

Title : EXTRAVASCULAR THERMAL VOLUME AS AN ESTIMATE OF LUNG WATER

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Introduction. Assessment of extravascular lung water (EVLW) by the double indicator dilution technique has proven unsatisfactory in pulmonary edema quantitation due to slow diffusion of the previously used indicators. This study evaluates the accuracy of a computer which calculates an extravascular thermal volume (EVTV) using heat and indocyanine green as the indicators. Heat was selected because of its high diffusibility. Normal animals and animals with acute pulmonary edema were examined comparing the computer assisted EVTV with the EVLW measured by gravimetric analysis of the excised lungs.

Methods. Eleven mongrel dogs weighing 15-30 Kg were anesthetized with pentobarbital 25 mg/Kg intravenously. The trachea was intubated and ventilation controlled. A 20 cm 5F thermister tipped catheter was placed in the femoral artery via cutdown. A 7F triple lumen flow directed pulmonary artery catheter was placed via the femoral vein. A 10F catheter was advanced into the superior vena cava from jugular vein cutdown. Blood pressure, pulmonary artery pressure and EKG were recorded continuously. Pulmonary capillary wedge (PCWP) and central venous pressures (CVP) were measured hourly and immediately prior to termination. Measurements of EVTV were also obtained hourly in the following manner: A 10 ml bolus of cold (0° C) indocyanine green dye (2 mg) was injected in the superior vena cava. Blood was withdrawn through a green dye densitometer via the thermister tipped femoral artery catheter. Curves for dye concentration versus time and femoral artery temperature versus time were simultaneously obtained. EVTV is calculated by the computer using the formula:

$$\text{EVTV} = \text{CO}(\text{TF}) \cdot (\text{MTT}_{\text{TF}} - \text{MTT}_{\text{dye}})$$

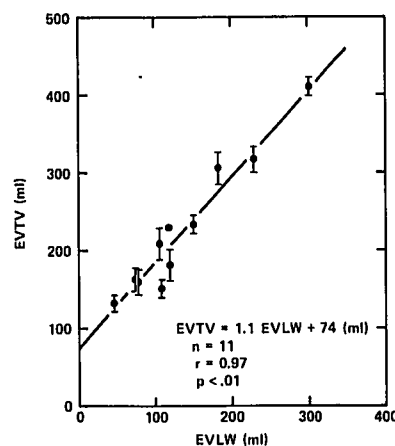
where: EVTV = extravascular thermal volume; CO_{TF} = thermodilution cardiac output from the femoral artery thermister; MTT_{TF} and MTT_{dye} = the transit times of the temperature and green dye curves. In seven control animals the PCWP was maintained at 1-10 mmHg and following final EVTV measurements the animal was immediately sacrificed, the chest opened, hilum clamped, lungs removed and EVLW measured by gravimetric technique. In four animals pulmonary edema was produced by passing an 8Fr double lumen large balloon tipped catheter into the left atrium. Eight to 15 ml of fluid was injected in to the balloon to increase the left atrial pressure (LAP) and PCWP to 25-40 mmHg with simultaneous intravenous infusion of normal saline. After 1-2 hours EVTV measurements in quadruplicate were obtained and the animals sacrificed with immediate gravimetric analysis of the lungs. EVTV as measured by the computer

assisted double indicator dilution technique was compared to the actual EVLW by gravimetric analysis using the least squares method.

Results. Significantly higher PCWP, EVLW and EVTV's were found in the pulmonary edema animals when compared to controls (see table).

	Controls	Edema	p
n	7	4	
PCWP (mmHg)	6 ± 3.5	33 ± 7.6	<0.0005
EVLW (ml)	98 ± 34	208 ± 77	<0.005
EVTV (ml)	176 ± 35	316 ± 74	<0.0025
mean ± SD			

A linear relationship between the computer assisted EVTV and gravimetrically determined EVLW existed with a correlation coefficient of 0.97 ($P < 0.01$) (see figure).



Discussion. The computer assisted measurement of EVTV was safe, simple to perform and correlated closely with the EVLW measured gravimetrically both in the controls and the animals with acute pulmonary edema. Previous attempts to use the double indicator dilution technique have noted inaccuracy, especially with increased lung water. Such inaccuracy was possibly due to the slow diffusion of the small molecule indicators such as tritiated water. Thermal diffusion is 100 times faster than molecular diffusion so that heat is more likely to mix completely with all the EVLW in its short exposure to the pulmonary capillaries. The computer provided results which were immediate, reproducible, and accurate in this model of acute pulmonary edema. The usefulness of this system in man awaits further study.