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Synchronous intermittent mandatory ventilation modes compared with patient triggered ventilation during weaning

G Dimitriou, A Greenough, F Giffin, V Chan

Abstract

The efficacy of combining rate and pressure reduction during weaning by synchronous intermittent mandatory ventilation (SIMV) were compared with weaning by patient triggered ventilation (PTV) (pressure reduction alone) in two randomised trials. Regardless of ventilation mode, pressure was reduced to the same level according to the size of the infant. In the first trial, the SIMV rate was also reduced progressively to a minimum of 20 breaths/minute, and in the second to five breaths/minute. Forty premature infants aged 15 days of age or less were randomly allocated into each trial. No significant differences were found in the first trial between ventilation modes in either the duration of weaning or the number of infants in whom weaning failed. In the second trial, the duration of weaning was shorter by PTV than by SIMV (median 24 hours, range 7–432 *v* 50 hours, range 12–500; $p<0.05$); weaning failed in two infants in the PTV group and in five in the SIMV group. It is concluded that weaning by a combination of pressure and rate reduction, such as can be achieved during SIMV, offers no significant advantage over pressure reduction alone.

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Keywords: synchronous intermittent mandatory ventilation, patient triggered ventilation, weaning.

During both patient triggered ventilation (PTV) and synchronous intermittent mandatory ventilation (SIMV), the infant is able to trigger positive pressure inflations, providing respiratory efforts exceed the critical trigger level. In SIMV, however, the number of 'supported' breaths is controlled by the SIMV rate: thus if the infant breathes at a rate of 80 breaths per minute and the SIMV rate is 20 breaths per minute, the maximum number of triggered breaths is 20. A randomised weaning trial comparing PTV and SIMV failed to show a clear advantage of weaning by pressure reduction (PTV) over weaning by rate reduction (SIMV), but neither regimen was universally successful.[1] Those data indicate that further investigation of weaning strategies is necessary; one possible approach would be to decrease both rate and pressure.

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Methods

Preterm infants of less than 35 weeks' gestation and aged 15 days or under were recruited in the recovery stage of their initial respiratory illness into two consecutive weaning studies. All infants were weaned from the ventilator according to the routine protocol[2] until a ventilator rate of 40 breaths/minute was reached. At that stage, all infants were given theophylline or aminophylline (4 mg/kg/day) and transferred to an SLE 2000 ventilator at the same ventilator settings. Random selection to either PTV or SIMV then took place by drawing a card from a sealed envelope. After a 30 minute period of stabilisation, the ventilator was switched over to provide either PTV or SIMV, as indicated by the randomisation card. The ventilator settings were unchanged unless changes were needed to achieve an inspiratory time of 0·3 seconds[3] and a positive end expiratory pressure (PEEP) of 3 cm H_2O (0·294 kPa), which were used throughout the weaning phase. In all cases the trigger sensitivity of the ventilator was set to maximum; this corresponded to a change in the airway pressure of 0·5 cm H_2O (0·049 kPa) or greater, triggering off a positive pressure inflation.[4]

In the first study weaning during SIMV was achieved by a reduction in both pressure (in 2 cm H_2O (0·196 kPa) increments until pressures of ≤16 cm H_2O (1·57 kPa) in infants of weight greater than 2 kg, ≤14 cm H_2O (1·37 kPa) in infants of weight greater than 1·0 kg, and ≤12 cm H_2O (1·18 kPa) but ≥8 cm H_2O (0·784 kPa) in an infant weighing less than 1·0 kg were reached) and rate. Rate reduction was achieved by reducing ventilator rate in steps of five breaths/minute (keeping the inspiratory time constant) until a rate of 20 breaths/minute was reached, when the baby was switched to continuous positive airways pressure (CPAP) delivered via the endotracheal tube. In the second study weaning by SIMV was achieved by a reduction in pressure and rate, as in the first study, but in this study rate was reduced to five breaths/minute before the infant was switched to CPAP. In both studies weaning during PTV was achieved by a reduction in ventilator pressure using the same protocol as pressure reduction during SIMV mode. In all other respects the protocol for weaning followed by the clinicians was similar, regardless of whether the infant was randomly selected to PTV or SIMV. Whichever weaning mode was used, if, after one hour on endotracheal CPAP, the infant was stable and had not developed a respiratory acidosis (pH <7·25), he or she was extubated. The infants were

*Table 1 Characteristics of patients in study 1**

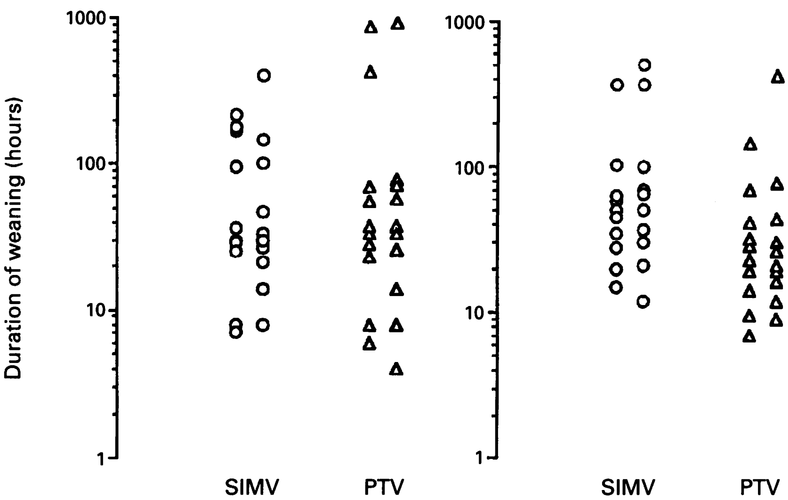
	PTV (n=20)	SIMV (n=20)
Gestational age (weeks)	28 (24–34)	27 (25–34)
Birthweight (g)	1017 (428–2375)	970 (644–2224)
Postnatal age (days)	3 (1–15)	3 (1–14)
Before weaning:		
Maximum peak inspiratory pressure (cm H_2O)	21 (16–39)	20 (16–35)
Maximum inspired oxygen concentration	0·65 (0·30–1·00)	0·53 (0·30–1·00)
Surfactant	13 (65%)	12 (60%)
Patent ductus arteriosus	4 (20%)	6 (30%)
Pneumothorax	1 (5%)	2 (10%)
At randomisation:		
Peak inspiratory pressure (cm H_2O)	17 (11–19)	17 (12–19)
Inspired oxygen concentration	0·27 (0·21–0·59)	0·25 (0·21–0·49)
Before extubation:		
Peak inspiratory pressure (cm H_2O)	12 (8–14)	13 (10–16)
Inspired oxygen concentration	0·28 (0·21–0·40)	0·23 (0·21–0·41)

*Results expressed as median (range) or n (%).

extubated into headboxes and received humidified oxygen at the appropriate concentration (including 21%) for at least 24 hours after extubation. Blood gases were measured every four hours and at least within an hour of making a change to the ventilator settings. The inspired oxygen concentration, ventilator rate, and pressure were decreased as necessary to maintain the PaO_2 between 5·33 and 9·33 kPa and the $PaCO_2$ between 4·67 and 6·67 kPa. Infants were monitored continuously using a Searle intra-arterial electrode or transcutaneous oxygen electrode.

Weaning was considered to have failed if no reduction in ventilator settings could be achieved within 48 hours of trial entry or if the infants needed reintubation within 48 hours of extubation. The indications for reintubation were the development of a respiratory acidosis (pH <7·25) or the occurrence of frequent troublesome apnoeas or one major apnoea. Infants who failed to wean were returned to conventional ventilation.

The trials were analysed according to the original randomisation mode, regardless of whether initial weaning failed. The duration of weaning was the time from randomisation to first successful extubation – that is, maintained for at least 48 hours. Differences between groups were assessed for significance using either a Wilcoxon rank sum test or the χ^2 test, as appropriate.



Duration of weaning according to ventilation mode in study 1 (left) and study 2(right). Individual data and the median (–) for each ventilation mode are shown. ○ SIMV; △ PTV; =indicates a break in the axes.

Randomisation of 40 babies (20 to each method of weaning) into each study permitted detection, with 80% power at the 5% level, of a difference of 24 hours in the duration of weaning between the two regimens.

In the first study the 40 patients had a median gestational age of 27 weeks (range 24–34), postnatal age of 3 days (range 1–15), and birthweight of 975 g (range 428–2375). In the second study the 40 patients had a median gestational age of 28 weeks (range 24–35), postnatal age of 2 days (1–8), and birthweight of 1060 g (range 576–2002).

The studies were approved by the King's College Hospital Ethics Committee.

Results

STUDY 1

There were no significant differences in the characteristics of the patients randomly selected to PTV or SIMV (table 1). The weaning method failed in six infants (median gestational age 26 weeks, range 24–28) in the PTV group and five infants in the SIMV group (median gestational age 26 weeks, range 25–30) (not significant). Four infants in each group failed because of increasing ventilatory requirements and the remaining three infants required reintubation within 48 hours. One infant in the SIMV group developed recurrent apnoea and two infants in the PTV group respiratory acidosis. The duration of weaning in the PTV (median 33 hours, range 4–912) and SIMV groups (median 30 hours, range 7–408) was not significantly different (figure).

STUDY 2

The only significant difference between the characteristics of the patients randomly selected to PTV or SIMV (table 2) was the higher peak inspiratory pressure immediately before extubation in the latter group (p>0·05). The weaning method failed in two infants in the PTV group (25 and 26 weeks, respectively) and in five infants in the SIMV group (median gestational age 25 weeks, range 24–30) (not significant). One infant in the PTV group and two in the SIMV group had increasing ventilatory requirements and the remaining four infants required reintubation. One infant in the PTV group and two infants in the SIMV group developed respiratory acidosis and one infant in the SIMV group developed apnoeas. The duration of weaning was significantly shorter in the PTV group (median 24 hours, range 7–432) compared with the SIMV group (median 50 hours, range 12–500), $p<0·05$ (figure).

Discussion

During SIMV, both rate and pressure were weaned and thus a greater number of steps were performed compared to during PTV weaning. Within an hour of each reduction in ventilator settings our protocol dictates a blood gas measurement and if that shows respiratory alkalosis, further weaning is undertaken. Thus,

*Table 2 Characteristics of patients in study 2**

	PTV (n=20)	*SIMV (n=20)*
Gestational age (weeks)	28 (25–35)	28 (24–32)
Birthweight (g)	1066 (576–1975)	1048 (584–2002)
Postnatal age (days)	2 (1–8)	2 (1–8)
Before weaning:		
Maximum peak inspiratory pressure (cm H_2O)	20 (16–39)	20 (16–27)
Maximum inspired oxygen concentration	0·55 (0·40–0·80)	0·58 (0·30–0·80)
Surfactant	14 (70%)	14 (70%)
Patent ductus arteriosus	4 (20%)	3 (15%)
Pneumothorax	1 (5%)	1 (5%)
At randomisation:		
Peak inspiratory pressure (cm H_2O)	14 (10–20)	14 (11–18)
Inspired oxygen concentration	0·25 (0·22–0·44)	0·25 (0·21–0·69)
Before extubation:		
Peak inspiratory pressure (cm H_2O)	10 (8–14)	11 (8–14)
Inspired oxygen concentration	0·24 (0·21–0·36)	0·24 (0·21–0·35)

*Results expressed as median (range) or n (%).

regardless of randomisation mode, the speed of weaning is tailored to an individual. A shorter duration of weaning was achieved using PTV compared with SIMV in study 2 and as this was not associated with a significant increase in weaning failures, these data suggest it is an advantageous form of weaning.

In both trials the groups were well matched. The only difference between the groups which reached significance was the peak pressure at extubation in the second study. The slightly higher pressure in the SIMV group at extubation was to the advantage of that weaning mode as it could, all other factors being equal, have facilitated a shorter duration of weaning. The difference between the two groups (table 2), however, was very small and unlikely to be clinically important.

Providing the critical trigger level is exceeded during PTV, all of the infant's breaths will trigger a positive pressure inflation. In SIMV, as rate is decreased so the number of the infant's breaths which are supported, are correspondingly reduced. This means that for increasingly longer periods the infant breathes on CPAP through the resistance of the endotracheal tube. This is likely to increase the work of breathing which would have a negative effect on weaning, and in this study we speculate that this was expressed as a longer weaning duration. This hypothesis is supported by data from studies in adults. In pressure support ventilation (PSV) a constant preset positive airway pressure is maintained during each spontaneous inspiration[5] and so is similar to the support provided during PTV. PSV has been shown to reduce the work imposed on the respiratory muscles.[6] Contrasting SIMV with and without pressure support showed the former to be associated with lower oxygen consumption[7] and shorter duration of weaning.[5]

The lack of a significant difference in the first trial in the number of infants in whom weaning failed and in the duration of weaning between the two modes suggests there may be a critical number of breaths (20) which should be pressure supported during weaning from mechanical ventilation. Our data do not show any significant advantage for weaning in SIMV mode versus pressure reduction alone (PTV). The shorter duration of weaning, and smaller number of weaning failures in trial 2 associated with PTV compared with SIMV suggest that PTV should be the preferred weaning method.

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