Is pressure support ventilation superior or more physiological as a weaning mode when compared to other conventional modes in the NICU?

Conventionally synchronised intermittent mandatory ventilation (SIMV) has been the most commonly used mode in neonatal ventilation, but other hybrid modes combining volume guarantee (VG) have gained popularity. Pressure support ventilation (PSV) has been shown to be physiologically superior for oxygen cost of breathing in adults and has also been used in paediatric populations. Its use in neonatal ventilation, though not new, is still infrequent. The physiological rationale behind its use has prompted many neonatal units to use it as a weaning mode. This article aims to review how PSV, used in isolation or with VG, compares to SIMV or assist-control when used for weaning ventilation in the neonatal population.

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Key points

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1. The conventional method to wean ventilation has been to reduce pressure and/or rate on SIMV or switch to SIMV from assist-control ventilation.
2. PSV is a flow-cycled mode of ventilation that is being used with increasing frequency due to strong physiological rationale.
3. PSV can be used in isolation or combined with SIMV and VG modes to aid extubation in preterm infants.

The strategies of ventilation in the neonatal population have undergone a change in the last two decades with more emphasis on early non-invasive support such as CPAP, even in the extremes of gestation to reduce incidence of chronic lung disease (CLD). Invasive ventilation has also been revolutionised by the emergence of accurate flow sensors that can sense flow and pressure changes in the airway. Even when invasive ventilation is required, PTV modes, such as ACV or SIMV, are generally preferred over IMV to support spontaneous breathing.

PTV is hypothesised to minimise patient ventilator synchrony. Earlier studies in preterm infants have reported improved gas exchange, ventilation and more consistent tidal volume delivery with synchronised ventilation compared to conventional ventilation.[1-5] Although these modalities appear more physiological, very few studies have shown consistent benefits of one mode over the other. In a Cochrane meta-analysis on synchronised mechanical ventilation for newborn infants, Greenough et al[2] concluded that, compared to IMV, triggered modes are associated with a shorter duration of ventilation (mean difference: −38.30 hours; 95% CI: −53.90 to −22.69). When comparing ACV with SIMV, the authors reported that duration of weaning was reduced in favour of ACV when compared to SIMV but did not reach statistical significance. In this review they also concluded that there were insufficient randomised trials comparing the other modes of ventilation for them to be recommended.

CPAP	Continuous positive airway pressure
PTV	Patient triggered ventilation
ACV	Assist controlled ventilation
SIMV	Synchronised intermittent mandatory ventilation
PSV	Pressure support ventilation
IMV	Intermittent mandatory ventilation
PIP	Peak inspiratory pressure
PEEP	Positive end expiratory pressure
EEV	End expiratory volume
MAP	Mean airway pressure
VG	Volume guarantee
Ve	Expiratory volume

TABLE 1 Ventilation-related abbreviations used in this article.

Pressure support ventilation

PSV is in principle a patient triggered flow-cycled and time-limited mode of ventilation where the ventilator provides a flow to support the triggered inspiration. There is a sharp increase in inspiratory

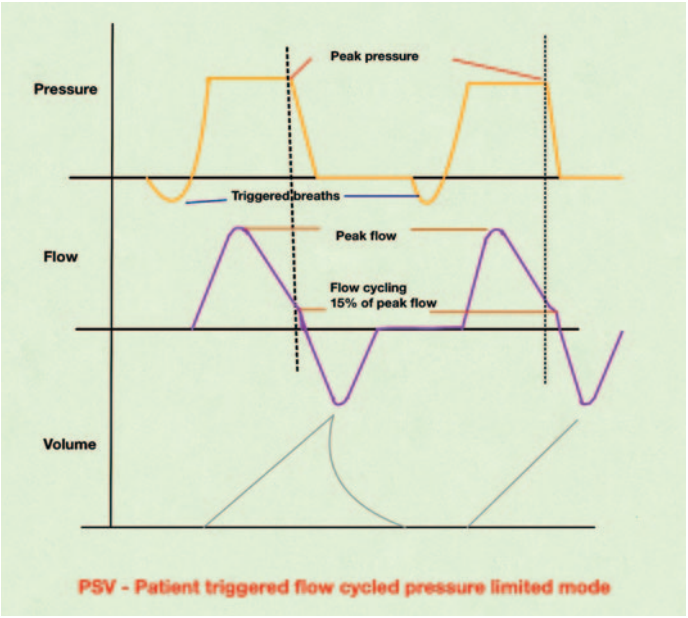

FIGURE 1 PSV mode scalar graphics.

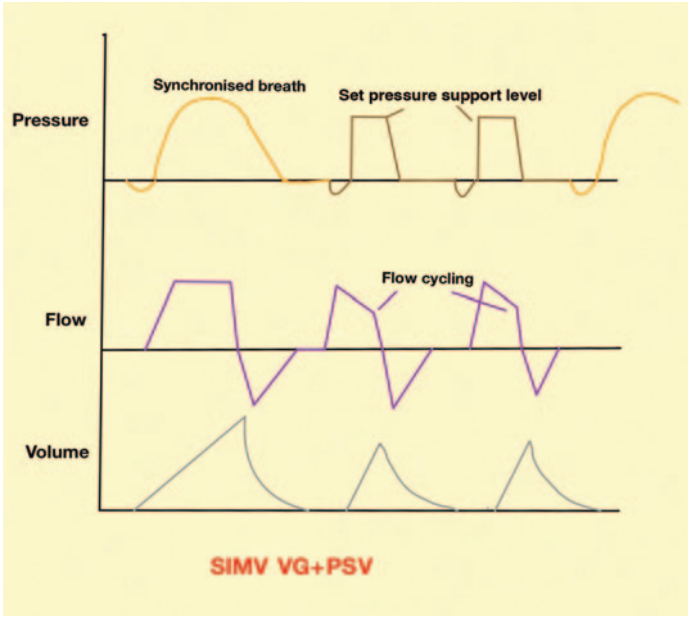

FIGURE 2 PSV combined with SIMV.

flow, which peaks and then decelerates rapidly. At the termination point, inspiratory flow ceases and the breath cycles directly into expiration (**FIGURE 1**). The specific termination point is usually a function of the delivered tidal volume and is almost always when flow has decelerated to 5-15% of peak flow. Inspiratory flow delivery during PSV is variable and is proportional to the patient's effort and pulmonary mechanics. The peak pressure is usually set by the clinician but when PSV is combined with volume targeting (PSV+VG), it varies to deliver the set tidal volume and changes according to compliance of the lung (**FIGURE 2**). PSV is thus a spontaneous ventilation mode in which the patient controls the rate and the inspiratory time. SIMV is used to provide a backup or safety net in the event of patient apnoea or decreased effort; however, PSV may be, and is often, used alone. These physiological benefits might reduce work of breathing and hence be potentially an attractive mode for weaning in the preterm population. In this review we seek to analyse the evidence behind this hypothesis.

Literature search

A literature search was performed of the primary sources Pubmed, MEDLINE and EMBASE using keywords (pressure support ventilation) OR (PSV). Additional filters used were age (up to one month) and type of study (clinical trials and randomised clinical trials, RCTs). Thirty-four unique articles were identified and six are included in this review. Only the RCTs comparing PSV or PSV+VG to SIMV or ACV were selected for inclusion. Reviews and observational studies were excluded. **TABLE 2** summarises the six studies with key conclusions.

Results and discussion

All six studies identified in this review were small single-centre RCTs reporting on a total of 169 infants. Five of these compared the hybrid mode of PSV+VG to SIMV or SIMV+VG (one study), and one study compared PSV to ACV. The outcome parameters compared were a combination of physiological and respiratory, ventilation and clinical. Considering the clinical question, three studies compared weaning time or extubation success between the modes (two SIMV vs PSV, and one ACV vs PSV). None of the studies found any difference in time to extubation. One study (Ozdemir et al[10]) reported on higher reintubation rates in SIMV+VG group when compared to the PSV group and concluded that post-extubation atelectasis might be higher in the former group.

All studies reported on ventilation parameters. There were conflicting results from the studies about PIP and MAP. If one mode is physiologically superior combined to another for weaning, consistently lower peak pressures would be expected. However, two studies (Olsen et al,[8] Nafday et al[11]) reported higher pressures in the PSV group as compared to SIMV. It is to be noted that in both of these studies VG was added in to PSV while there was no VG with the SIMV, which would mean the pressures were decreased manually in the latter mode and were automatically being adjusted according to lung compliance in the other. Also, the study by Olsen et al[8] collected minute-to-minute data instead of a mean data output from the ventilator and this could easily lead to significant fluctuations. The reported tidal volume at the end of the study was, however, lower in the SIMV group as compared to PSV+VG, understandably due to breath-to-breath variations. Two studies reported a significantly decreased PIP in the PSV group (Erdemir et al[7] and El-Moneim et al[12]).

More detailed physiological parameters were looked into in two studies. One of them (Shefali-Patel et al[6]) compared PSV with ACV, and the other compared PSV+VG with SIMV. The former assessed parameters such as work of breathing and thoraco-abdominal asynchrony between two modes and inferred on a non-inferiority of PSV when compared to ACV. The study by El-Moneim et al[12] reported longer periods of rhythmic breathing in the PSV+VG group (p=0.03) when compared to SIMV. Interestingly this group also published a supplement[12] reporting favourable alterations in cerebral blood flow, as evidenced by decreased pulsatility index in the anterior cerebral artery (p=0.002) in infants ventilated on PSV+VG as compared to SIMV.

No studies found any difference in immediate clinical outcomes (eg pneumothorax) or long-term outcomes such as mortality, incidence of CLD and

Citation	Study group	Study type	Outcome	Key result	Comments
Shefali-Patel et al[6]	36 infants, gestational ages ranging from 24-39 weeks (mean 29 weeks) were randomised to AC or PSV for extubation when predefined criteria were met	Single centre RCT	PIP, work of breathing (PTP), TAA, expiration time, duration of weaning and successful extubation were measured as outcome parameters between two groups	There were no differences noted in the outcome physiological parameters at baseline, 24 hours into recruitment and pre-extubation	This was a physiological study aimed at analysing respiratory mechanics during both modes and inferred that if clinicians were aware enough to alter termination sensitivity in PSV based on inflation time, it would not lead to increased work of breathing
Erdemir et al[7]	60 preterm infants <33 weeks' gestation who were requiring ventilation for RDS were randomised to PSV+VG or SIMV group for weaning after surfactant administration	Single centre RCT	Ventilation outcomes: extubation time, weaning variables including PIP, MAP, volume delivered and respiratory rate Neonatal outcomes: IVH, ROP, BPD, etc	No significant difference in weaning time between the two modes PIP was significantly lowered in PSV+VG mode during the entire weaning period No significant difference found in other ventilation variables and neonatal outcomes	This was a small study which inferred that PSV when combined with volume targeting is non-inferior to SIMV for extubation and generates lower peak pressures during the weaning period
Olsen et al[8]	14 infants of 30-37 weeks' gestation were randomised to receive alternative PSV+VG and SIMV for four hours each	Single centre crossover RCT	Primary outcome variable was minute ventilation (Ve) Secondary outcome variables were a/A ratio, EEV and sCdyn	Mean Ve was higher during PSV+VG than during SIMV No differences in the other outcome variables MAP was higher in PSV+VG EEV revealed significant decrease in PSV+VG mode	This was a small cohort that did not have extreme preterm infants. Considering that the MAP was higher and EEV was lower in PSV+VG, the authors could not recommend PSV+VG as a preferred mode of ventilation
Abd El-Moneim et al[9]	25 infants (median 26.1 weeks' gestation) were initially on SIMV and under-went two separate cycles For cycle 1 they were switched to PSV+VG for 30 mins and back to SIMV for 30 mins (ie S-P-S). For cycle 2, the reverse was performed (ie P-S-P)	Single centre crossover RCT	During each 30-minute period several data points were collected including physiological and respiratory parameters	PSV+VG resulted in lower PIP, lower Paw and shorter Ti although they didn't reach statistical significance The infants who remained on PSV+VG showed significantly longer duration of rhythmic breathing, lower PIP, lower Ti	This was a small study but the study group comprised of extreme preterm infants. The authors concluded that with PSV there was greater synchrony between patient and ventilator and lower peak pressures. They inferred that this was a safe and feasible mode of ventilation when used with VG for preterm infants
Ozdemir et al[10]	34 infants <32 weeks' gestation were randomised to SIMV+VG or PSV+VG within the first 12-48 hours of life	Single centre RCT	Ventilation outcomes: PIP, PEEP, FiO_2, MAP and Vt Neonatal outcomes: IVH, ROP, oxygen dependency at 28 days or 36 weeks, post-extubation atelectasis, re-intubaton rate and mortality	The only parameter that reached significance was rate of re-intubation All other parameters were comparable between the two groups	The authors concluded that VG when combined with PSV might lead to lesser extubation failures This was a small study that was not sufficiently powered
Nafday et al[11]	34 preterm infants weighing <1,500g were randomised to either PSV+VG or SIMV in the first 12 hours	Single centre RCT	Ventilation parameters: blood gases and oxygenation index were compared Neonatal outcomes: survival at the time of discharge, incidence of CLD, IVH, PDA, NEC, ROP, air dissection (pulmonary interstitial emphysema, pneumothorax, or pneumomediastinum)	No significant differences were observed in any clinical and outcome parameters Age at extubation was comparable in both groups PIP and MAP at 0 hours and 6, 12, 18 and 24 hours (post-surfactant) were decreased in both groups but rate of decrease was faster in the SIMV group The number of blood gases performed was more for the SIMV group	The authors concluded that PSV combined with VG did not offer any advantage to weaning ventilation in preterm RDS The pressures were decreased faster in SIMV although number of blood gases was more in SIMV because the weaning process was based on blood gases

TABLE 2 A summary of the studies with important conclusions. Key: a/A ratio=arterial/alveolar oxygen tension ratio; AC=assist controlled ventilation; CLD= chronic lung disease; EEV=end expiratory volume; FiO_2=fraction of inspired oxygen; IVH=intraventricular haemorrhage; MAP=mean airway pressure; NEC=necrotising enterocolitis; Paw=airway pressure; PDA= patent ductus arteriosus; PEEP=positive end expiratory pressure; PIP=peak inspiratory pressure; PSV=pressure support ventilation; PTP=pressure-time product (work of breathing); RCT=randomised controlled trial; RDS=respiratory distress syndrome; ROP=retinopathy of prematurity; sCdyn=specific dynamic compliance; SIMV=synchronised intermittent mandatory ventilation; TAA=thoraco-abdominal asynchrony; Ti=inflation time; Ve=expiratory volume; VG=volume guarantee; Vt=tidal volume.

retinopathy of prematurity between PSV and ACV or SIMV. It is worthwhile mentioning that the Cochrane meta-analysis by Greenough et al[13] did not report any difference in outcomes compared between PSV used independently or in conjunction with SIMV, but it did show that in preterm infants with weight between 700g and 1,000g, the days of supplementary oxygen were lower in the SIMV plus PSV group (p=0.034) as compared to SIMV alone.

The triggered modes of ventilation depend on a complex interplay of lung mechanics, patient condition, disease pathology and ventilator sensitivity. Physiologically PSV sounds attractive given the fact that there are less wasted breaths and more patient autonomy. A recent physiological meta-analysis[14] also concluded that when performing spontaneous breathing test methods for extubation, PSV significantly reduced work of breathing and rapid shallow breathing index. But it has to be remembered that in the neonatal population and especially the preterm cohort, such extubation readiness testing is still not conventionally performed and the work of breathing imposed on a neonate when breathing through a high resistance circuit spontaneously with flow cycling has not been extensively tested.

Conclusion

This review finds no evidence to suggest that PSV alone or in combination with volume targeting (PSV+VG) provides any additional advantage over conventionally used SIMV or ACV when weaning the neonate from ventilation. There is, however, weak evidence to suggest its non-inferiority and that it reduces work of breathing. The studies identified were small, improperly powered, diverse in outcomes and also followed varying protocols. The physiological inferences are appealing but more detailed standardised research is required to make a definitive recommendation in its favour.

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