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High-frequency Jet Ventilation for Laryngoscopy

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Jet ventilation techniques have gained wide acceptance for bronchoscopy and laryngoscopy during general anesthesia.[1–8]

High-frequency positive-pressure ventilation (HFPPV) was originally used in experimental studies by Jonzon *et al.*[9] and evaluated clinically by Heijman *et al.*[10] Later, HFPPV was applied by Eriksson and Sjostrand for laryngoscopy[11,12] and bronchoscopy,[13] and used during transthoracic resection of tracheal stenosis by Eriksson *et al.*[14] These investigators showed that ventilation at a rapid rate with small tidal volumes can provide adequate ventilation with a low airway pressure. Klain and Smith,[15] using HFPPV transtracheally in dogs, found similar results.

This clinical report describes the application of high-frequency jet ventilation for operative laryngoscopy.

MATERIAL AND METHODS

Eighty-seven patients undergoing laryngoscopy under general anesthesia were ventilated using rapid intermittent jet insufflation. A fluidic logic-controlled ventilator[15–17] was utilized to obtain respiratory rates of 60–100/min. The ventilator can be connected to an oxygen outlet at 50 psi or it can be used with a nitrous oxide–oxygen blender.

Premedication was with atropine, pentobarbital, and hydroxyzine, administered im. Anesthesia was maintained with thiamylal and fentanyl. Infusion of succinylcholine (0.2 per cent) was used to achieve muscle relaxation, monitored with a peripheral nerve stimulator.

For the first 18 adult patients (ASA 1 and 2) a respiratory rate of 100/min was used. These patient's tracheas were intubated with a 3.5-mm internal diameter (ID) plastic catheter of our design.[7] The endotracheal catheter has a 14-gauge Angiocath® inserted in the upper end and several holes close to the upper end and close to the tip. The upper holes allow for air entrainment during ventilation, diluting the respiratory gases. The 14-gauge Angiocath was connected to the ventilator. Oxygen, 100 per cent, with a driving pressure of 50 psi was used. Because of air entrainment, $F_{I_{O_2}}$ was less than 1.0. In this open-system type of ventilation, expiration occurred around the tracheal tube, and intratracheal pressure measured above the carina was never higher than 7 torr.

The next 69 patients were ventilated at a rate of 60/min by use of 4-mm ID tracheal tube (cuffless§) connected directly to the ventilator via a nitrous oxide–oxygen blender. The $F_{I_{O_2}}$s ranged from 0.3 to 0.7 and driving pressures ranged from 6 to 20 psi. In this group of patients, 16 were ASA physical status (PS) 1; 37, PS 2; 16, PS 3. Among them were 12 patients with chronic obstructive pulmonary disease (COPD) and six with marked obesity.

All patients were monitored with a cardioscope, precordial stethoscope, indirect blood pressure, and temperature probe. Whenever possible, arterial blood samples were taken prior to the induction of anesthesia and during the operative procedure.

RESULTS

Mean values of Pa_{O_2} and Pa_{CO_2} in first group of 18 patients are shown in figures 1 and 2. In all cases adequate ventilation was obtained. Figures 3 and 4 show the Pa_{O_2} and Pa_{CO_2} values prior to anesthesia and at the end of anesthesia in the second group of 69 patients. In seven patients, Pa_{CO_2} was 50 torr or more at the end of the procedure. Two of these patients were extremely obese, and in five cases, ventilator driving pressure was deliberately lowered to decrease movement of the vocal cords during microscopic surgical procedures, which also resulted in low Pa_{O_2} levels.

All except two of the 12 patients who had COPD were adequately oxygenated and ventilated. There was no correlation between preoperative arterial blood-gas values and the results obtained during the

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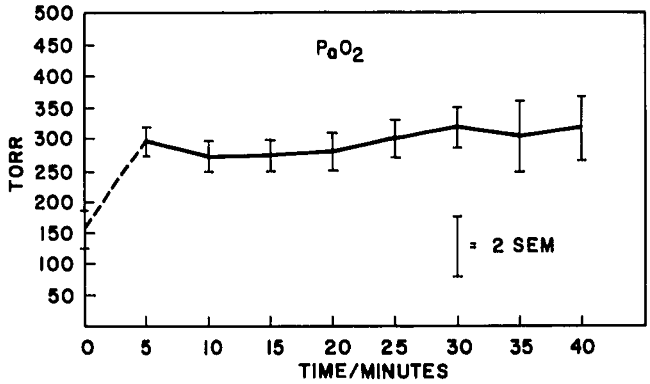

FIG. 1. Pa_{O_2} in the first group of 18 patients.

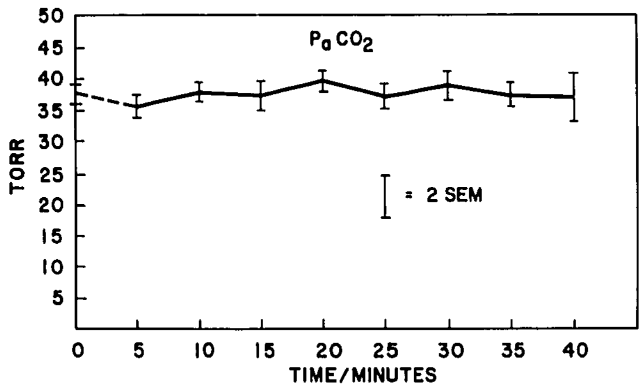

FIG. 2. Pa_{CO_2} in the first group of 18 patients.

procedure. (In comparison with the rest of the patients, patients with COPD were usually ventilated with higher FI_{O_2}s and higher driving pressures.) Frequently, changes in Pa_{O_2} and Pa_{CO_2} were related to the position of the laryngoscope and intentional decrease in the driving pressure, hence a reduced flow of gases. Preoperative values of Pa_{CO_2} and Pa_{O_2} in patients with COPD ranged from 30 to 44 torr and from 51 to 81 torr, respectively. At the end of the procedures, these values ranged from 35 to 53 torr for Pa_{CO_2} and from 73 to 234 torr for Pa_{O_2}.

In several patients temporary increases in blood pressure were observed related to the surgical instrumentation and hypercarbia. In six patients, cardiac dysrhythmias, mainly premature ventricular contractions, occurred. These were related to light anesthesia and disappeared after additional doses of thiamylal. Intratracheal pressures measured at the carina at the peak of inspiration ranged from 3 to 7 torr.

During recovery from muscle relaxation, when the patients started to breathe spontaneously, ventilation could be superimposed on normal breathing. Although the patients' tracheas were still intubated and they were still being ventilated, coughing and bucking were not observed.

Discussion

A critical period during the use of the jet ventilation technique is when the patient emerges from anesthesia and starts to cough or buck on the tube. On the other hand, premature removal of the tube may lead to obstruction of the upper airway or aspiration of blood when biopsy has been performed.

Favorable experimental results[15] of high-frequency ventilation applied transtracheally and the fact that the ventilation can be superimposed on spontaneous breathing led us to apply this method clinically to laryngoscopy. The results support the findings of other investigators[9–15] that adequate alveolar ventilation can be achieved with low-tidal-volume, high-rate ventilation. The low intratracheal pressure is an advantage to the endoscopist, as the vocal cords remain motionless, unaffected by the outflow of ventilating gases. However, this might adversely affect ventilation, producing hypercarbia and lower Pa_{O_2} in patients with extreme obesity or COPD.

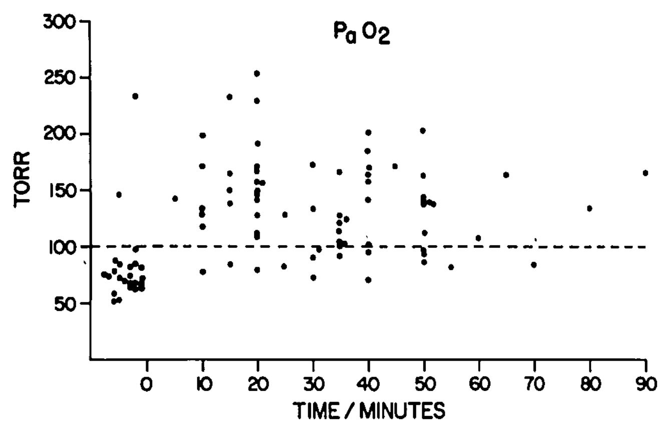

FIG. 3. Pa_{O_2} in the second group of 69 patients.

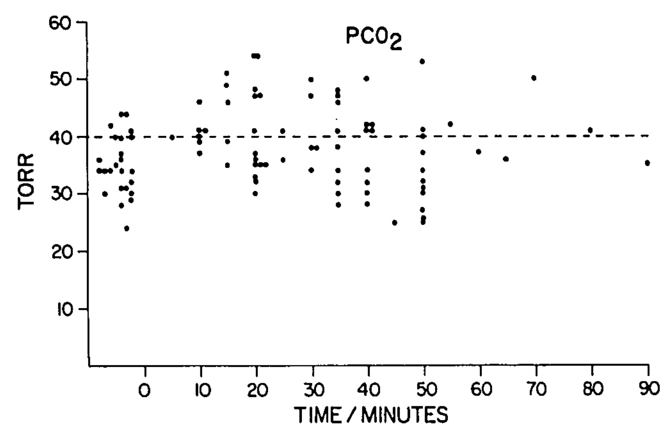

FIG. 4. Pa_{CO_2} in the second group of 69 patients.

In the first group of 18 patients, $F_{I_{O_2}}$ was less than 1.0 because air entrainment occurred and patients were ventilated with an air–oxygen mixture. The oxygen concentration in the ventilating gas was high enough that Pa_{O_2} remained in a safe range, between 220 and 350 torr. Driving pressure was kept constant during the procedures, with a respiratory rate of 100/min producing Pa_{CO_2} levels within normal limits.

In the 69 patients in whom the 4-mm ID tracheal tube and N_2O-O_2 mixture with variable $F_{I_{O_2}}$ were used for ventilation, driving pressures were changed frequently. This approach produced wide fluctuations in arterial blood-gas values. The respiratory rate was kept constant at 60/min, as was found to be optimal by other investigators.[18] To provide a wider margin of safety, at least 50 per cent oxygen should be used.

At the end of anesthesia, high-frequency ventilation was extremely well tolerated by awake patients recovering from residual muscle paralysis. Ventilation was continued until patients fully recovered from the effects of anesthesia and muscle relaxants. All patients could breathe spontaneously while still being ventilated. This suggests that high-frequency ventilation could be of value as a new way of assisted ventilation.

Further technical modification of our unrefined ventilating system, use of conditioned respiratory gases,[19] and further development of a fail-safe system[17] to prevent barotrauma will make the application of high-frequency ventilation a more acceptable alternative to conventional ventilation techniques.

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