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High-frequency jet ventilation – a review of its role in laryngology

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Abstract

High-frequency jet ventilation (HFJV) is a safe, effective anaesthetic technique with a low risk of aspiration which has not yet gained wide acceptance in laryngology. Following anaesthesia and muscular relaxation the patient is intubated with a size 7FG infant feeding catheter and ventilation is achieved by delivering small bursts of anaesthetic gas at high frequency. The mechanisms of gas exchange are thought to be little different from those of conventional ventilation. We have found HFJV to be of value in laryngoscopy, laryngo-tracheal reconstruction, tracheoplasty, bronchoscopy and tonsillectomy.

The advantages include:

(a) ease of intubation, especially in the presence of a supraglottic mass;

(b) improved surgical access compared with a conventional endotracheal tube; and

(c) protection of the airway by the inherent 'auto-PEEP' effect. Care must be taken to ensure that conditions allow adequate exhaust of expired gas. Humidification of inspired gas is essential during prolonged procedures.

Key words: High-frequency jet ventilation; Anaesthesia; Laryngoscopy

Introduction

Direct examination and surgical procedures involving the larynx require close cooperation between the anaesthetist and the laryngologist as a balance must be achieved between adequate surgical access and safe, effective ventilation. High-frequency jet ventilation (HFJV) has been an established anaesthetic technique for over 13 years (Babinski *et al.*, 1980) but has failed to gain the more widespread acceptance enjoyed by low-frequency Venturi ventilation using the Sanders injector (Sanders, 1967). High-frequency jet ventilation involves the delivery of small volumes of gas through a narrow catheter placed in the trachea via the nose or mouth causing minimal obstruction to the surgical field. Percutaneous trans-tracheal HFJV has also been described (Boucek *et al.*, 1987).

Method

Following adequate premedication, the patient is pre-oxygenated and noninvasive blood pressure, pulse oximetry and electrocardiograph monitoring are applied. In our practice, anaesthesia is induced with propofol, the dose being titrated against the response, and muscular relaxation is achieved with vecuronium (0.1 mg/kg). The patient is then intubated with a size 7 French gauge (FG) infant feeding catheter. We have found intubation to be both easier and quicker using the Bullard laryngoscope rather than the Mackintosh laryngoscope (Mendel and Bristow, 1993). A second catheter is introduced to measure the end-tidal pCO_2 which is maintained in the range 4.5–5.3 kPa by adjusting the driving pressure of the jet ventilator. High frequency small volume bursts of gas are delivered at pressures varying between 0.4–2 bar, (usually less than 1 bar). The volumes are small (2–3 ml/kg) compared with intermittent positive pressure ventilation (6–10 ml/kg). The ventilation frequency varies between 60 and 300 cycles per minute.

Additional anaesthetic gases may be entrained from a low-pressure circuit. Unfortunately it is difficult to control the inspired, entrained, gas tensions because of patients' unpredictable and varying pulmonary compliance (Smith, 1990a). Moreover the need for an endotracheal tube may obscure the surgical field. We therefore employed a total intravenous anaesthetic technique (TIVA) using an infusion of propofol to maintain anaesthesia. The ventilator has a facility for humidification during long procedures.

When the surgical procedure is complete, neuromuscular blockade is reversed with neostigmine and glycopyrronium. The catheter may be left *in situ* without discomfort until the patient is fully conscious. If laryngospasm develops, the catheter can be reconnected to the ventilator and HFJV restarted (Mendel, 1992). No sedation is necessary, unlike conventional ventilation, but considerable care is required to ensure that the vocal folds are not fully adducted. In this event inadequate exhaust of gases through the larynx may lead to pulmonary barotrauma.

Mechanism

Theories regarding the mechanisms of gas exchange

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are controversial but may be little different from those of conventional ventilation. Lung volume is increased by the injection of gas from the ventilator, but such increase is limited by the expiratory flow which creates a positive end expiratory pressure (PEEP) in the alveoli enabling adequate oxygen exchange with smaller tidal volumes than conventional ventilation (Rouby and Viars, 1989). Gas exchange can be adjusted by altering: (i) the oxygen concentration in the driving gas; (ii) the frequency of ventilatory bursts; (iii) the driving pressure; and (iv) the ratio of inspiratory to expiratory time.

Carbon dioxide elimination is proportional to the diameter of the catheter. We employed a 7FG infant feeding catheter as it is a readily available device of suitable length and rigidity. This may cause the end tidal pCO_2 to fall below normal but is acceptable for short procedures. For long-term ventilation in the intensive care unit, a 14 or 16FG catheter is preferred to ensure that the pCO_2 is maintained within normal limits.

Conventional anaesthetic techniques employ a physical barrier such as an inflatable cuff or pharyngeal pack to prevent the aspiration of blood and secretions into the lower airway. In HFJV airway protection is achieved by the inherent 'auto-PEEP' effect and the risk of aspiration is reported as low (Carlon *et al.*, 1981; Beamer *et al.*, 1984).

Indications

Laryngoscopy

High-frequency jet ventilation overcomes the inherent disadvantage of the conventional anaesthetic technique using an endotracheal tube which tends to obscure the posterior commissure and the subglottic space. HFJV induces tiny oscillations of the vocal folds but these can be minimized by adjusting the frequency and driving pressure of the ventilator and this has not impeded endolaryngeal microsurgery in our practice. We have found intubation with a catheter in conjunction with a Bullard laryngoscope easier in the presence of a supraglottic or glottic mass and the risk of bleeding from a friable tumour is reduced (Mendel and Bristow, 1993). Reversal of muscular relaxation without the need for extubation at the conclusion of the examination allows assessment of vocal movements under anaesthesia.

Laryngo-tracheal reconstructive surgery, including resection of tracheal stenosis, closure of high cervical tracheo-oesophageal fistula or posterior laryngo-tracheal cleft

The small outer diameter of the catheter causes minimal restriction of surgical access, especially to the posterior tracheal wall which would normally be obscured by a conventional tracheotomy tube. Despite the absence of a cuff, the 'auto-PEEP' effect of HFJV prevents aspiration of blood and secretions into the bronchial tree. If necessary, the distal tracheo-bronchial tree can be suctioned during the procedure without interruption of either ventilation or surgery (Rogers *et al.*, 1985; Watanabe *et al.*, 1988).

Tracheoplasty/stomaplasty

Severe stenosis of the tracheostome following laryngectomy requires surgical correction. A narrow catheter is easily manipulated by the surgeon during the procedure improving access to the stenotic area of skin and trachea. Care must be taken in positioning the catheter to ensure that it is placed far enough down the trachea to prevent expulsion, but also that the catheter tip remains above the carina.

Bronchoscopy

HFJV can be administered through the side channel of a bronchoscope as with manual Venturi jet ventilation. The technique is safe for use with or without laser resection. Instruments and telescopes can be readily changed or removed for cleaning without compromising ventilation. The bronchial wall remains almost immobile with this technique allowing greater surgical precision, an advantage when using the laser (Schneider and Probust, 1990).

Tonsillectomy

Uncuffed endotracheal tubes are normally used during tonsillectomy in children. These offer little protection from the aspiration of blood. The 'auto-PEEP' effect of HFJV can minimize this risk (Carlon *et al.*, 1981; Beamer *et al.*, 1984).

Precautions

High-frequency jet ventilation must be monitored with extreme care in patients with chronic obstructive airway disease. The positive end expiratory pressure effect of this form of ventilation may be enhanced because of increased static respiratory compliance and elevated bronchial resistance and this can lead to barotrauma (Pinsky *et al.*, 1987).

As with conventional techniques, it may be difficult to avoid hypercapnia and hypoxia with HFJV in the obese patient (Desrunnes *et al.*, 1991).

Complications

High-frequency jet ventilation delivers small volumes of air and oxygen under high pressure. The airway may be partially obstructed by laryngeal disease or by bleeding and debris from surgical resection. Obstruction to the passive outflow of gas can lead to intrapulmonary trapping, barotrauma, pneumothorax, pneumomediastinum and cardiac failure (Craft *et al.*, 1990; Smith, 1990b; Desrunnes *et al.*, 1991). This risk can be minimized by use of pressure sensing devices which will rapidly deactivate the ventilator if the end expiratory pressure does not fall below a predetermined level. Proximal airway pressure, which triggers the alarm system used on current jet ventilators, is a poor correlate with intrathoracic pressure and a more accurate assessment is obtained by monitoring the intraoesophageal pressure (Smith *et al.*, 1988).

Adequate humidification is important with HFJV especially during a lengthy procedure. Necrotizing tracheobronchitis has been described in neonates who have been ventilated in this manner for long periods. The cause may be related to a combination of inadequate humidification and high gas pressures (Circeo *et al.*, 1991). Necrotizing tracheobronchitis has also been described with more conventional mechanical ventilation techniques, but there is a greater degree of tissue damage associated with HFJV. We use an Acutronic jet ventilator which humidifies the inspired gases by adding saline to the proximal end of the patient circuit.

Conclusions

High-frequency jet ventilation is an established anaesthetic technique. Its valuable role in laryngeal surgery has not been widely reported. The advantages include minimal intubation trauma and increased access to the surgical field without reducing the anaesthetist's ability to maintain adequate ventilation of the patient throughout the procedure. The risk of aspiration is low. Leaving the ventilation catheter *in situ* during the early recovery period affords good control of the airway at a time when reintubation may be difficult.

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