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Effects of high-frequency jet ventilation on intracranial pressure in experimental head-brain injury

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Abstract

Based on experimental studies, ventilation with small volumes of gas and rates of up to 100–400/minute, high-frequency jet ventilation (HFJV), seems to present a true alternative to conventional intermittent positive pressure ventilation (IPPV), especially in patients with multiple organ damage.

In order to determine the effects of high-frequency jet ventilation on intracranial pressure, we examined the effects of the HFJV in comparison to conventional ventilation in experimental balloon brain trauma. Ten young pigs were studied using continous invasive hemodynamic, pulmonal, and intracranial pressure monitoring. There was no increase in brain pressure over normal ventilation. As a matter of fact, there was a temporary decrease of the intracranial pressure by about 5 mmHg, which returned to the initial pre-HFJV value after 5 minutes. In contrast to conventional ventilation, HFJV allows for tracheobronchial suctioning and interruption of ventilation without any noticeable increase of ICP.

Keywords: Head-brain injury, high frequency jet ventilation, intracranial pressure, pigs.

1 Introduction

Based on experimental studies [2, 7, 10, 12], ventilation with small volumes of gas and rates of up to 100–400/minute, high-frequency jet ventilation, seems to present a true alternative to conventional intermittent positive pressure ventilation (IPPV). In this type of ventilation, gases under high pressure are delivered in short bursts into the patient's airways.

High frequency jet ventilation has been used successfully for intensive care, mainly of patients with thoracic cavity and multiple injuries, and for adult respiratory distress syndrome [1, 4, 5, 8, 9, 10, 13, 14].

To determine the effects of high-frequency jet ventilation in patients with cerebral trauma, experimental studies seemed necessary. Thereby, we examined the effects of different types of jet ventilation, as compared to conventional IPPV, particularly in connection with the treatment of craniocerebral injuries with concurrent pulmonary or thorax injuries.

2 Material and methods

Ten young pigs, weighing 20–30 kg, were studied. The pigs were anesthetized with piritramide 4 mg/kg, paralyzed with pancuronium bromide 0,6 mg/kg i. v., and intubated with a 12 mm diameter cuffed endotracheal tube. Supplemental doses of piritramide and pancuronium were injected as needed.

A 16 gauge catheter was placed in the upper vena cava for infusion and central venous pressure measurement. Catheters were inserted in both femoral arteries for arterial pressure monitoring and for blood–gases analysis. Invasive hemodynamic monitoring was achieved by using a 7 French Swan Ganz thermodilution catheter (American Edwards Colaboratories, Santa Ana California). Intracranial pressure was monitored by an epidural Gaeltec pressure sensor (Medical Measurements Inc., Hackensack).

To measure airway pressure, a 14 gauge catheter was inserted into the tracheal tube with the tip at the bronchial bifurcation. To measure the pleural pressure, a 16 gauge cannula was inserted into the intrapleural space. After stabilization of the intracranial pressure over 30 minutes, an experimental head injury was performed. A 14 charrier urine-catheter was introduced epidurally through a burrhole, and was instilled into the cuff. The burrhole was placed 2 cm in front of the biauricular line and 2 cm lateral to the midline. All animals were ventilated by conventional means both during and for one hour following the injury. Thereafter, ventilation techniques were varied. Five pigs were ventilated mechanically, and then were hyperventilated to a PA CO_2 = 25 mmHg (Servo-ventilator, Siemens). The remaining 5 pigs were ventilated with a high frequency jet ventilator which was connected to a humidifier (Acutrom MR 800, Stimotron). Respiratory rates and driving pressures were set between 50 and 250. Inspiratory time was 30% of the respiratory cycle. Oxygen and nitrogen were supplied through a 14 gauge cannula which was inserted into a three-way swivel adapter and affixed to the endotracheal tube.

3 Results

3.1 Mechanical conventional ventilation

Under mechanical ventilation, the circulatory and pulmonary functions were stable, with balanced blood gas values of PA CO_2 40 mmHg and PA O_2 in excess of 200 mmHg. Under hyperventilation, the circulatory parameters remained stable, with a slight increase in pulmonary pressure and blood gas values of PA CO_2 around 26 mmHg, PA O_2 240 mmHg, and PH of 7.6.

Intracranial pressure response (ICP): The normal initial ICP – value was 10 mmHg. It increased to far beyond 50 mmHg following the injury and later dropped exponentially to an average of 20–25 mmHg (Figure 1). Under conventional hyperventilation, an additional decrease of 5 mmHg was observed, as compared to conventional ventilation.

3.2 High-frequency jet ventilation

Various frequencies and ventilation volumes were tested. The optimal setting for the jet generator was found to be frequencies around 150/minute and a pressure of 1.0 bar. Under these conditions the re-

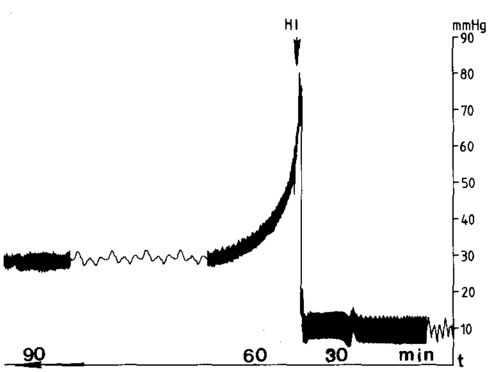

Figure 1. ICP – response after the instillation of 3 ml NaCl in an epidurally introduced ballon-catheter (HI) during conventional mechanical ventilation.

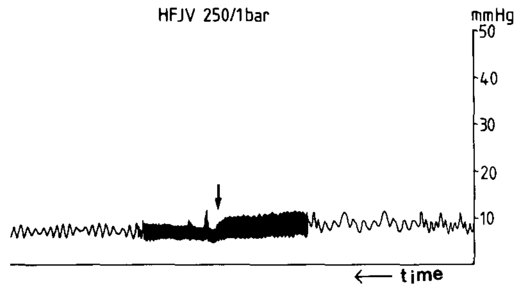

Figure 2. Without head brain injury, HFJV with a frequency-rate of 250 produces no negative side effects.

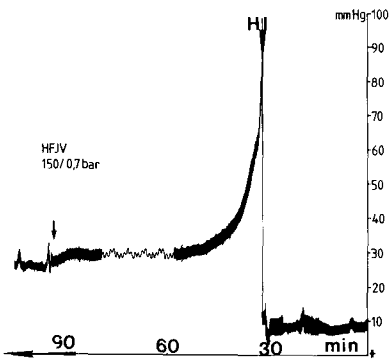

Figure 3. Epidural ICP–monitoring after HI: One hour after the brain injury the pig was treated with high frequency jet ventilation. A temporary decrease of ICP can be observed.

spiratory-minute-volume is approximately 7 l, with a tidal volume of 46 ml at an inspiration rate of 30%. Ventilation was performed with an oxygen-nitrogen mixture of 50:50.

No increase in brain pressure was noted when comparing HFJV to normal ventilation (Figure 2). As a matter of fact, there was a temporary decrease by about 5 mmHg with a return to the initial pre-HFJV value after 5 minutes (Figure 3). In contrast to conventional ventilation, HFJV also allows for tracheobronchial suctioning and interruption of ventilation without any noticeable increase of ICP.

Blood gas values were found to fluctuate with frequencies below 100 or above 400. However, an excessive increase in brain pressure values was noted, especially for frequency rates in excess of 200, with a driving pressure of less than 1.0 bar (Figure 4). With the above setting of 150/1.0 bar the hemodynamic variables and pulmonary variables stayed within the normal range with a PA CO_2 around 36 mmHg and oxygen values higher than PA 170 mmHg.

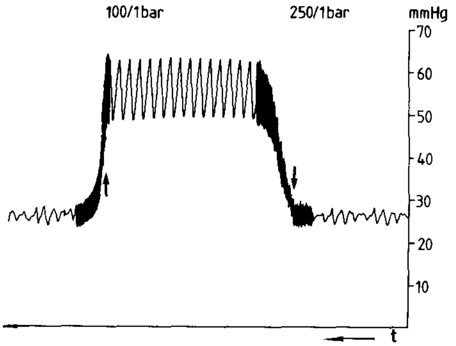

Figure 4. After trauma, HFJV (250/1 bar; cf. Figure 2) leads to excessive intracranial pressure elevation.

4 Discussion

A ventilation process which avoids excessive intrathoracic peak pressures is of special interest to the neurosurgeon. HFJV has provided excellent results in comparison to conventional ventilation in the treatment of acute respiratory failure and/or multiple injuries with significant pulmonary pathology. Quite often, overpressure ventilation with positive endexpiratory pressures are required for the treatment of multiple injuries including significant pulmonary injury. In most cases this leads to major increases in ICP. With HFJV, good oxygenation is achieved without the unfavorable effects of conventional positive pressure ventilation [6, 13]. Effects on the circulatory system are minimal and the risk of barotrauma is notably reduced [3, 4, 8, 9].

With this method only a short temporary drop in intracranial pressure is noted in head-brain injuries.

5 Conclusions

Our studies and existing research in the field of HFJV for experimental head-brain injuries show that the use of high frequency jet ventilation is worth considering for patients with multiple system organ injuries since it avoids the high respiratory pressures often required by conventional hyperventilation.

Continuous brain pressure readings should be taken and frequent blood gas analyses should be performed on a regular basis in order to optimize ventilation with high frequency jet ventilation.

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