Title: HIGH FREQUENCY JET VENTILATION VS CONTROLLED MECHANICAL VENTILATION IN ACUTE PULMONARY EMBOLISM

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Introduction. High frequency ventilation may result in greater cardiovascular stability than controlled mechanical ventilation (CMV). Because pulmonary embolism can cause major hemodynamic disturbances,[1] we compared the effects of high frequency jet ventilation (HFJV) and CMV in a new canine model of pulmonary embolism.

Materials and Methods. Sixteen mongrel dogs (21.3 ± 3.7 kg), anesthetized with a continuous infusion of sodium pentobarbital, were intubated and paralyzed with pancuronium. Arterial and thermodilution pulmonary artery catheters were inserted. Cardiac output (CO) and vascular pressures were measured. Airway pressures were measured through a small lumen in the side of the endotracheal tube (National) by an air-filled transducer (Gould-Statham P50) and mean airway pressure ($\overline{Paw}$) was determined as a time averaged electrical mean. End-tidal CO_2 ($P_{ET}CO_2$) was measured during CMV with an infrared CO_2 analyzer (Beckman). $P_{ET}CO_2$ was measured during HFJV with a single-breath technique.[2] The left sartorius and part of the quadriceps muscle were surgically excised from each dog, trimmed of fat, and cut into 2-mm cubes. A 16-Fr Levene catheter was placed to the level of the inferior vena cava via the left femoral vein. A $PaCO_2$ of 35-45 mmHg was maintained during CMV (Emerson) at a 15-ml/kg tidal volume by adjusting rate and during HFJV (Healthdyne) at a rate of 100 breaths/min by adjusting drive pressure; F_IO_2 was 0.21 for both ventilatory modes throughout. Dogs were ventilated at the same settings before and after embolism. The sequence of CMV and HFJV was alternated between dogs (Table 1); 30 min were allowed for equilibration after each change before measurements. Embolism was induced in 8 dogs during HFJV and in 8 during CMV (Table 1) by infusing muscle cubes in saline through the inferior vena cava catheter until pulmonary artery pressures had doubled and were stable. In the last 7 dogs, CMV was compared with HFJV at the same $PaCO_2$ (± 2 mm Hg) by reinstituting CMV at its previous tidal volume and adjusting the rate. Seven dogs were examined post mortem. Analysis of variance and Duncan's comparison of means were used. For data during CMV adjusted to the same $PaCO_2$ as during HFJV, a paired Student's *t* test was used ($P < 0.05$ was considered significant).

Results (Tables 2 and 3). Control data were identical for both ventilatory modes except peak inflation pressure was lower with HFJV (5.0 ± 1.4 vs 9.6 ± 1.4 mm Hg). After embolism, mean pulmonary artery (PAP) and pulmonary capillary wedge (PCWP) pressures, pulmonary vascular resistance (PVR), venous admixture (Qsp/Qt), and $P(a\text{-}ET)CO_2$ significantly increased during both HFJV and CMV. $PaCO_2$ increased significantly only during CMV. The increase in Qsp/Qt and $P(a\text{-}ET)CO_2$ was significantly greater with CMV. Embolism decreased cardiac index (CI), PaO_2, and O_2 delivery (DO_2); but PaO_2 and DO_2 were better maintained with HFJV than with CMV. With CMV increased to achieve the same $PaCO_2$ as with HFJV after embolism, CI decreased significantly and, despite an increased PaO_2, DO_2 remained significantly less than with HFJV. Muscle was recovered in the pulmonary circulation in dogs examined post mortem.

Conclusion. In this model, HFJV appears to maintain gas exchange better than CMV does. At the same $PaCO_2$, HFJV has significantly less detrimental hemodynamic effects and better maintains DO_2.

References

1. Mangano DT: Immediate hemodynamic and pulmonary changes following pulmonary thromboembolism. ANESTHESIOLOGY 52:173-175, 1980.
2. Mihm FG, Feeley TW, Rodarte A, Ashton JPA: Monitoring HFJV by end-tidal carbon dioxide concentrations. (Abstract) ANESTHESIOLOGY 57:A87, 1982.

TABLE 1. Ventilatory Sequence*

	Before Embolism		After Embolism	
Group 1 (n = 8)	HFJV	CMV	CMV	HFJV
Group 2 (n = 8)	CMV	HFJV	HFJV	CMV

*Abbreviations are defined within the text.

TABLE 2. Effects of Pulmonary Embolism With CMV and HFJV*

	CMV (N = 16)		HFJV (N = 16)	
	Control	Embolism	Control	Embolism
MAP	127 ± 22	124 ± 15	131 ± 21	126 ± 18
CI	6.0 ± 1.0	4.3 ± 1.1†	6.0 ± 1.1	4.7 ± 1.1†
PAP	18 ± 3	37 ± 5†	18 ± 2	37 ± 4†
CVP	4 ± 2	6 ± 2	5 ± 2	6 ± 2†
PCWP	7 ± 2	10 ± 5†	7 ± 2	10 ± 5†
$\overline{Paw}$	2.5 ± 0.6	2.8 ± 1.1	2.3 ± 0.5	2.7 ± 0.7
$PaCO_2$	39.5 ± 4.7	50.9 ± 6.9†	39.2 ± 3.2	42.4 ± 7.2‡
PaO_2	102.4 ± 7.9	62.5 ± 12.9†	102.5 ± 6.2	79.7 ± 18.0†‡
Qsp/Qt	.03 ± .028	.35 ± .180†	.02 ± .025	.18 ± .166†‡
DO_2	794 ± 215	465 ± 132†	781 ± 182	558 ± 130†‡
$P(a\text{-}ET)CO_2$	6.5 ± 5.2	22.8 ± 6.6†	7.7 ± 3.6	19.8 ± 4.5†‡

*Values are mean ± SD. Abbreviations: MAP, mean arterial pressure; CVP, central venous pressure; others are defined within the text of the abstract. Units of measure: all pressures and tensions, mm Hg; CI, $L \cdot min^{-1} \cdot m^{-2}$; and DO_2, ml/min.
†$P < 0.05$ when control is compared with after embolism.
‡$P < 0.05$ when CMV and HFJV are compared after embolism.

TABLE 3. Comparison of HFJV and CMV at the Same Alveolar Ventilation After Embolism*

	CMV (N = 7)	HFJV (N = 7)
CI ($L \cdot min^{-1} \cdot m^{-2}$)	3.8 ± 1.1	4.6 ± 0.8†
PAP (mm Hg)	35 ± 5	36 ± 4
CVP (mm Hg)	5 ± 3	6 ± 2
PCWP (mm Hg)	14 ± 5	13 ± 3
$\overline{Paw}$ (mm Hg)	3.0 ± 1.4	2.6 ± 0.7
$PaCO_2$ (mm Hg)	44.6 ± 8.8	44.2 ± 8.4
PaO_2 (mm Hg)	69.6 ± 15.3	76.1 ± 17.5†
Qsp/Qt	.24 ± .13	.19 ± .16
DO_2 (ml/min)	456 ± 139	587 ± 116†

*Values are mean ± SD. All abbreviations are defined within the text of the abstract or in Table 2. †$P < 0.05$.