RESPIRATION IV

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FACTORS INFLUENCING TIDAL VOLUME DURING HIGH-FREQUENCY JET VENTILATION

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INTRODUCTION:

During high-frequency jet ventilation (HFJV), tidal volume (Vt) results from the addition to the jet gas volume delivered by the ventilator (Vjet) of an additional volume entrained by the Venturi effect (E). Up to now CO2 clearance mechanisms during HFJV have not been completely understood, due mainly to the inadequacy of most methods using direct spirometry for measuring VT and E in clinical conditions. In this study, an external spirometric method (1) was used to determine factors influencing Vt, Vjet, E and CO2 clearance in patients under HFJV.

METHODS:

Patients and equipment: Twenty-two critically ill patients with respiratory failure were studied after informed consent had been obtained. At the time of the study all were sedated with Fentanyl 60 mcg. kg⁻¹ and paralysed with Pancuronium 0.1 mg.kg⁻¹. HFJV was provided as previously described (2) using an Acutronic Ventilator, a 14 gauge injector cannula and a 3-way swivel adapter allowing a bias flow of additional gases (30 l.min⁻¹).

Volumetric measurements: An elastic band with a differential linear transducer (DLT) was connected around the thorax at the nipple level in order to measure changes in rib cage perimeter (1). Assuming that the volume measured at the mouth by spirometry is equal to the change in rib cage volume in a paralysed patient, DLT signals were calibrated using a graduated 2 liter-syringe. The displacements corresponding to successive injections of 50 ml were recorded on a Gould ES 1000 recorder and the calibration curve was constructed.

The accuracy of the DLT whose frequency response was 60 Hz, for measuring VT at high frequencies was assessed in 8 patients. Bias flow and expiratory line were closed and Vjet, which is independent to the out-put mechanical load, was measured using 2 methods: directly by connecting the ventilator to a Tissot spirometer and indirectly with DLT by inflating lung’s patients with the ventilator up to 1500 ml above anaesthetic FRC. Inspiratory/Expiratory (I/E) ratio and driving pressure (DP) were kept constant and 4 frequencies were used at random. Measurements were made in triplicate. Results (Table, mean ± SD) show that DLT accurately measured Vjet at any frequency: Frequency (B.min⁻¹) 100 200 400 600 Vjet ml (DLT) 217 ± 10 123 ± 9 69 ± 1 49 ± 1 Vjet ml (Tissot) 209 ± 10 116 ± 10 66 ± 2 45 ± 1

Procedures: Eight different ventilatory settings were used at random in order to determine changes in Vt, Vjet and E induced by increasing I/E ratio (0.25, 0.43 and 0.67), DP (1.8, 2.2 and 2.6 bars) and frequency (100, 200, 400 and 600.min⁻¹). After a steady state of 15 min at FiO2 0.4, arterial blood gas, VT and Vjet were measured using DLT. E (X) was calculated as Vt/Vjet and were compared using analysis of variance and Student’s paired t-test.

RESULTS: As shown in fig 1, increasing DP increased Vt, Vjet and E (*) p < 0.05. PaCO2 significantly increased (63 ± 33 mmHg, 67 ± 29 mmHg, 72 ± 34 mmHg) and PaCO2 significantly decreased (32 ± 10 mmHg, 29 ± 9 mmHg, 26 ± 7 mmHg, * p < 0.05).

As shown in fig 2, increasing I/E ratio significantly increased Vjet, significantly decreased E and significantly increased VT. PaCO2 increased (63 ± 33 mmHg, 67 ± 29 mmHg, 72 ± 34 mmHg, 84 ± 47 mmHg) and PaCO2 decreased (32 ± 10 mmHg, 29 ± 9 mmHg, 26 ± 7 mmHg, * p < 0.05).

As shown in fig 3, increasing frequency significantly decreased VT, Vjet and E (* p < 0.05). PaCO2 remained unchanged (70 ± 40 mmHg, 72 ± 34 mmHg, 72 ± 32 mmHg, 74 ± 24 mmHg) and PaCO2 increased (21 ± 6 mmHg, 26 ± 7 mmHg, 62 ± 11 mmHg, 53 ± 15 mmHg, * p < 0.05).

As shown in fig 4, a significant relationship was found between PaCO2 and Vt. No significant relationship was found between PaCO2 and the product VT x Frequency.

DISCUSSION:

Several conclusions can be drawn from this study: 1) when using a frequency < 200.min⁻¹ with a DP > 2 bars, HFJV cannot be considered anymore as low tidal volume high-frequency ventilation; 2) gas entrainment which is mainly dependent on driving pressure, remained important up to frequencies of 10 Hz; 3) increasing I/E ratio decreases E; 4) PaCO2 during HFJV is mainly dependent on the absolute level of VT and not on the product VT x Frequency. Moreover, since most patients with VT < 100 ml were hypocapnic it is likely that convection rather than enhanced diffusion or 'pendeluff' plays a determinant role in CO2 elimination during HFJV.