Title: Interpretation of Pulmonary Artery Wedge Pressure Measurements during Positive End-expiratory Pressure Ventilation and after Exclusion of Bronchial Arterial Circulation in the Dog

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Introduction: When pulmonary arterial wedge pressure (PWP) accurately reflects left atrial pressure (LAP) is a useful indicator of left ventricular filling pressure. Estimation of LAP from PWP is affected by the position of the catheter, positive breathing ventilation[1], pulmonary compliance, and intravascular volume. In addition, bronchial arterial collateral flow distal to the wedged catheter tip may also affect PWP and blood sampling.[2] The purpose of this study was to evaluate the relationship between PWP and LAP by examining the assumptions upon which this relationship is based. Our study emphasized, (a) interpretation of PWP in the setting of different levels of positive end-expiratory pressure (PEEP), (b) evaluation of "proper" location of the catheter tip by identifying arterialized wedge blood samples, and (c) studying the influence of bronchial collateral system on the measured PWP and wedged blood sampling.

Methods: Five healthy pentobarbital anesthetized dogs (19-25kg) were intubated and ventilated (FIO_2:0.21). Under fluorscopy, a Swan-Ganz pulmonary artery catheter was inserted through the external jugular veins into each lung. A left atrial line was placed via the femoral artery as well. Additional monitoring included femoral arterial, esophageal, and airway pressure. Each dog was placed in the right lateral decubitus position. It is postulated that the superior (left) and the dependent (right) lung represented zone I and III respectively.[3] After a 30 min rest period, control measurements were obtained: PWP in dependent right lung (PWPd), PWP in superior left lung (PWPs), LAP, esophageal, airway and transpulmonary pressure, mean femoral ($\overline{AP}$), mean pulmonary arterial pressure in dependent ($\overline{PAP}$d) and superior ($\overline{PAP}$s) lung, and cardic output (CO). Blood samples were concurrently obtained for $Pa0_2$, $PaCO_2$, mixed venous PO_2 ($P\bar{v}0_2$), $P\bar{v}CO_2$, and wedge PO_2 and PCO_2 from both the dependent ($Pwd0_2$ $PwdCO_2$) and superior ($Pws0_2$, $PwsCO_2$) lung. PEEP was added in 5cm H_20 increments up to 20 cm H_20 and measurements were made 20 min after each increment. Then, the chest was opened and bronchial arterial blood supply to the lungs was eliminated by ligation and transection of the first 8 couples of intercostal and both internal thoracic arteries. After the chest was closed, repeat baseline measurements were obtained and PEEP was applied as previously. Finally, the dog was turned on the opposite side (now, the left lung was dependent) and the measurements were repeated. Statistical significance was determined using student's two-tailed t-test; all data are expressed as mean±SEM. Pressures are given in mm Hg and CO in L/min.

Results: Data are summarized in the table.

Wedge PCO_2 in both lungs was persistently lower than $PaCO_2$ ($p < 0.02$) Wedge PO_2 was arterialized in all specimens. We were able to withdraw wedge blood from both lungs at all PEEP levels.

	CONTROL	PEEP (cm H_20)			
		5	10	15	20
$\overline{AP}$	106±8	109±10	100±14	124±11	120±14
$\overline{PAP}_d$	11±1	14±2	18±2*	19±2*	23±2*
$\overline{PAP}_s$	11±1	14±2	19±2*	21±3*	27±2*
PWP_d	2±1	4±2	6±1*	7±2*	11±2*
LAP	3±1	5±2	7±1*	8±1*	12±2*
PWP_s	4±1	7±2*	10±2*	12±2*	17±2*
P_a0_2	100±7	89±8	105±10	95±10	96±10
P_aCO_2	39±5	45±2	40±6	45±3	57±4
$P_{\bar{v}}0_2$	43±4	48±2	40±4	40±2	43±2
$P_{wd}0_2$	102±15	99±7	92±13	103±13	123±9
$P_{wd}CO_2$	29±6	38±2	30±4	35±3	34±2
$P_{ws}0_2$	102±11	109±11	95±14	102±11	81±6
$P_{ws}CO_2$	25±4	37±6	29±3	32±5	33±4
CO	2.6±0.3	2.4±0.2	2.3±0.3	2.2±0.2	2±0.3*

* Statistically significant in comparison to control values

PWPd consistently approximated LAP even at higher PEEP values (ns); PWPs closely approximated LAP only at zero and 5 PEEP (ns); overestimated LAP at higher PEEP levels ($p<0.01$), and approximated to airway pressure (ns). Elimination of bronchial artery supply, did not affect either PWP or wedge blood gas measurements. The results were identical in the superior and dependent lung when the dog was turned on the opposite side.

Conclusions: First, we confirm that the tip of the wedged catheter must be below the left atrium to accurately reflect LAP when PEEP is used. Second, arterialization of wedge blood does not ensure that the catheter tip is in zone III. Third, the bronchial artery blood supply does not affect PWP in normal lung and does not appear to be a source of blood aspirated from the wedged pulmonary artery catheters. Fourth, the consistent ability to pull back arterialized wedge blood samples suggests that zone I does not exist for all pulmonary vasculature even at high PEEP.

References:

1. Moser KM et al: Ann Internal Med 98:53-8, 1983.
2. Lefcoe MS et al: Crit Care Med 7:449-53, 1979.
3. West JB et al: J App Physiol 19:713-24, 1964.