Title: QUANTITATIVE DETECTION OF VENOUS AIR EMBOLISM IN THE DOG BY MASS SPECTROMETRY MEASUREMENT OF END TIDAL NITROGEN

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Introduction: Very sensitive qualitative methods exist for detecting air embolism (Doppler ultrasound). This study was undertaken in order to determine if mass spectrometry measurement of pulmonary nitrogen washout could provide a quantitative estimation of bolus venous air embolism.

Methods: Six dogs were studied using a Perkin Elmer MGA 1100 Medical Gas Analyzer (sensitivity 0.01%) for continuous N2 measurements. After IV pentobarbital anesthesia (20–30 mg/kg), dogs were intubated and ventilated with a Harvard pump using 100% hospital grade O2. A 7F Swan Ganz catheter was inserted to measure cardiac output (CO) and pulmonary artery pressure (PAP). Each dog received 5–11 (mean 8) air embolus injections through the proximal Swan Ganz port. Prior to each embolus injection, baseline measurements of N2, PAO2, PAO3, and VT/Vn were made, and if any parameter differed from control the animal was removed from the study. Thirty minutes was allowed between randomized doses of air ranging between 10cc/kg-60cc/kg in 10cc/kg increments. An x-y plotter connected to the mass spectrometer N2 channel recorded N2 washout curves. A 0-3% N2 scale was calibrated on the x-y plotter using pre-mixed N2 samples. The sensitivity of the Perkin Elmer mass spectrometer (N2 scale 0-100%) at low range N2 levels was determined by comparing N2 concentrations with a quadrupole mass spectrometer (0-100N2 scale) and simultaneous measurements made by the Perkin Elmer system. The correlation coefficient (r) of quadrupole vs. Perkin Elmer measurements was 0.99. The standard error of the means (SEM) at both 1% and 2% N2 was 0.02% N2.

Results: Fig. 1 shows a typical series of N2 washout curves from one dog. This illustrates the reproducibility of N2 washout curves at several doses of air. Fig. 2 shows a dose response curve (r=0.96) relating peak end tidal nitrogen (N2ET) to the size of the embolus dose. Using one way analysis of variance with the Scheffe multiple comparison test, the mean N2ET peaks were statistically significantly different (p<0.05) only between non adjacent embolus doses. A breath by breath analysis was undertaken to determine the fraction (f) of each embolus expired through the lungs. Since each breath's N2ET is representative of alveolar nitrogen, the following equation was used to calculate f:

\[ f = \frac{\Delta N2ET}{V_T - V_D} \times (1.28) \]

where the factor 1.28 compensates for the proportion of N2 in air. Fig. 3 shows percent air embolism recovered from the lungs (fx100) for each air embolus dose.

Discussion: Presently no quantitative method of detecting air embolism is in general use. Our method, using equipment that is reliable, highly sensitive, and relatively easy to use, has been shown to be useful in estimating bolus air embolus size. It is not surprising that the dose response curve has relatively large variance. This is because venous air embolism results in very complex cardiopulmonary pathophysiologic changes that may quantitatively affect peak N2ET and that may change from dog to dog and within one dog after multiple air embolizations. This study also reveals information regarding the natural pathophysiologic characteristics of sublethal air embolism. An overall average of 66% of the volume of injected air was recovered from the lungs (within 3-6 minutes of injection). Fig. 1 shows an initial plateau before the typical monophasic N2 washout curve (5cc/kg) indicative of reduced pulmonary artery outflow with large emboli. This technique could be applied to study the efficacy of various air embolism treatment modalities.

Fig. 1

Fig. 2. Variance intervals represent SEM.

Fig. 3. Variance intervals represent SEM.

References: