INTERMITTENT MANDATORY VENTILATION DURING ANAESTHESIA USING THE MANLEY SERVOVENT VENTILATOR

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SUMMARY

The lungs of 25 patients were ventilated with intermittent mandatory ventilation (IMV) during anaesthesia using the Manley Servovent Model MS. This ventilatory mode is especially suitable for prolonged operations in which there is no need for muscle relaxation. While incorporating the advantages of spontaneous and mechanical ventilation, it is superior to both in selected cases. The Manley Servovent Model MS ventilator is capable of delivering IMV without modification, using a single source of gas.

Intermittent mandatory ventilation (IMV) is a ventilatory mode which enables the patient to breathe spontaneously between mandatory mechanical respirations, the rate of which is set according to the efficiency of spontaneous ventilation. The advantages of IMV include ease of weaning from mechanical ventilation (Downs et al., 1973), the continuation of spontaneous breathing during mechanical ventilation without the need for narcotic or myoneural blocking drugs or deliberate hyperventilation, and the ability to use high values of positive end-expiratory pressure (PEEP) without cardiovascular depressions (Kirby et al., 1975).

After finding IMV to be valuable in the intensive respiratory care unit, it seemed worthwhile to assess its potentialities during anaesthesia. The Manley Servovent Model MS ventilator (B.O.C., Medishield, Great Britain) includes the circuitry for this respiratory mode.

MATERIALS AND METHODS

Nine males and 16 females, in the age range 3–71 yr (mean 38.6) and weight range 15–93 kg (mean 59.3 kg) were studied. The patients were undergoing anaesthesia for surgery that did not require profound muscle relaxation (table I). Premedication was with oral diazepam 0.25 mg kg⁻¹ body weight and atropine 0.5 mg or hyoscine 0.25 mg given i.m. Anaesthesia was induced with thiopentone 3 mg kg⁻¹ and maintained with thiopentone 3 mg kg⁻¹ and maintained with 1–2% halothane in 33% oxygen in nitrous oxide using a semi-closed system and a circle carbon dioxide absorber. Tracheal intubation was facilitated with suxamethonium 1 mg kg⁻¹, and the lungs were ventilated using a Manley Servovent Model MS until recovery from the effects of suxamethonium. Tidal volume was 12–15 ml kg⁻¹ and the initial rate 12 b.p.m. The end-tidal carbon dioxide concentration was monitored continuously using a Capnograph analyser (Godart). Following recovery from the initial muscle paralysis the patients were allowed to breathe spontaneously. When end-tidal $P_{CO_2}$ reached 6.7–7.3 kPa, arterial blood was sampled and analysed for $P_{O_2}$, $P_{CO_2}$ and pHa (ABL2, Radiometer, Copenhagen). An initial controlled frequency of 3 b.p.m. (tidal volume 12 ml kg⁻¹) was used, and later increased to achieve an end-tidal $P_{CO_2}$ of 4.5–5.5 kPa. Arterial blood was sampled again. IMV rate was maintained until the surgical procedure neared completion, at which time it was reduced gradually to zero, with the patient resuming spontaneous breathing fully.

Anaesthetic equipment

The Manley Servovent Model MS with a Boyle Mark IV absorber circuit was used in all cases. This volume-preset ventilator is operated by a servo-gas supply delivered from the anaesthetic apparatus. The ventilator incorporates a reservoir bag in direct communication with the patient's airway and the bellows, except during mandatory inspiration when...
the mechanical valve ($V_1$) is closed (fig. 1), and enables the patient to breathe spontaneously or to receive mechanical ventilation from an identical gas mixture. Excess anaesthetic gas and the patient’s expired air leave the circuits through the unidirectional exhaust valve.

![Fig. 1. Schematic drawing of IMV circuit in the Manley Servovent. During mechanical inspiration valve $V_1$ closes, thus excluding reservoir bag R and expiratory valve $V_2$ from the breathing circuit, and directing gas from the bellows to the patient. The patient’s expiratory gas flows back through the now open $V_1$ valve into the reservoir bag R, and through $V_2$ valve to the atmosphere. During spontaneous breathing, valve $V_1$ is open, thus enabling patient to breathe from reservoir bag R. Constant flow of fresh gas, the excess of which is dumped through valve $V_2$, limits rebreathing.](https://academic.oup.com/bja/article-abstract/50/6/583/308708)

**RESULTS**

Mean IMV rate necessary to maintain end-tidal $P_{CO_2}$ in the range of 4.5–5.5 kPa was $6.5 \pm 2.3$ (SD) ventilations per minute. The means of $P_{O_2}$, $P_{CO_2}$, pH, end-tidal carbon dioxide and rate of spontaneous breathing before and after the institution of IMV are presented in table II. In 14 patients, spontaneous breathing ceased after the institution of IMV and reduction of end-tidal carbon dioxide. $P_{CO_2}$, pH and $P_{O_2}$ before and during IMV were compared using the $t$ test. $P_{CO_2}$ and pH changed significantly ($P<0.001$) while $P_{O_2}$ was not significantly different. However, in 15 patients, $P_{O_2}$ increased by more than 1.3 kPa following the commencement of IMV. In six patients $P_{O_2}$ did not change, and in four it decreased (in one case by 8.8 kPa). Throughout the surgical procedure there was no important change in heart rate and arterial pressure in any patient. Supraventricular premature beats occurred in one patient during spontaneous breathing, but disappeared when IMV was initiated and end-tidal carbon dioxide was reduced.

**DISCUSSION**

Intermittent mandatory ventilation (IMV) was introduced originally as a technique of ventilation for infants with respiratory distress syndrome (Kirby et al., 1972) and was used later for weaning older children and adults at the end of a period of mechanical ventilation (Downs et al., 1973). This ventilatory mode resembles an anaesthetic technique of the 1960’s which combined spontaneous breathing with periodic manual hyperinflations.

Spontaneous breathing alone during prolonged halothane anaesthesia leads eventually to hypercarbia as a result of depressed ventilation (Wylie and Churchill-Davidson, 1972). Furthermore, it has been demonstrated that anaesthesia with spontaneous breathing is liable to be associated with an increased alveolar–arterial oxygen gradient as a result of an increase in the volume of trapped air (Don, Wahba and Craig, 1972) and that ventilation with a large tidal volume reversed this trend (Weenig et al., 1974).

Controlled mechanical ventilation during anaesthesia often necessitates the use of myoneural blocking drugs, narcotic analgesics, deliberate hyperventilation or combinations of these. Both neuromuscular blocking drugs and the agents used for antagonizing their action have additional undesirable cardiovascular and secretory activities. The use of blocking drugs

<table>
<thead>
<tr>
<th>Spontaneous rate (b.p.m.)</th>
<th>End-tidal CO$_2$ (%)</th>
<th>$P_{CO_2}$ (kPa)</th>
<th>$P_{O_2}$ (kPa)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>IMV rate</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>34.3</td>
<td>12.07</td>
<td>6.5 ± 2.3</td>
<td>7.34</td>
<td>5.45</td>
</tr>
<tr>
<td>±9.9</td>
<td>±16.0</td>
<td>±0.98 ±0.72</td>
<td>±0.96 ±0.76</td>
<td>±3.5</td>
</tr>
</tbody>
</table>

A = during spontaneous ventilation; B = during IMV.
and narcotics can lead to hypoxia and hypercarbia after operation as a result of either residual muscle paralysis or central respiratory depression. Deliberate or accidental hyperventilation, which is so common in anaesthetic practice, causes acute hypocapnia and alkalalaemia. The possible detrimental effects of respiratory alkalosis include a decrease in cardiac output (Trimble et al., 1971) and cerebral blood flow (Kety and Schmidt, 1948), an increase in airway resistance and a decrease in lung compliance (Monkcom and Patterson, 1972), and an increase in oxygen consumption (Karetzky and Cain, 1970; Khambatta and Sullivan, 1973). Furthermore, there may be difficulties in re-establishing spontaneous respiration, particularly in patients with respiratory disease.

Other potentially detrimental effects of controlled mechanical ventilation are the reduction of venous return and cardiac output in the presence of hypovolaemia; increase of ventilation–perfusion imbalance (Froese and Bryan, 1974); a gradual development of intrapulmonary shunt during prolonged anaesthesia with mechanical ventilation, the shunt responding to periodic hyperinflation (Nunn, Bergman and Coleman, 1965).

IMV incorporates the advantages of both spontaneous and controlled mechanical ventilation and in selected cases may be superior to either, for the management of patients undergoing prolonged surgery which does not require muscle relaxation.

During IMV the mean intrapleural pressure is less than that during controlled mechanical ventilation because of the reduced frequency of positive pressure breaths and the retention of spontaneous ventilation. Thus, IMV causes less impediment to venous return. Similarly, IMV may be the preferred ventilatory mode in association with PEEP during anaesthesia; fully controlled mechanical ventilation with PEEP has been shown to improve oxygenation, but at the price of reduced cardiac output and oxygen transport (Santesson, 1976).

In 14 of 25 patients, spontaneous breathing ceased when end-tidal $PcO_2$ was less than 4.5–5.5 kPa following the institution of IMV, presumably because of the anaesthesia-induced shift of the $P_{ACO_2}$–ventilation response curve to the right (Nunn, 1975). During these periods the patients received controlled ventilation of low frequency. End-tidal carbon dioxide, however, was maintained within normal range, and $P_{A_2}O_2$ was greater than 13.3 kPa in all cases ($FIO_2 = 0.33$; barometric pressure approximately 94 kPa). When the surgical stimulus was increased, or anaesthesia was lightened, spontaneous breathing usually was re-established. This was useful as a sign for judging the depth of anaesthesia. Even when the level of anaesthesia was known to be light there was no problem of “fighting the respirator” and the use of muscle relaxants, narcotics or hyperventilation to achieve control of ventilation was unnecessary.

Some lung ventilators used in anaesthesia have already been modified for IMV (Manson and Ross, 1976; Lawler and Nunn, 1977). The Manley Servovent, however, can provide IMV without any changes, using only one source of gas. Two practical points are worth noting. During both spontaneous and mandatory ventilation the potential for rebreathing exists. In the former situation the patient’s airways are in direct communication with the reservoir bag without the intervention of a unidirectional valve, and in the latter the bellows fill mainly from the reservoir bag (fig. 1). Accumulation of carbon dioxide in the apparatus was prevented in this study by the use of an absorber in the anaesthetic circuit. However, the Bain system has also been found to function satisfactorily in this respect using a fresh gas flow of 100 ml min$^{-1}$ kg$^{-1}$ body weight as advocated for controlled ventilation (Henville and Adams, 1976).

When PEEP is applied, the distal end of a tube connected to the expiratory port is placed under a suitable column of water. Because there is no valve between the patient’s airway and the reservoir bag it is essential to maintain the pressure in the bag at the selected value of PEEP by using suitable flow rates of fresh gas. This tends to facilitate spontaneous inspiration as the patient inhales from a reservoir in which there is positive, not atmospheric, pressure (Nunn, 1975).

REFERENCES


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