A HOME - MADE IMV-CPAP SYSTEM FOR DIFFICULT TO WEAN PATIENTS

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Abstract. A continuous, high flow gas was incorporated into the conventional intermittent mandatory ventilation (IMV) circuit attached to the pressure or volume cycled ventilator which had no built-in IMV mode. These created a continuous flow IMV-CPAP system. During the spontaneous breathing period, the gas flow was high enough to raise a 5-6 cm H_2O CPAP level and cause minimal airway pressure fluctuation, an indicator of reduced breathing work. Sixteen patients who were unable to tolerate T-piece weaning were weaned successfully by this IMV-CPAP system. They were medical and surgical patients with prolonged ventilatory support (10-62 days). The respiratory mechanics prior to weaning were relatively marginal. Tidal volume, minute volume and respiratory rate were 260.71 ± 104 cc, 9.71 ± 3.54 LPM and 30.29 ± 5.31/minute respectively. During the weaning course arterial pCO_2 retained gradually to their steady states in chronic CO_2 retaining patients. This resulted in very minimal fluctuations in arterial pH. All patients were weaned successfully with the average weaning duration of 14.19 days.

INTRODUCTION

Intermittent mandatory ventilation (IMV) has been a popular alternate mode of ventilation and weaning (Down *et al,* 1973, 1974; Pierson, 1983). However, variable amount of inspiratory work of breathing was needed during the spontaneous breathing period particularly the demand flow IMV system (Kacmarek and Willson, 1985; Christopher *et al,* 1987). This caused muscle fatique and became a major limitation of IMV weaning. Continuous flow IMV system was later found to result in minimal airway pressure fluctuation and, therefore, less inspiratory work of breathing used (Kacmarek and Wilson, 1985; Christopher *et al,* 1987). Recently, inspiratory pressure support (PS) was introduced as a stand alone ventilatory mode or in conjunction with IMV (MacIntyre, 1986a,b; 1987; Kacmarek, 1988). Several studies demonstrated that PS provided a more balanced pressure-volume change form of muscle work and increased muscle endurance (MacIntyre, 1986a,b; 1987; Kacmarek, 1988). This may facilitate weaning, particularly, in patients with ventilatory muscle weakness. However, the built-in pressure support system was incorporated mainly in the sophisticated and expensive ventilators which were not available elsewhere in the developing countries. We therefore integrated a continuous high flow gas system into the externally attached conventional IMV cercuit. This created a home-made IMV-CPAP system and was tried in a number of patients with weaning problems.

METERIALS AND METHODS

IMV circuit

The conventional IMV apparatus (Hudson RCI, Hudson Respiratory Care Inc CA USA) which is composed of an one-way valve, a gas inlet port and an elastic gas reservoir bag was used throughout the study. These were attached externally to ventilators which had no built-in continuous flow IMV system such as Bird mark 7, Bennett MAI and Bennett 2800 (Fig 1).

CPAP system

The continuous high flow of compressed air was derived from either a variable flow CPAP air compressor (Bennett companion 318) or an air entrained humidifier attached to the flow meter and pipeline compressed air outlet. The F_IO_2 of the humidifier was adjusted to the lowest setting to provide maximum air entrainment and, therefore, highest gas flow. This high flow of air, from the air compressor or flow meter, was the major gas supply to the gas inlet port of IMV circuit. The gas flow rate was adjusted in order to obtain an airway pressure of 5-6 cmH_2O during the expiratory phase of the mandatory breath. This resulted in a continuous flow CPAP system, 5-6 cmH_2O, during the spontaneous breathing period of IMV.

When applying this IMV/CPAP system to the patients, minimal flow of oxygen (3-6 LPM) was fed into the inspiratory pathway of the breathing circuit to provide adequate oxygenation. The point where the nebulizer was located was usually chosen to be the oxygen breed in point (Fig 1). This would provide a continuous flow of aerosol to the patient when water was added to the nebulizer vial and thus help preventing mucosal dryness during the spontaneous breathing period.

Patient population and weaning method

Patients who recovered or improved from various causes of respiratory failure and had been in stable hemodynamic status, but unable to tolerate 5-10 minute conventional T-piece weaning for 3 or more successive days, were enrolled in the study. They were then put on the IMV/CPAP system with the ventilator "sensitivity" adjusted to "control" setting. Initial IMV rate was varied and ranged from 40-80 percent of patients' spontaneous breathing rate. The optimum initial IMV rate was chosen in order to provide best ventilator-patient synchrony and best patient comfort. The rate was then decreased slowly every 1, 2 or more days depending on the patient's breathing ability as evidenced by respiratory mechanics and arterial blood gases. When the patient's was able to do most of the breathing work or needed less than 4 per minute of ventilator rate, he then was placed on T-piece weaning and the ventilatory support was discontinued.

Airway pressure, tidal volume and flow rate during IMV/CPAP breathing were monitored in some cases via a differential pressure transducer respiratory monitor (Bicore® pulmonary monitor model CP-100, CA (Fig 2).

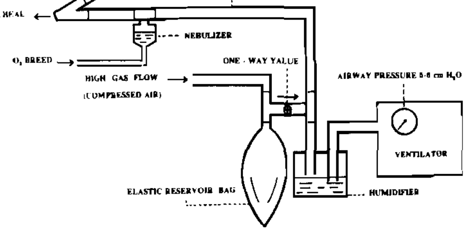

Fig 1–Illustration of an IMV/CPAP circuit using high flow compressed air as the main gas supply to the IMV apparatus while oxygen was kept minimal and bred through the circuit nebulizer.

RESULTS

Sixteen patients who suffer respiratory failure from various causes were enrolled in the study (Tables 1,2). Most of them were adult patients and needed prolonged ventilatory support (10-62 days) prior to the initiation of weaning. The major clinical diagnoses included diseases with previously normal lungs (SLE, CVA, brain injury, sepsis) and chronic lung diseases (COPD, bronchiectasis). Patients' own respiratory mechanics prior to weaning revealed the

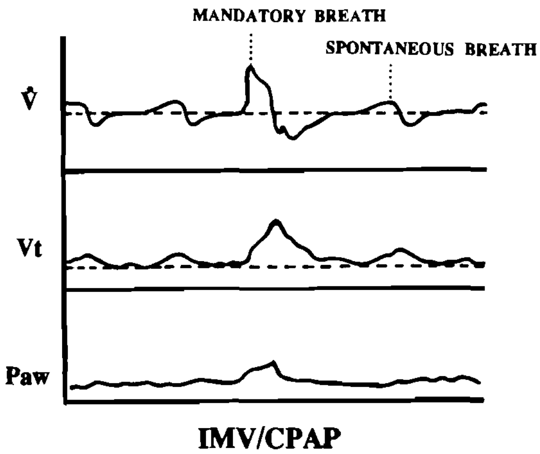

Fig 2–Tracings of airway pressure, tidal volume and flow during IMV/CPAP breathing.
Paw-airway pressure, Vt-tidal volume, V-flow rate
Mandatory breath-breath delivered by ventilator,
Spontaneous breath-patient's own breath

Table 1

Patients' profile.

No. of cases	16
Female : Male	10 : 6
Age (years)	48.9 ± 21.4 (min 12, max 87)
Duration of ventilatory support (days)	25.3 ± 15.2 (min 10, max 62)

Table 2

Major clinical diagnoses.

Disease category		No.
Severe brain injury		
	Confusion	3
	CVA/anoxia	4
	Encephalitis	1
COPD/Bronchiectasis		3 (2)*
Laparotomy, sepsis and multiple organ failure		
	with ARDS	2 (1)*
	without ARDS	2 (1)*
SLE with lung involvement		1 (10*

( )*number of patients with CO_2 retention at recovery

Table 3

Patients' respiratory mechanics prior to IMV.

Tidal volume	260.71 ± 104.11 cc (min 150, max 500)
Minute volume	9.71 ± 3.54 LPM (min 16, max 19)
Respiratory rate	30.29 ± 5.31 per min (min 24, max 44)

average tidal volume, minute volume and respiratory rate of 260 ml, 9.71 LPM and 30/minute respectively (Table 3). At the beginning of IMV/CPAP weaning, the initial IMV rate ranged from 8 to 18/minute (Table 4). During weaning, the amount of oxygen bred into the breathing circuit was kept minimal and ranged from 3 to 6 LPM. The average duration of IMV/ CPAP weaning in this group was 14.19 days (Table 5).

Arterial blood gases during IMV are shown in Table 4. As the IMV rate declined, there was a slight increase in pCO_2 without much alteration in pH (Fig 3). All patients in this series were successfully weaned by this IMV/CPAP system. However, there were three late non-respiratory deaths caused mainly by sepsis and acute renal failure (Table 5). Five patients, two carried chronic lung diseases, showed permanent CO_2 retention at recovery.

DISCUSSION

Weaning from mechanical ventilation is an-important lesson in the scope of respiratory care. Different techniques of weaning were used in different places, depending on the physicans' or therapists' skill (Sahn *et al*, 1976; Pierson, 1983; MacIntyre, 1986a,b). Among them, conventional T-piece weaning is the most popular, reliable and understandable method, and has be-come the basic weaning technique in most places (Sahn *et al*, 1976; Pierson, 1983). Since there is no back up ventilation, such T-piece technique usually calls for more attention or monitoring. Furthermore, switching from full ventilatory sup-

Table 4

Arterial blood gases at various IMV rates.

IMV rate	No.	pH	pCO_2 (Torr)	pO_2 (Torr)
8	6	7.46 ± 0.04	49.83 ± 13.81	87.8 ± 24.64
		(7.38 – 7.48)*	(31.2 – 69.9)	(52.6 – 122.3)
5-6	5	7.42 ± 0.06	50.34 ± 17.18	156.36 ± 67.26
		(7.36 – 7.52)	(27.8 – 73.2)	(61.8 – 246.4)
3-4	3	7.37 ± 0.03	47.03 ± 26.15	79.53 ± 37.66
		(7.33 – 7.39)	(27.7 – 76.8)	(50.5 – 122.1)

NB *minimum to maximum values
Initial IMV rate 8-18/min, mean 9.94 ± 2.59
O_2 bred to the circuit 3-6 LPM, mean 5.0 ± 0.73

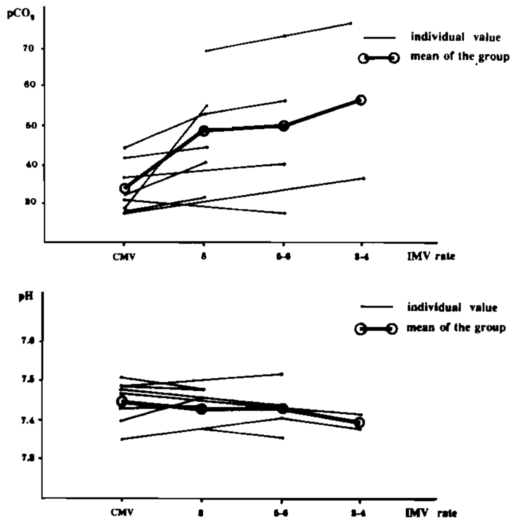

Fig 3–Arterial pCO_2 and pH at different IMV rates.

port to unassisted spontaneous breathing in chronic CO_2 retaining patients such as COPD and neuromuscular disorders usually resulted in a rapid increment of arterial pCO_2. This led to respiratory acidosis, followed shortly by dyspnea and was one of the major causes of weaning failure (Pierson, 1983). Intermittent mandatory ventilation was introduced in the early nineteen seventies (Down *et al,* 1973, 1974). Theoretically, on the breath by breath basis, the more gradual training of respiratory muscles and changes in arterial pCO_2 may lead to more patients' tolerability and favorable outcome (Down *et al,* 1973, 1974; Pieson, 1983). Therefore, IMV was incorporated as an alternate mode in most of the second generation ventilators. However, demand flow IMV systems usually create variable amounts of valve and circuitry resistance, requiring patients additional inspiratory work of breathing (Gibney *et al,* 1982; Kacmarek and Wilson, 1985; Christopher *et al,* 1987). Such magnitude of breathing work becomes a major limitation of IMV weaning, particulary those patients who have neuromuscular weakness or overloaded respiratory muscles secondary to abnormal lungs (Gibney *et al,* 1982; Christopher *et al,* 1987). The currently introduced inspiratory pressure support in conjunction with IMV helped to overcome circuitry resistance, reduce oxygen cost and work of breathing during the patients' spontaneous breaths (Kanak *et al,* 1985; MacIntyre, 1987; Kacmarek, 1988). In the ready to wean lungs, the levels of PS needed are oftenly 5-6 cm H_2O and less than 10 cm H_2O (MacIntyre, 1986a,b; Kacmarek, 1988). This PS concept is now widely accepted and IMV-PS has been used in conventional as well as difficult weaning. Unfortunately, the pressure support systems are mainly incorporated in modern computerized third generation ventilators which are not available elsewhere in developing countries. Our home-made IMV-CPAP system was set up utilizing the already existing simple equipments and intended to reach the two main objective functions: firstly, to create a continuous flow IMV system and secondly, to imitate inspiratory pressure support. Since there was no computer predetermined cessation of gas flow at the end of the inspiratory phase, the design resulted in a continuous flow IMV with adjustable CPAP system. As compared to the demand flow system, both continuous flow IMV and CPAP systems were clearly shown to decrease inspiratory work of breathing (Gibne *et al,* 1982; Christopher *et al,* 1987). With a gas flow equal to or greater than four times minute volumes, the fall in airway pressure during the spontaneous inspiratory phase would be very small (Nunn, 1977). This minimal fall or fluctuation of inspiratory pressure during CPAP has been shown to be associated with decreased work of breathing (Gherini *et al,* 1979). In this study, the gas flow feeding the IMV circuit, by calculation, was equal to or greater than 60 liters per minute. This was an excess flow and was high enough to create a continuous airway pressure of 5-6 cmH_2O during the spontaneous breathing period. Such a high gas flow rate, together with the addition of an elastic reservior bag in the IMV circuit, caused minimal fluctuation of the airway pressure and therefore reduced work of spontaneous breathing (Fig 5). Since oxygenation was not a major problem in most ready to wean lungs, compre-ssed air was used as the main gas supply of the IMV circuit and oxygen bred into the circuit was kept minimal. These combinations, therefore, resulted in an economical IMV-CPAP system.

Table 5

Outcome of IMV-CPAP weaning.

Weaning duration	14.19 ± 6 days (min 5, max 27)
Successful weaning	16 cases
survive at discharge	13 cases
non-respiratory death	3 cases

Patients enrolled in this study were both surgical and medical patients, five of them harbored bad diseased lungs. This, together with the multiple organ involved diseases and severe injured brain, explained the need for prolonged ventilatory support. Prior to IMV, most patients were relatively hypoventilated and had marginal respiratory mechanics. These undoubtedly contributed to the rapid shallow breathing and dyspnea short after unassisted T-piece breathing. With IMV-CPAP, patients' mechanical support was withdrawn slowly, *ie* not more than 2 breaths per minute each day. This caused very small physiologic change, if any, in work of breathing and arterial blood gases. Therefore, respiratory muscle training was more gradual and patients, particulary the chronic CO_2 retainers, reached their final equilibrium states without much fluctuation in arterial pH and pCO_2. The highest CO_2 retaining patient in this study was a case of COPD who had been ventilated for 2 months with multiple unsuccessful T-piece trials. He was finally weaned off the ventilator by this IMV-CPAP system within 20 days, and discharged home with a resting pCO_2 of 76 Torr.

Since the IMV-CPAP system is externally attached to the ventilator, asynchronization between the patient's and ventilator's breaths may occasionally occur. Patients may have the sense of "fighting respirator" and "feeling unpleasant", particulary those with strong respiratory muscles. This IMV-CPAP system is probably suitable and has its specific place in weaning patients with weak muscles, rapid shallow breathing patterns and chronic CO_2 retention. In developing countries where financial support is limited, such simplified and economical IMV-CPAP system may serve as an alternate weaning tool for those difficult to wean patients.

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