Hemodynamic Effects of High Frequency Jet Ventilation during Acute Hypovolemia

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Summary: The hemodynamic effects of high frequency jet ventilation (HFJV) at three different rates (60, 100, 200/min) and at rate 200/min combined with jet sighs 12/min (HFJV-200+12S) during two degrees of hemorrhagic hypovolemia were investigated in dogs. Also, the results were compared with those of intermittent positive pressure ventilation (IPPV). Two degrees of hypovolemia were produced by bleeding dogs until mean arterial pressure was 25 % or 50 % lower than basic value respectively. At both periods of hypovolemia, HFJV at rate 60 or 100 were found to have better hemodynamic effects than IPPV due to their lower airway pressures. However, HFJV at rate 200 or HFJV-200+12S did not demonstrate the same superiority because of their higher airway pressure, the latter even represented a tendency of worse hemodynamic effect than IPPV. The best cardiovascular effect was seen during HFJV at rate 100. Our study indicated that the hemodynamic effect of HFJV better than that of IPPV during acute hypovolemia can be seen only when proper ventilatory settings are chosen. Jet sighs at 12/min added to usual HFJV are not beneficial to circulatory function. It is recommended that HFJV at a rate below 200/min without jet sighs be used in patients who need respiratory support during acute hypovolemia or shock.

Key words: high frequency jet ventilation, hypovolemia

Conventional mechanical ventilation (CMV) has been previously demonstrated to have harmful cardiovascular effects due to its high airway pressure, especially during circulatory decompensation. One of the original rationales for developing high frequency jet ventilation (HFJV) was that by lowering airway pressure the harmful cardiovascular effect of CMV may be avoided, especially during circulatory failure. Jet sighs have been used to increase carbon dioxide elimination during HFJV. What effects jet sighs have on hemodynamics during HFJV needs to be investigated. Two modes of jet ventilation were included in the present study. One of them was the usual one as described previously. Three respiratory rates, 60, 100, 200/min (HFJV-60, 100, 200), were chosen during usual HFJV. In another form of jet ventilation, 12 new jet pulses used as jet sighs were created and superimposed independently upon the usual HFJV at a respiratory rate of 200/min (HFJV-200+12S). The hemodynamic effects of the two forms of jet ventilation during two degrees of hypovolemia were investigated and compared with those of intermittent positive pressure ventilation (IPPV).
MATERIALS AND METHODS

10 healthy mongrel dogs of both sexes, weighing 14.3±1.2 kg, were randomly divided into two groups of 5 dogs each. The dogs in each group were used to compose a 5*5 Latin square plan together with 5 different ventilation modes. The Latin square plan was utilized to eradicate experimental order error. 2 same 5*5 Latin square plans with the experimental order being entirely the same were used to make the results more accurate (fig.1).

Case 1,6 A B C D E
Case 2,7 B A E C D
Case 3,8 C D A E B
Case 4,9 D E B A C
Case 5,10 E C D B A

Fig.1. 5*5 Latin square plan.
The experimental order was arranged from left to right for each numbered case. A, B, C, D, E each refers to IPPV, HFJV-60, HFJV-100, HFJV-200 and HFJV-200+12S, respectively.

The animals were anesthetized with pentobarbital sodium intravenously (20–25 mg/kg). The trachea was incubated using a 9 mm ID cuffed endotracheal tube, with its distal tip 4 cm below the glottis. A 2 mm ID polyethylene catheter was placed in the endotracheal tube through its side wall and fixed with its distal orifice 5 cm away from the endotracheal tube tip. This catheter was used for measuring airway pressure or delivering oxygen during spontaneous respiration. An infrared transducer from a carbon dioxide concentration analyzer (Engström Co., Sweden) was connected to the proximal end of the endotracheal tube for monitoring end-tidal carbon dioxide concentration. A 7.5F Swan–Ganz catheter (Elecath, Electro-Catheter Co., USA) was inserted into one of the main pulmonary arteries via femoral vein for measuring pulmonary artery and pulmonary capillary wedge pressure. 2 flexible short catheters were placed into the femoral arteries on both sides, one for measuring artery pressures, and the other for bleeding or collecting blood samples. Vascular pressures were measured with two transducers connected to an eight-channel physiological recorder (RM-680, Nihon Kohden, Japan), from which standard limb electrocardiogram leads were also attached to the dogs. Both transducers were independently calibrated with a mercury manometer before each experiment. Cardiac output was measured in triplicate using thermodilution method with a computer system (Gould 9520A, Gould Co., USA). This computer was also utilized to monitor blood temperature continuously when not used to measure cardiac output. Arterial blood–gas tension was analyzed by a computerized analyzer (ABL-3, Niselson, Denmark). Body temperature was maintained at normal physiologic range by using heating blanket.

IPPV was delivered by a conventional volume-controlled ventilator (SC–I, Shanghai Med. Co., China). Working parameters during hypovolemia were set as: Vt 15–20 ml/kg; I/E ratio 1:1.5; Fio2 0.75, respiratory rate was adjusted to obtain a PaCO2 of 5.32±0.67 kPa. High frequency jet ventilation was provided by an electromechanical jet ventilation system with two similar solenoid valves (HFV–I, Nanchang Med. Co., China). One valve was used to produce a usual HFJV as described by Otto et al.[7]. Jet pulse is formed when high pressure oxygen periodically passes through one of the electromechanically controlled solenoid valves. The other valve generating the same kind of jet pulse was used to produce jet sigh. Jet sighs superimposed on usual HFJV were utilized to increase lung volume and carbon dioxide elimination[8]. The two valves were