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Unilateral high frequency jet ventilation

Reduction of leak in bronchopleural fistula

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Abstract. A young alcoholic presented with severe bilateral bronchopneumonia, which required prolonged treatment with intermittent positive pressure ventilation. High airway pressures were necessary for effective gas exchange. A recurrent tension pneumothorax led to a persistent bronchopleural fistula which resulted in hypercarbia and hypoxaemia despite the use of large minute volumes. Surgical resection was not considered feasible because of extensive local infection. Asynchronous independent lung ventilation was instituted, using a double-lumen endobronchial tube. A considerable leak still occurred through the bronchopleural fistula, and it was only when high frequency jet ventilation was substituted to the fistula-containing lung that the leak was virtually abolished, while improving gas exchange. High frequency jet ventilation in bronchopleural fistula is of potential benefit.

Key words: Airway pressure – Barotrauma – Bronchial fistula – Pneumothorax

A persistent bronchopleural fistula (BPF) is a serious complication of chest injury, thoracic surgery, suppurative lung disease and pulmonary barotrauma, mortality ranging from 10% at least in adults [5] to 30% in neonates [2]. In patients requiring intermittent positive pressure ventilation (IPPV) because of inadequate pulmonary function, ventilatory management is challenging because the increased airway pressure invariably increases the proportion of inspired gas which escapes through the fistula, resulting in arterial hypoxaemia and hypercarbia.

Although asynchronous independent lung ventilation (AILV) is useful in patients with predominantly unilateral pulmonary pathology, high frequency jet ventilation (HFJV) is a new approach to the management of bronchopleural fistula. The delivery of low tidal volumes at frequencies of sixty or more breaths per minute is associated with reduced peak and mean airway pressures and improved distribution of inspired gas compared with IPPV.

In this case IPPV was applied to the lung without the fistula and HFJV to the lung with the fistula.

High frequency jet ventilator

The high frequency jet ventilator used was modelled on the device described by Carlon et al. [1]. Hospital pipeline air and oxygen are supplied to the ventilator through a quantiflex air/oxygen blender at a pressure of 4 kPa × 100 (Bar), reduced to 3 kPa × 100 (Bar), by a pressure regulator. The gas mixture is pulsed by four electronically operated solenoid valves which allow changes in ventilator tidal volume, frequency and I:E ratio. The pulsed gas is delivered to the patient through noncompliant tubing via a nozzle seated in a T-piece. Humidification is provided by directing air from a blower humidifier aross the T-piece.

Case history

A 35-year-old 68-kg male alcoholic presented with severe bilateral bronchopneumonia. IPPV with an inspired oxygen fraction (F_1O_2) of 0.6 and a positive end-expiratory pressure (PEEP) of 10 cm of water were required to maintain arterial oxygen saturation greater than 90%. A left-sided tension pneumothorax occurred which despite continuous drainage of the pleural space developed into a persistent BPF. Surgical closure was considered impracticable in the face of the extensive infection. Peak airway pressures of 80 cm of water and minute volumes of 17 – 20 l were required to prevent hypercarbia, a leak occurring

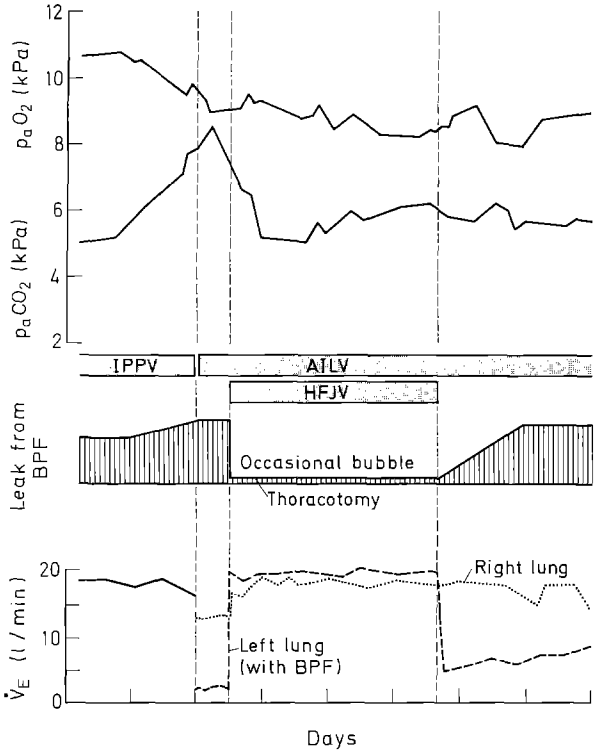

Fig. 1. Diagram showing blood gas analysis (top), expired minute volume (V_EL/min) and leak from BPF (represented schematically) during ventilatory management. Closure of the BPF at thoracotomy is indicated by the *arrow*

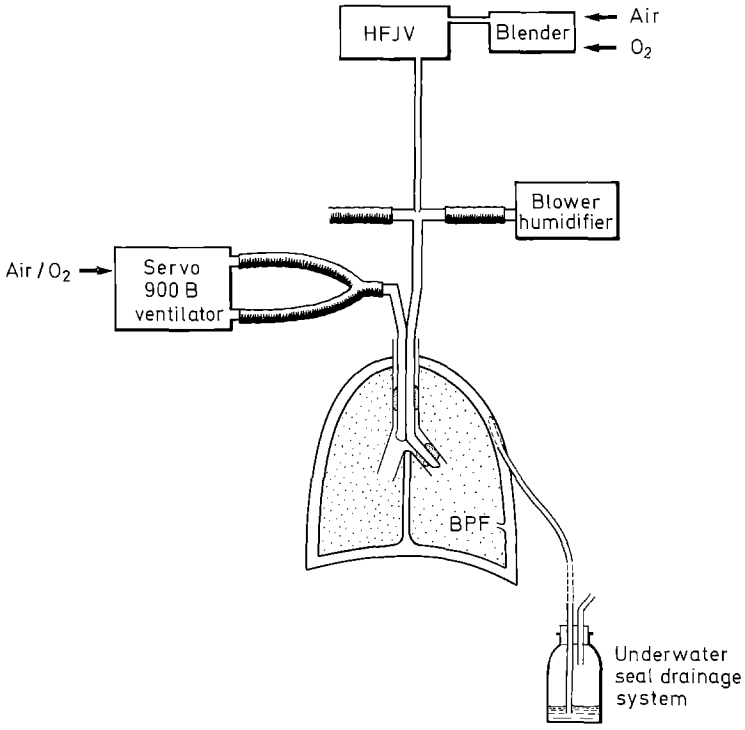

Fig. 2. Schematic diagram to show method of asynchronous independent lung ventilation with high frequency jet ventilator on side of BPF-containing lung

through the BPF of 2–8 l/min depending upon patient position. After 22 days without improvement despite antibiotics, gas exchange began to deterioriate further and it was decided to employ AILV, using a different ventilator for each lung.

A disposable left-sided double-lumen endobronchial tube (Portex 6.0 mm + 6.0 mm) was inserted, and a Servo 900B ventilator (Siemens-Elema) connected to the right lumen; a volume preset positive pressure ventilator (Oxford) was connected to the left lumen. The right lung (without BPF) was ventilated with a tidal volume of 700 ml at a frequency of 24 per minute, using an F_IO_2 of 0.6, PEEP of 10 cm of water and, as before, generating peak airway pressures of 80 cm of water. The left lung (with BPF) was ventilated with a tidal volume of 350 ml at a frequency of 12 per minute, using an F_IO_2 of 0.6 and generating peak airway pressures of 45 cm of water.

After 12 h, the leak from the fistula was unchanged and hypercarbia persisted (Fig. 1). It was therefore decided to substitute HFJV for the Oxford ventilator on the side with the BPF, and at once the leak was virtually abolished, only an occasional bubble escaping. (Fig. 2). An F_IO_2 of 0.6 was used for the pulsed gas, at a frequency of 60 per minute and I:E ratio of 1:2; gas exchange was less effective at higher frequencies. The arterial $PaCO_2$ returned to previous values and oxygenation remained adequate (Fig. 1). Blood pressure and pulse were unaffected by this manoeuvre.

Surgical closure of the BPF was attempted two days later. Thoracotomy revealed a large necrotic abscess cavity which was debrided, and the fistula in its base oversewn. Post-operative ventilation continued with HFJV for two more days when it had to be discontinued for technical reasons. The reintroduction of the Oxford ventilator was followed almost immediately by the reappearance of the bronchopleural leak.

The intervention of further septicaemia with hepato-renal failure unfortunately led to the patient's death 8 days later.

Discussion

Pulmonary barotrauma is a common complication of IPPV. A pulmonary leak that continues unchanged for more than a few days carries a particularly poor prognosis, indicating failure of normal healing. Resection of the damaged portion then offers the only effective solution.

We managed the ventilation of this patient by increasing the minute volume sufficiently to prevent hypercarbia. However, this became progressively ineffective as further increases in minute volume increased the leak without producing any significant rise in alveolar ventilation.

Several techniques for reducing the leak across a BPF have been described [4], whereby intrapleural pressure is raised to reduce the gradient between the airways and pleural cavity. We used AILV initially in this patient, as described recently in the management of unilateral massive air leak [3], but found that while hypercarbia was reduced, the bronchopleural leak was undiminished despite the substitution of reduced minute volumes and airway pressure to the lung with the fistula. When HFJV was introduced to this lung, the leak was abolished and blood gas values improved. The leak recurred rapidly when IPPV was resumed.

The potential benefits of HFJV in the ventilatory treatment of BPF are probably twofold. Firstly, as low mean airway pressures are generated, the fistula has an opportunity to heal because the leak is reduced or abolished. Peak airway pressure is known to be reduced as much as fivefold during HFJV, although we have no measurements of this in the present case. Secondly, improved distribution of ventilation allows adequate alveolar ventilation despite the use of low tidal volumes.

HFJV clearly has a useful role in the ventilatory management of BPF. It has mostly been used in frequency range of 60 – 120 breaths per minute. There is great scope for further investigations into the relationships between respiratory frequency, peak and mean airway pressures, bronchopleural leak and gas exchange.

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