CLINICAL EVALUATION OF PRESSURE SUPPORT VENTILATION

K. G. STEWART

Despite the frequent use of pressure support ventilation in patients requiring ventilatory assistance in the intensive care unit, there are few published reports which either confirm clinical benefits from the technique, or suggest the most appropriate machine settings for use. This case report describes a patient who required a prolonged period of ventilatory assistance which was provided in the form of pressure support with no added mandatory ventilator breaths.

CASE REPORT

A 5-yr-old boy (weight 15 kg) underwent cardiac surgery for closure of bilateral modified Blalock Taussig shunts, patch closure of a ventricular septal defect, and right ventricular outflow tract reconstruction using a pericardial gusset. After operation, he required moderate doses of inotropic drugs to control right ventricular failure, underwent a brief period of peritoneal dialysis because of renal impairment, and developed a chest infection. These problems had resolved largely by the 20th day after operation and inotropic support was withdrawn. However, it proved impossible to wean the patient from ventilator support. The surgical repair and cardiac function was judged to be satisfactory by echocardiography, and there was no obvious biochemical reason for the residual respiratory impairment. He was receiving adequate enteral nutrition via a nasogastric tube, and had not received recently any drug likely to cause weakness of ventilatory muscles. A clinical diagnosis of bilateral phrenic nerve palsy was confirmed by ultrasonic diaphragmatic screening.

By day 29 the patient had been weaned to pressure support alone, delivered by a Siemens Elema Servo 900-C ventilator with a humidifying chamber (Fisher and Paykel) placed in the inspiratory limb of the patient tubing. Over the course of the next 26 days his condition remained stable and it was possible to assess the effects of various ventilator settings.

For the main part, the inspiratory pressure was set at 10 cm H₂O greater than positive end-expiratory pressure (PEEP). However, in order to ascertain if further weaning was likely to be successful, each day the pressure support was reduced for varying periods of time. Initially, inspiratory pressure was reduced to 5 cm H₂O on each occasion but, after 5 days, it was decided to reduce the level randomly to any one of five lower settings.

One hundred and four samples were sent for arterial blood-gas analysis during the period of study at the ventilator settings shown in figure 1. All samples were drawn from a radial artery cannula at least 1 h after the most recent adjustment of settings. Thirty-one samples were taken whilst the trigger level (the degree of negative pressure which the patient must generate to activate the inspiratory support of the ven-

K. G. STEWART, B.SC., M.B., CH.B., F.F.A.R.C.S.; Department of Anaesthesia, The Grantham Hospital, 125 Wong Chuk Hang Road, Aberdeen, Hong Kong. Accepted for Publication: February 18, 1989.

SUMMARY

A 5-year-old child required a prolonged period of ventilatory assistance, provided in the form of pressure support ventilation. There was a significant negative correlation between the level of pressure support and the $P_{air}$. Requirements for sedation were reduced with pressure support compared with conventional controlled ventilation. Changing the ventilator trigger level from $-1$ cm H₂O to $-3$ cm H₂O did not affect $P_{air}$. Satisfactory arterial blood-gas tensions were obtained only when the inspiratory pressure was increased to $10$ cm H₂O above positive end-expiratory pressure.
PRESSURE SUPPORT

Sedation was administered as judged necessary by the nurses attending the patient. Requirements were reduced on pressure support compared with conventional controlled ventilation. Before institution of pressure support, the patient had been receiving a low dose morphine infusion (25 µg kg\(^{-1}\) h\(^{-1}\)) and he received a mean of 5.0 supplementary doses of sedatives (midazolam or chloral hydrate) per day. On pressure support, the morphine was discontinued and only chloral hydrate (450 mg via nasogastric tube) was given, in a mean of 2.4 doses per day.

Towards the end of the period of study, the patient demonstrated clinical improvement in ventilatory function. Weaning to CPAP was possible over the course of the next 5 days, and the trachea was extubated on the 63rd day after operation.

DISCUSSION

Pressure support is a form of assisted ventilation whereby modern, microprocessor controlled ventilators augment the inspiratory effort of a spontaneously breathing patient. In response to a patient-initiated breath, the machine increases the airway pressure (Paw) to a constant, pre-set value. During the expiratory phase, Paw decreases to the ambient or the pre-set PEEP level. Although clinical impressions are favourable [1], there are a limited number of published reports evaluating the technique of pressure support. This is partly because of difficulties in obtaining comparable groups of patients in whom controlled studies may be performed. Consequently, most appraisals of pressure support, and of demand valve breathing systems in general, have involved either the study of healthy young adults or the use of simulated models of spontaneous ventilation.

The major disadvantage of demand valve breathing systems is that the negative pressure which the patient must generate to overcome the apparatus inertia and activate the valve may result in an increased work of breathing, as demonstrated by normal subjects breathing through various CPAP delivery systems [2]. Using a model of spontaneous ventilation, a nett reduction in work of breathing was demonstrated when pressure support of 5 cm H\(_2\)O or greater was provided from a Servo 900-C ventilator [3]. In models of spontaneous breathing, any decrease in Paw during inspiration is interpreted as increased work of breathing, and this is quantified by

![Graph showing the relationship between level of pressure support (greater than PEEP) and PaCO\(_2\) (mean, SEM).](https://academic.oup.com/bja/article-abstract/63/3/362/273366)

\[
y = -0.24x + 8.25 \\
r = -0.63
\]

\(n = 10, 8, 18, 11, 8, 49\)

Inspiratory pressure greater than PEEP (cm H\(_2\)O)

Cardiovascular measurements remained stable throughout the study period. Systolic arterial pressure and heart rate was unaffected by the level of pressure support. There was no further evidence of renal insufficiency.

The trigger level did not affect PaCO\(_2\). At a trigger of -3 cm H\(_2\)O, mean (SD) PaCO\(_2\) was 6.36 (1.07) kPa, compared with 6.47 (1.02) kPa when the setting was -1 cm H\(_2\)O.

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analysis of the pressure–volume loop. This may be an underestimate of the increased energy utilization during the short period of airway obstruction, where Paw may decrease greatly, before the demand valve opens and air flow begins. Katz, Kraemer and Gjerde suggested that this extra work of breathing in patients with impaired respiratory function may result in patient distress which cannot be quantified using lung models [4]. For this reason, it is necessary to assess the clinical effects of different ventilator settings in patients with compromised ventilatory mechanics. Rutten and Bersten, using a lung model which simulated spontaneous adult breathing patterns, concluded that a pressure support setting of at least 10 cm H2O was needed to obtain clinical benefit [3]. The present study supported their findings, as at lower settings the assistance provided was not sufficient to enable the patient to maintain a satisfactory PaCO2.

The CPAP circuit which we used delivered a fresh gas flow of 15 litre min⁻¹, which should have been adequate as this exceeded four times minute volume. However, no reservoir was incorporated in the circuit to act as a capacitance, so it is possible that a reduction in Paw did occur at peak inspiratory flow. In a study involving healthy volunteers, Gherini, Peters and Virgilio demonstrated an increased work of breathing with CPAP if Paw decreased during inspiration [5], and this may have contributed to the particularly poor results with CPAP in this case. Additionally, it would have been interesting to use greater CPAP as a comparison, although this was not performed.

It was surprising that the trigger level did not affect PaCO2. The Servo 900-C has an improved inspiratory valve “stepper motor” compared with its predecessor, allowing the ventilator to respond more rapidly to a patient inspiration. Any additional work of breathing at a trigger setting of —3 cm H2O must have been insufficiently significant to produce poorer PaCO2 results.

The question remains unanswered as to whether the use of assisted modes of ventilation may slow the weaning process. In this case, repeated attempts to reduce the pressure support to less than 10 cm H2O resulted in unsatisfactory PaCO2 values. However, the use of pressure support, as opposed to controlled ventilation, allowed a reduction in level of sedation and permitted the patient to continue to exercise his other muscles of ventilation, possibly preventing disuse atrophy.

In conclusion, pressure support has been shown to be an effective technique in assisting the spontaneous ventilatory effort of a patient with diaphragmatic paralysis. This clinical study supports the findings of previous laboratory work which suggested that pressures less than 10 cm H2O greater than baseline are of little benefit. However, controlled clinical studies are required in order to demonstrate any advantage of newer techniques of ventilatory support over the more established methods in terms of eventual outcome.

REFERENCES
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