonates with higher RSS (contributed by either a high Paw or FiO2) were also extubated successfully, which could be related to the resolving of underlying primary illness.

Farhadi *et al*.[23] observed incidence of pneumothorax with a pressure of 14 cmH_2O, which was not statistically proven. In our study, none of the neonates had pneumothorax or required high-frequency oscillatory V̇e due to PSV mode. Pressure support was set according to the target VT (4–6 ml/kg) for neonates with gestational age >26 weeks, and the Paw was also on the lower limit. The individualized approach toward setting pressure support might have resulted in less incidence of pneumothorax.

Neonates are highly sensitive and are vulnerable to injury, even with a small change in care. Lack of funding to take care of such injuries limited the conduct of a controlled study. PSV being a promising mode for weaning in neonatal V̇e, further studies with a control group should be conducted to provide more substantial evidence.

Conclusion

PSV mode can be safely used as a stand-alone mode for weaning in neonates with appropriate settings and close monitoring. It is not associated with any significant changes in hemodynamic or measured ventilator parameters.

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Conflicts of interest

There are no conflicts of interest.

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