Compliance loss in patients on intermittent mandatory ventilation

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Intermittent mandatory ventilation (IMV) can be a useful method of providing respiratory support for patients who require assistance but have some capacity to breathe. The authors present four case studies to illustrate this. They further define the conditions for the patient to be a suitable IMV candidate and highlight the indications that may warn the clinician of impending hypoxemia from ventilation-perfusion mismatch.

Intermittent mandatory ventilation (IMV) is recommended as a controllable way to wean patients from the mechanical ventilator. The patient must, however, be able to sustain normal tidal volumes during the periods of spontaneous effort. Unless this admonition is observed, there will be progressive development of microatelectasis and ventilation/perfusion mismatch, with resulting hypoxemia.

Total static compliance measurements are helpful in identifying patients for whom intermittent ventilation is ill-advised. Four case summaries are presented of patients who did not tolerate intermittent ventilation, and showed deterioration of their blood gas values. Each represents a different type of respiratory failure.

Case 1 focuses on a patient with a brainstem injury and failure of central respiratory cycling. Case 2 exemplifies neuromuscular failure where the patient, suffering from Guillain-Barré syndrome, is too weak to breathe. Cases 3 and 4 illustrate instances where the work requirement of breathing has become excessive. Case 3 consists of a patient with a ruptured aortic aneurysm who developed stiff lungs postoperatively; the primary problem was compliance loss. Case 4 involves both a decrease in compliance and an increase in airway resistance due to mucus accumulation; the patient had an acute exacerbation of chronic obstructive pulmonary disease (COPD) following drug overdose.

In each instance, failure of intermittent ventilation was clearly presaged by a decrease in total static compliance.

Method

At the hourly, routine check on ventilator cases, those on IMV had measurements of total static compliance. The mandatory breaths, in all instances, were delivered from a constant flow generator (Bennett MA-1). The tidal volume was read from the spirometer and corrected for tubing compliance. The system pressure at zero flow (plateau pressure) was read with the patient on inspiratory hold.

The corrected tidal volume divided by the plateau pressure was recorded as the total static compliance. The differ-
ence between the maximum inspiratory pressure (peak pressure) and the plateau pressure was recorded as an index of airway resistance.

Case 1
A 25-year-old woman sustained a basal skull fracture and brainstem concussion in an automobile accident. Continuous mechanical ventilatory support was required. Considerable improvement occurred during the first week of hospitalization. Spontaneous movement of all four extremities was restored, and ocular reflexes returned to normal.

IMV was begun at a mandatory rate of 6/min, about one-third of her spontaneous rate. After 24 hours, the rate began to rise and eventually reached 30/min; asynchrony became increasingly evident. The total static compliance, which had been 50 ml/cm H₂O, fell to 25 ml/cm H₂O. Arterial blood gases were drawn and showed: pH 7.32, PaCO₂ 36 mmHg, PaO₂ 55 mmHg (FiO₂ 0.4). A chest film revealed basal infiltrates.

Continuous ventilation was reinstituted and antibiotic therapy begun. The patient was weaned one week later and eventually made a complete recovery.

Case 2
A 34-year-old man was admitted complaining of progressive weakness of the lower extremities about 10 days following a flu-like illness. The paralytic level rose rapidly, and continuous ventilation was begun 48 hours later. A tracheostomy was performed the following day. His paralysis continued to worsen for another week, then began to improve.

On the 22nd postadmission day, he apparently had recovered sufficiently to be placed on IMV at a rate of 8/min. Within 12 hours, this was shown to be premature. Total static compliance measurements showed a rapid decline from 70 ml/cm H₂O to 33 ml/cm H₂O. The PaO₂ on 40% oxygen was 48 mmHg, and patchy densities appeared on the chest x-ray.

Parenteral chloramphenicol was begun. Four more days on continuous ventilation were necessary before the lung fields cleared and the weaning process could be resumed.

Case 3
A 74-year-old man required an emergency aortic resection and graft for a leaking aneurysm. He was markedly hypotensive for at least 2 hours, and postoperatively did not produce more than 100 ml urine during the next 48 hours. The following day both of his legs became cold, pulseless, and cyanotic. He was again taken to surgery, the graft site was re-explored, and clots were removed from both femoral arteries.

Continuous mechanical ventilation was employed throughout this period, as well as for a total of 6 days following the original operation. Increments of PEEP were applied up to 12 cm H₂O to improve oxygenation. On the 7th postoperative day, the PEEP was removed. The arterial blood gases on 40% oxygen were: pH 7.43, PaCO₂ 34 mmHg, PaO₂ 81 mmHg. He was placed on IMV with a support rate of 6/min.

The next day, he spiked a temperature of 39° C. Total static compliance fell from 40 to 22 ml/cm H₂O in a 3-hour period. Breath sounds diminished in both lower lobes, and basal infiltrates appeared on the chest x-ray. Continuous ventilation was again started, and gentamicin administration was begun. By the 9th postoperative day, the infiltrates were diminishing and total static compliance had risen to 38 ml/cm H₂O.

On the 11th day, he had a vital capacity of 1500 ml and a negative inspiratory pressure of 32 cm H₂O. He was again placed on IMV at a mandatory rate of 8 breaths per minute. This was gradually decreased; and on the 13th day, extubation was performed. No further respiratory support was necessary. Treatment of renal insufficiency required another 3 weeks in the hospital.

Case 4
A 58-year-old man was found co-
matose in a hotel room. Several empty wine bottles were on the table and floor. On admission to the hospital, his blood gases on room air were: pH 7.27, PaCO₂ 68 mmHg, PaO₂ 38 mmHg. The chest film revealed a bilateral bronchopneumonia involving all five lobes.

Intubation was performed and continuous mechanical ventilation was provided. The pneumonia was shown to be of the mixed gram-negative variety, and responded slowly to antibiotics (cefazolin and gentamicin). The patient regained consciousness within 4 hours, but required serial doses of diazepam to control restlessness due to alcohol withdrawal.

On the 8th day after admission, he was fighting the ventilator, and showed some capacity to breathe spontaneously. IMV was begun at a rate of 6/min. Frequent suctioning was required for removal of secretions. Bronchial irritability and persistent efforts to cough interfered markedly with the mandatory breaths. The total static compliance declined from 45 to 20 ml/cm H₂O within 8 hours. The peak-plateau pressure difference increased from 8 to 25 cm H₂O, indicating a marked rise in airway resistance.

Continuous ventilation was resumed; the patient was sedated heavily with diazepam, and paralyzed with pancuronium. Fiberoptic bronchoscopy was performed every day for the next 5 days. Weaning was successfully accomplished on the 14th postadmission day; IMV was not employed.

Discussion

Intermittent mandatory ventilation was originally proposed as a way to bridge the period of transition between mechanical and spontaneous breathing. With the newer modalities of synchronized IMV (SIMV) and intermittent demand ventilation (IDV), a comfortable and satisfactory period of partial support can easily be provided. A mechanical continuum between fully controlled and spontaneous ventilation is now available, which allows a complete spectrum of ventilatory patterns to be chosen, depending on the needs and capabilities of the patient.

It is now feasible to institute IMV at any time during the episode of respiratory insufficiency. An indication of increasing prominence is patient-ventilator asynchrony ("fighting the ventilator"), where machine control can be achieved only with the use of central depressant drugs or neuromuscular blocking agents. Patients who can actively interfere with the imposed ventilatory pattern obviously possess some capacity to breathe spontaneously. If they can generate normal tidal volumes for periods of several minutes without undue dyspnea, tachypnea, or periodic respiration, IMV should be considered as an alternative to continuous ventilation accompanied by pharmacologic control.

The patient on IMV retains two important physiologic attributes. First, the rhythmic excursions of the muscles of respiration are continued. Often, a significant impediment to weaning is lack of coordination between contractions of the diaphragm and intercostals. Second, there is no interference with venous return to the heart (except during the mandatory breaths), and normal hemodynamics can be maintained, despite changes in circulating volume or peripheral vascular tone.

IMV should be maintained only if tidal volumes generated by the patient's spontaneous efforts are undiminished. Experience has shown that periodic sighing of the patient (with volumes of 15-20 ml/kg) is often ineffective in preventing the development of atelectasis. The same reasoning applies with the use of IMV. Unless spontaneous breathing is sufficient to maintain lung expansion, the positive pressure of the mandatory cycles cannot be depended upon to open small airways and collapsed alveoli.

It should be emphasized that intermittent ventilatory techniques require the same continuous monitoring and expert surveillance necessary for contin-
uous controlled or assisted respiration. If the patient shows signs of progressive exhaustion, if marked changes in compliance or airway resistance develop, or if apneic intervals occur, the risks of IMV become prohibitive, and continuous ventilatory support must be instituted without delay. A high index of suspicion can be directed toward those cases where the patient's total static compliance values are decreasing.

REFERENCES

AUTHORS
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