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TITLE: THE RELATIVE SENSITIVITIES OF PULMONARY ARTERY PRESSURE END-TIDAL CO_2 AND END-TIDAL N_2 ANALYSIS IN THE DETECTION OF VENOUS AIR EMBOLISM

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In order to define the relative sensitivities of end tidal CO_2 ($ETCO_2$), pulmonary artery pressure (PAP) and end tidal nitrogen analysis (ETN_2) in the detection of venous air embolism (VAE), the authors performed serial air injections in dogs.

Methods: Six dogs (weight 25.7+8.1 kg) were anesthetized with pentobarbital, mechanically hyperventilated (VT:20ml.kg^{-1}, rate 15-20 bpm) and placed in a supine/20° head-up posture. Systemic and pulmonary artery pressure, $ETCO_2$ (Beckman LB2) and ETN_2 (Perkin-Elmer 1100 Series mass-spectrometer) were monitored continuously. An 18 gauge, two inch catheter was placed in the right external vein (EJV). After stabilization (45 min), 5 air injections (0.25, 0.5, 0.75, 1.0 and 1.5cc.kg^{-1}) were made via the EJV in random sequence at 30-40 min intervals. Increases in PAP and ETN_2, and decreases in $ETCO_2$ of 2mmHg, 0.04% and 0.2% respectively were considered positive responses. The time to maximum change and the time to return to baseline following VAE were noted.

Results: The results (expressed as % positive responses for each injectate volume) are shown in Table 1. The sensitivity of the three modalities was comparable. The times to maximum response for the 1.0 and 1.5 cc.kg^{-1} injectates (Table 2) were not different for PAP and ETN2. Both were more rapid than ETCO2 ($p<.005$, paired t) although the range for the three was narrow. ETN2 returned to baseline (Table 2) following VAE much more rapidly than did ETCO2 ($p<.002$) which was in turn slightly more rapid than PAP ($p<.05$).

Discussion: The results of this study indicate that the sensitivities of PAP, $ETCO_2$ and ETN_2 in the detection of VAE are very similar. While ETN_2 enjoys the theoretical advantage of greater specificity for VAE and might therefore appear preferable, our study indicates two limitations. First, the instrumentation employed must be capable of reliably detecting ETN_2 concentration changes on the order of 0.05%. This exceeds the capability of existing commercially available OR systems. Second, ETN_2 returns to pre-VAE levels more rapidly than PAP and $ETCO_2$ suggesting that it may not be a reliable indicator of the resolution of the physiologic disturbance caused by VAE. This observation may be the result of ai "held up" in the pulmonary vasculature proximal to the alveolus[1].

The specificity of ETN_2 analysis is attractive but ETN_2 analysis (with appropriately sensitive detection systems) should probably be used in conjunction with rather than as an alternative to other monitoring modalities.

Reference: 1. Lechner et al. Quantitative recovery of expired nitrogen and nitrous oxide from venous gas emboli. Pflug Arch 397:225-231, 1983.

	Percent Positive Responses (n=6)				
Injectate Vol (cc/kg)	0.25	0.50	0.75	1.0	1.5
PAP	16.7	33.3	66.7	100	100
$ETCO_2$	16.7	66.7	83.3	100	100
ETN_2	16.7	50	83.3	100	100

Table 1. The frequency (expressed as percent) of positive responses of PAP, $ETCO_2$ and ETN_2 after intravenous injection of various volumes of air.

		Maximum $\bar{\Delta}$±SD	Time (mins) ± SD	
			To Max Δ	To Baseline
1.0cc.kg^{-1}	PAP	7.33±4.5mmHg	1.35±1.5	19.7±3.5
	$ETCO_2$	0.77±.29%	2.10±1.1	15.3±2.1
	ETN_2	0.11±.06%	1.25±0.5	8.5±3.9
1.5cc.kg^{-1}	PAP	13.33±12.2mmHg	0.92±0.7	23.8±6.1
	$ETCO_2$	0.88±.25%	1.85±0.7	19.4±6.0
	ETN_2	0.20±.16%	1.20±0.5	8.0±4.3

Table 2. The mean maximum changes ($\bar{\Delta}$) in PAP, $ETCO_2$ and ETN_2, the time (in minutes) from air injection to maximum change (MaxΔ), and the time from air injection to return to stable baseline after 1.0 and 1.5cc.kg^{-1} air injections. Statistical comparisons in text.

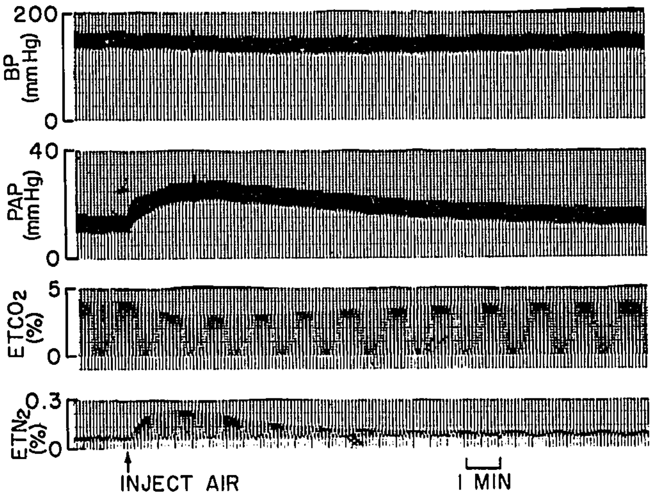

Figure. BP, PAP, $ETCO_2$, and ENT_2 response to injection of 1cc/kg of air into the right ventricle of a dog.

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