Title: DETECTION OF VENOUS AIR EMBOLISM IN DOGS WITH TRANSCUTANEOUS O_2 AND TRANSESOPHAGEAL ECHOCARDIOGRAPHY

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Introduction. Clinical data in humans has shown that transcutaneous O_2 ($P_{tc}O_2$) monitoring can detect air embolism and may be more sensitive than end-tidal CO_2 ($P_{ET}CO_2$) monitoring.[1] It has been suggested that transesophagal echocardiography (echo) is more sensitive than the Doppler ultrasound in detecting air emboli.[2] This study was undertaken to compare $P_{tc}O_2$ and echo with pulmonary artery pressure (PAP), $P_{ET}CO_2$ and Doppler to determine the sensitivities of each in detecting air embolism and their ability to reflect the volume of air infused.

Methods. Eight mongrel dogs (15.2-23.5 kg) were anesthetized, intubated and ventilated to maintain a baseline $PaCO_2$ of 35-40 mmHg. Four dogs received 100% O_2 and 4 received 50% O_2 in a O_2/N_2 mixture. A Doppler ultrasound transducer was placed over the right heart chambers. A Diasonic esophageal transducer was positioned to give a view of the right ventricular outflow tract. Air was infused at randomized rates of 0.001 and 0.005 $ml \cdot kg^{-1} \cdot min^{-1}$ for 1 minute and 0.01, 0.05, 0.1, 0.2 and 0.4 $ml \cdot kg^{-1} \cdot min^{-1}$ for 6 minutes. A bolus of 5 $ml \cdot kg^{-1}$ was given at the termination of the study. Echo and Doppler changes were monitored by blinded experienced observers. At doses greater than 0.005 $ml \cdot kg^{-1} \cdot min^{-1}$ arterial blood gas samples were obtained prior to and 1, 3, 6, 12 minutes following air infusion. Mean PAP, $P_{tc}O_2$, $P_{tc}CO_2$, and $P_{ET}CO_2$ were continuously monitored.

Results. The esophageal echo was the most sensitive detection method (table), detecting air in 6 infusions in which the Doppler failed. The $P_{tc}O_2$ did not function properly in 11/47 air infusions and these were excluded from further analysis of $P_{tc}O_2$ data. Response time of the $P_{tc}O_2$ monitor in dogs was slower than previously noted in humans. Maximum change in $P_{tc}O_2$ significantly correlated with maximum change in PaO_2 during each air infusion ($r = 0.89$). The positive responses of $P_{tc}O_2$ and $P_{ET}CO_2$ at given air infusions were comparable (table). $P_{tc}O_2$ changed first in 4/25 cases, $P_{ET}CO_2$ changed first in 11/25 and both changed simultaneously in 10/25. The response of $P_{tc}O_2$, $P_{ET}CO_2$ and PAP equally reflected the volume of air infused (figure). With the 5 $ml \cdot kg^{-1}$ bolus dose the decrease in $P_{tc}O_2$ was considerably greater than the decrease in PaO_2 presumably due to an accompanying decrease in cardiac output.

Table:

Comparison of sensitivity of monitoring methods

Monitor	% of dogs with positive response at total air dose (ml/kg)				
	0.06	0.3	0.6	1.2	> 2.4
Echo	57	86	71	100	100
Doppler	25	62	75	100	100
PAP	12	12	75	100	100
$P_{tc}O_2$	0	50	67	80	100
$P_{ET}CO_2$	0	37	62	100	100

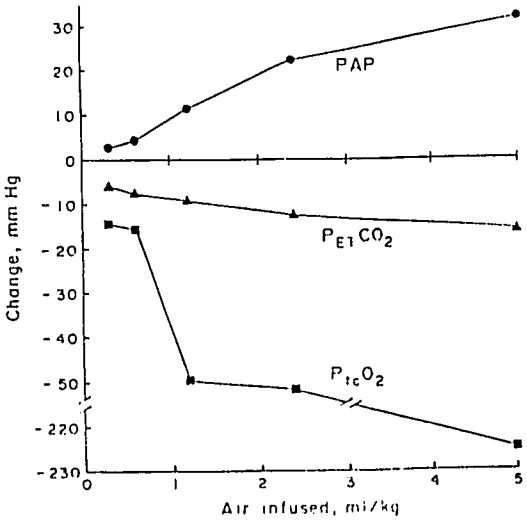

Figure: Maximal response of $P_{tc}O_2$, $P_{ET}CO_2$, PAP mmHg to air infusion (ml/kg)

Discussion. These data confirm the earlier suggestion that esophageal echo is more sensitive than Doppler in detecting air embolism. The clinical advantage of the echo is not primarily its superior sensitivity but its ability to detect left sided emboli.[2] These data also confirm that $P_{tc}O_2$ accurately follows the decreases in PaO_2 that occur during air embolism. In addition the magnitude of change in $P_{tc}O_2$ reflected volume of air infused. This study could not identically duplicate the human data[1] since the $P_{tc}O_2$ response time in dogs is slower. In the dog $P_{tc}O_2$ and $P_{ET}CO_2$ are equally sensitive in detecting air embolism. Clinically, the value of $P_{tc}O_2$ monitoring is not limited to detecting air embolism. $P_{tc}O_2$ also provides continuous trend monitoring of the patient's oxygenation and tissue perfusion.

References.

1. Glenski JA, Cucchiara RF: Transcutaneous O_2 and CO_2 monitoring of neurosurgical patients - detection of air embolism. Anesth Analg 63:220, 1984.

2. Cucchiara RF, Nugent M, Seward JB, Messick JM: Air embolism in upright neurosurgical patients - detection and localization by two-dimensional transesophageal echocardiography. Anesthesiology 60:353-355, 1984.