TITLE: LIVER BLOOD FLOW DURING HIGH FREQUENCY OSCILLATION AND CONVENTIONAL MECHANICAL VENTILATION

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Introduction. High frequency ventilation (HFV) is advocated as a useful technique for management of respiratory distress syndrome, bronchopleural fistula and as a means of improving gas exchange in the non-compliant lung. However, despite these pulmonary advantages there may be disadvantages associated with HFV on other organ function. To determine if liver blood flow (LBF) differed between HFV and conventional intermittent positive pressure (IPPV) ventilation, 8 pigs were studied.

Methods. Pigs were anesthetized with an intramuscular dose of ketamine (44mg/kg) followed by pentobarbital and pancuronium delivered by continuous infusion pump. Initial ventilation was with IPPV during surgery when portosystemic collateral perfusion of the liver was ablated so that all blood supply to the liver flowed through the hepatic artery (HA) or portal vein (PV). An occluding clamp which could be opened (total LBF) or closed (PV flow) after surgery was placed around the common HA. The carotid and pulmonary artery and superior vena cava were cannulated and pressures transduced. Urine output and fluid intake (4 ml/kg/hr) were monitored. The pigs were ventilated with either IPPV (Engstrom Vt = 15 ml/kg, rate = 12, FIO_2 = 1.0) or HFO (Emerson prototype oscillator, rate 1000/min in all 8 pigs, diaphragm displacement 125ml and fresh gas flow 7 L/min. O_2), so that arterial CO_2 ($PaCO_2$) was 45 ± 10 torr. In addition, 6 of these pigs were also ventilated by HFO at 1500/min. Cardiac output (CI) was measured by thermodilution and intravascular pressures were recorded during each mode of ventilation. Arterial and mixed venous blood gases were sampled simultaneously and analyzed on an IL 713 blood gas analyzer with direct measurement of hemoglobin and saturation (OSM2 Hemoximeter). Arteriovenous O_2 difference ($a\text{-}\bar{v}DO_2$), oxygen consumption ($\dot{V}O_2$), and intrapulmonary shunt ($\dot{Q}s/\dot{Q}t$) were calculated. Airway pressure was transduced (Statham P23 BB) from a bronchoscopically placed cannula in proximity to the carina. Mean airway pressure was maintained the same during HFO and IPPV by a vacuum pump attached to the gas outflow port during HFO. Liver blood flow was measured by gamma camera (Nucleonics) using Xenon (Xe) in saline washout following injection into the PV with the HA open in all 8 pigs (total LBF) and closed in 4 pigs (PV flow). Xe washout data was plotted and the slope of the fast component of the semilog linear regression curve between 100 and 200 seconds after Xe injection was determined. LBF ml/min/100g hepatic tissue was given by Flow = $\log_e 2 \times \lambda \times 60 \times 100 \div d \times T\ 1/2$ where T 1/2 is the half-time clearance, d=density of liver tissue, λ = liver/blood partition coefficient for Xe = 0.74. Data was statistically analysed using the paired t-test and tabulated as mean ± standard deviation.

Results. Cardiorespiratory function and LBF during IPPV and HFO is shown in Table 1.

Table 1:	IPPV	HFO
CI L/min/m^2	5.7 ± 1.73	5.4 ± 1.62
paO_2 torr	241 ± 74.0	183 ± 74.0*
$paCO_2$ torr	44 ± 8.0	48 ± 9.8
pH	7.4 ± 0.09	7.4 ± 0.11
$a\text{-}\bar{v}DO_2$ ml/100 ml	6.0 ± 2.20	6.9 ± 2.62
$\dot{V}O_2$ ml/min	183 ± 62.9	179 ± 50.9
$\dot{Q}s/\dot{Q}t$ %	20 ± 11.3	21 ± 6.1
LBF ml/mm/100g	15.5 ± 5.37	17.2 ± 6.41

There was a significant (*$p < 0.05$) difference between arterial O_2 (paO_2) with IPPV and HFO, otherwise there were no differences in cardiorespiratory function including intravascular pressures, O_2 delivery, consumption or cardiac index. LBF was not different even when normalized for cardiac index. In six of the same 8 pigs LBF was also measured during HFO with the same ventilator settings and airway pressure but at a rate of 1500/min. The LBF values for these six animals during IPPV HFO at 1000/min and HFO at 1500/min are shown in Table 2.

Table 2:	IPPV	HFO 1000	HFO 1500	n=6
LBF ml/min/100g	14.9 ±6.0	17.8 ±4.91	16.0 ±4.90	

p = N.S. between IPPV HFO 1000 and HFO 1500

In 4 of the 8 pigs LBF was measured with the hepatic artery open (HAO) and closed (HAC). The values during IPPV, HFO at 1000/min, and HFO at 1500/min for these 4 animals are shown in Table 3.

	IPPV		HFO 1000		HFO 1500	n=4
Table 3:	HAO	HAC	HAO	HAC	HAO	HAC
LBF ml/min/100g	14.8 ±5.68	12.6 ±5.34	19.6 ±5.14	11.6 ±5.67	17.2 ±5.54	10.7 ±4.11

p = N.S. between IPPV, HFO 1000 and HFO 1500

Discussion. These studies demonstrate that when mean airway pressure was the same LBF was unchanged whether the pigs were ventilated with IPPV or HFO. There were no significant differences in LBF with different rates of HFO. Portal vein flow with HAC was no different with IPPV or either rate of HFO. We postulate that the difference in paO_2 found between pigs ventilated with IPPV and HFO may be explained by anatomic pecularities of pigs which have few, if any, collateral ventilation channels.

Conclusion. After normalizing mean airway pressure during HFO and IPPV, HFO did not significantly alter cardiac function, intrapulmonary shunt or liver blood flow.