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PEEP-induced Discrepancy Between Pulmonary Arterial Wedge Pressure and Left Atrial Pressure:

The Effects of Controlled vs. Spontaneous Ventilation and Compliant vs. Noncompliant Lungs in the Dog

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Pulmonary-artery (PA) wedge pressure (P_{paw}) is usually considered to be an accurate reflection of left atrial pressure (P_{la}). Recent reports had demonstrated that during controlled positive-pressure ventilation (CV) in normal lungs, a progressive increase in positive end-expiratory pressure (PEEP) produced a progressive positive $P_{paw}-P_{la}$ discrepancy when the PA catheter tip was positioned vertically above the left atrium (LA). In seven anesthetized dogs the $P_{paw}-P_{la}$ relationship (as transmural pressures) was studied at PEEP = 0, 5, 10, 15, and 20 torr, in two ways: 1) in compliant lungs with the PA catheter tip above the LA, CV was compared with spontaneous ventilation (SV); 2) during CV with PA catheter tip both above (C_{up}) and below (C_{down}) the LA compliant lungs were compared with noncompliant lungs. A 35 per cent decrease in static pulmonary compliance was induced by administering oleic acid, 0.06 ml/kg, intravenously, and 0.01N HCl, 5 ml, intratracheally. In compliant lungs with the PA catheter tip above the LA during CV, P_{paw} was significantly greater than P_{la} at PEEP ≥ 5 torr and equalled PEEP when PEEP ≥ 10 torr, whereas during SV, P_{paw} did not differ significantly from P_{la} at any PEEP. During CV in compliant lung, P_{paw} recorded from C_{up} and C_{down} was significantly greater than P_{la} at PEEP ≥ 5 and PEEP ≥ 15 torr, respectively. During CV in noncompliant lung, P_{paw} recorded from C_{up} and C_{down} was significantly greater than P_{la} at PEEP ≥ 10 and PEEP ≥ 15 torr, respectively. The $P_{paw}-P_{la}$ difference from C_{up} at PEEP ≥ 10 torr was significantly less in noncompliant lung than in compliant lung. It is concluded that SV affords complete protection of the P_{paw}-to-P_{la} relationship even at high PEEP, whereas a decrease in pulmonary compliance affords moderate protection of the P_{paw}-to-P_{la} relationship. These results are important because they further our ability to assess the accuracy of P_{paw} during varying clinical situations. (Key words: Equipment, catheters, Swan-Ganz. Heart, vascular pressures. Lung, compliance; intravascular pressues. Ventilation: pattern; mechanical; spontaneous; positive end-expiratory pressure.)

PULMONARY-ARTERY WEDGE PRESSURE (P_{paw}) is considered to be an accurate reflection of left atrial pressure (P_{la}) provided there is a continuous column of fluid between the wedged pulmonary-artery catheter tip and the left atrium (Zone III, a region within the lung where pulmonary arterial pressure [P_a] exceeds pulmonary venous pressure [P_v], which in turn exceeds alveolar pressure [P_A], $P_a > P_v > P_A$[1–3]). Positive end-expiratory pressure (PEEP) can result in intermittent collapse (Zone II, $P_a > P_A > P_v$) and perhaps continuous collapse (Zone I, $P_A > P_a > P_v$) of this column of fluid, depending upon 1) the magnitude of the change in transpulmonary pressure secondary to PEEP; 2) the vertical hydrostatic gradient between the wedged pulmonary-artery catheter tip and left atrium; 3) the transmission of PEEP to the pulmonary vasculature as a function of pulmonary parenchymal compliance; 4) the pressure changes occurring in the pleural space during the ventilatory cycle. A recent study demonstrated, in dogs with normal lungs and normal P_{la} during controlled positive-pressure ventilation, that a progressive increase in PEEP ≥ 5 torr produced a progressive positive discrepancy between P_{paw} and P_{la} (*i.e.*, $P_{paw} > P_{la}$) when the pulmonary-artery catheter was wedged above the level of the left atrium.[4] We questioned how changes in the ventilatory pattern and pulmonary compliance would affect this previously described PEEP-induced $P_{paw}-P_{la}$ discrepancy. The purpose of this study was to examine quantitatively the relationship between P_{paw} and P_{la} as a function of PEEP during controlled ventilation compared with spontaneous ventilation and in compliant compared with noncompliant lungs.

Methods

Seven mongrel dogs, weighing 16 to 23 kg, were anesthetized with pentobarbital, 25 mg/kg, intravenously (iv), tracheally intubated, paralyzed with pancuronium, 0.1 mg/kg, iv, and mechanically ventilated with oxygen ($F_{I_{O_2}}$ = 1.0) at a tidal volume of 15 ml/kg and a ventilatory rate so that end-tidal CO_2 = 5 per cent (Beckman LB-2). Anesthesia was maintained with pentobarbital, 2–3 mg/kg, iv, every hour. The animals were placed in the right lateral decubitus position. A left thoracotomy was performed for placement of left atrial and pleural catheters. While the chest was open, two transcutaneously passed (via the femoral veins) triple-lumen balloon-tipped pulmonary-artery catheters (Edwards #93-113-7F) were

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TABLE 1. Pulmonary Vascular Pressure and Cardiac Output during Controlled *vs.* Spontaneous Ventilation in Compliant Lung

PEEP (torr)	Controlled Ventilation			Spontaneous Ventilation		
	P_{paw} (torr)	P_{la} (torr)	$\dot{Q}_t$ (l/min)	P_{paw} (torr)	P_{la} (torr)	$\dot{Q}_t$ (l/min)
0	6.5 ± 0.7	5.5 ± 0.7	4.1 ± 0.2	7.3 ± 0.7	5.7 ± 0.6	5.0 ± 0.5
5	7.8 ± 0.8*	5.1 ± 0.7	4.4 ± 0.3	7.3 ± 1.1	5.4 ± 0.7	4.7 ± 0.4
10	9.4 ± 1.0*	4.9 ± 0.6	3.3 ± 0.3†	8.0 ± 0.8	6.2 ± 0.5	4.5 ± 0.4
15	13.4 ± 1.0*	5.0 ± 0.6	2.4 ± 0.2†	8.9 ± 1.0	7.0 ± 1.1	4.2 ± 0.4
20	19.0 ± 1.6*	5.8 ± 0.7	1.6 ± 0.1†	9.8 ± 2.0	8.1 ± 2.0	3.9 ± 0.6†‡

PEEP = positive end-expiratory pressure; P_{paw} = transmural pulmonary arterial wedge pressure; P_{la} = transmural left atrial pressure; $\dot{Q}_t$ = cardiac output.
* $P < 0.01$, significantly greater than P_{la}.
† $P < 0.01$, significantly less than $\dot{Q}_t$ at PEEP = 0.
‡ $P < 0.01$, significantly greater than $\dot{Q}_t$ at PEEP = 20 torr during controlled ventilation.

guided from within the chest so that when wedged via balloon inflation one catheter was positioned 2.5–3.5 cm (3.2 cm ± 0.2 SE) above (C_{up}) the left atrial catheter and one catheter was positioned 2.0–2.5 cm (2.3 cm ± 0.1 SE) below (C_{down}) the left atrial catheter. The chest was then closed and the pneumothorax evacuated. Pertinent measured pressures were P_{paw} from C_{up} and C_{down}, P_{la}, airway (P_{aw}) and pleural (P_{pl}). All pressure transducers (Hewlett-Packard 1280 C) were calibrated with standard mercury manometers and were referenced to atmosphere at the level of the left atrium. All pressures were recorded in torr at end expiration (Hewlett-Packard eight-channel recorder), and all pulmonary vascular and left atrial pressures are expressed as mean transmural pressure (relative to P_{pl}) ± SE. Static pulmonary compliance was measured during paralysis after 7 sec of inflation from functional residual capacity to volumes of 15 and 30 ml/kg and was calculated as static pulmonary compliance = inflated tidal volume/$P_{aw} - P_{pl}$. Changes in static pulmonary compliance were effected by administration of oleic acid, 0.06 ml/kg, iv, and 0.01 N HCl, 5 ml, intratracheally.

The experimental sequence in each animal consisted of measurement of P_{paw} from C_{up} and C_{down} and P_{la} at PEEP = 0, 5, 10, 15, and 20 torr during the following steps in order of: a) paralysis and controlled ventilation; b) spontaneous ventilation (following reversal of paralysis with neostigmine, 0.08 mg/kg, and atropine, 0.02 mg/kg, iv); c) paralysis and controlled ventilation in lungs damaged by oleic and hydrochloric acids. Comparison was made of 1) transmural P_{paw} from C_{up} only and transmural P_{la} between steps a and b (controlled *vs.* spontaneous ventilation, n = six dogs); 2) transmural P_{paw} from both C_{up} and C_{down} and transmural P_{la} between steps a and c (compliant *vs.* noncompliant lungs, n = seven dogs). Results were analyzed by t test for paired data, with $P < 0.01$ considered significant.

TABLE 2. Pleural and Transpulmonary Pressures during Controlled *vs.* Spontaneous Ventilation in Compliant Lung

PEEP (torr)	Controlled Ventilation		Spontaneous Ventilation	
	P_{pl} (torr)	P_{tp} (torr)	P_{pl} (torr)	P_{tp} (torr)
0	−3.4 ± 0.5	3.4 ± 0.5	−2.5 ± 0.7	2.5 ± 0.7
5	−1.1 ± 0.6	6.1 ± 0.6	0.5 ± 0.6	4.2 ± 0.5
10	1.2 ± 0.6	8.8 ± 0.6	4.3 ± 0.6	5.7 ± 0.6
15	2.2 ± 0.8	11.9 ± 0.7	7.8 ± 0.7	7.2 ± 0.7
20	4.7 ± 0.7	15.3 ± 0.7	11.3 ± 1.6	8.7 ± 1.6

PEEP = positive end-expiratory pressure; P_{pl} = pleural pressure; P_{tp} = transpulmonary pressure.

The following procedures were performed at the following times. Step c was performed three hours after the administration of oleic acid and HCl. Static pulmonary compliance was measured during steps a and c. Arterial blood-gas and *p*H analyses were performed at the beginning of steps a, b and c. Thermodilution cardiac output ($\dot{Q}_t$) was determined at all levels of PEEP and during all experimental steps. Steps a, b and c each took approximately 60 min to complete. Dextrose, 5 per cent, in lactated Ringer's solution was administered iv at a maintenance rate only.

Results

Controlled vs. Spontaneous Ventilation in Compliant Lung

Transmural P_{la} did not change significantly at any level of PEEP during controlled or spontaneous ventilation (table 1). During controlled ventilation P_{paw} (from C_{up} only in this section) was significantly greater than P_{la} at PEEP ≥ 5 torr, and at PEEP ≥ 10 torr P_{paw} closely reflected PEEP. During spontaneous ventilation P_{paw} did not differ significantly from P_{la} at any level of PEEP. $\dot{Q}_t$ decreased significantly at PEEP values of 10 torr or more during controlled ventilation, but only at 20 torr during spontaneous ventilation. However, $\dot{Q}_t$ at PEEP = 20 torr was significantly greater during spontaneous ventilation compared with controlled ventilation. P_{pl} relative to atmospheric pressure and transpulmonary pressures (P_{tp}) recorded at each level of PEEP during both controlled ventilation and spontaneous ventilation are shown in table 2. The most striking observation was that P_{tp} was much greater during controlled ventilation than during spontaneous ventilation. With increasing PEEP, the difference between P_{paw} and P_{la}, ($P_{(paw-la)}$) progressively increased during controlled ventilation (fig. 1). Using P_{pl} at end expiration as the reference pressure, the P_{pl} at peak inspiration during controlled ventilation at PEEP = 0, 5, 10, 15, and 20 torr *increased* by 4 ± 0, 3 ± 0, 2 ± 0, 2 ± 0, and 2 ± 0 torr, respectively, whereas P_{pl} at peak inspiration during spontaneous ventilation *decreased* by 10 ± 2, 12 ± 1, 16 ± 1, 20 ± 1, and 24 ± 2 torr, respectively. During spontaneous ventilation end-tidal CO_2 values at PEEP = 0, 5, 10, 15, and 20 torr were 5.0 ± 0.1, 5.7 ± 0.2, 6.3 ± 0.1, 7.1 ± 0.1, and 7.8 ± 0.2 per cent, respectively. During controlled ventilation end-tidal CO_2 was constant at 5 per cent.

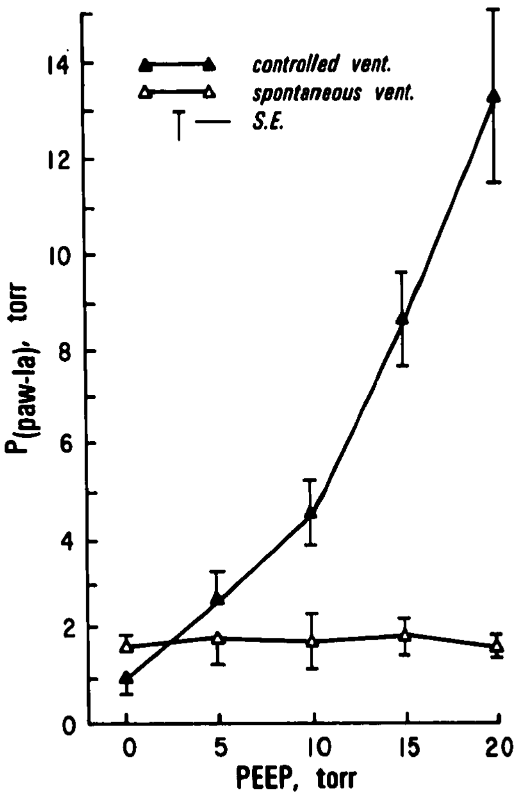

FIG. 1. PEEP = positive end-expiratory pressure. P_{paw-la} = transmural pulmonary arterial wedge pressure − transmural left atrial pressure.

Controlled Ventilation in Compliant Lung vs. Non-compliant Lung

Static pulmonary compliances in compliant lung at 15 and 30 ml/kg were 51 ± 9 and 65 ± 8 ml/torr, respectively, and in noncompliant lung, 32 ± 2 and 46 ± 4 ml/torr, respectively. Transmural P_{la} did not change significantly at any PEEP in compliant or noncompliant lung (table 3). In compliant lung when PEEP = 5 torr and was progressively increased to 20 torr, P_{paw} from C_{up} was progressively greater than P_{paw} from C_{down}. In noncompliant lung when PEEP = 10 torr and was progressively increased to 20 torr, P_{paw} from C_{up} was progressively greater than P_{paw} from C_{down}, but the difference between C_{up} and C_{down} was less in noncompliant lung than in compliant lung. In compliant lung P_{paw} recorded from C_{up} and C_{down} was significantly greater than P_{la} at PEEP ≥ 5 and PEEP ≥ 15 torr, respectively. In noncompliant lung, however, P_{paw} recorded from C_{up} and C_{down} was significantly greater than P_{la} at PEEP ≥ 10 torr and PEEP ≥ 15 torr, respectively. P_{paw-la} from C_{up} in noncompliant lung was significantly less than P_{paw-la} from C_{up} in compliant lung at PEEP ≥ 10 torr (fig. 2). P_{paw-la} from C_{down} was not significantly different between compliant and noncompliant lung at any level of PEEP. P_{pl} relative to atmospheric pressure and P_{tp} recorded at each level of PEEP in both compliant lung and noncompliant lung are shown in table 4. $\dot{Q}_t$ was

TABLE 3. Pulmonary Vascular Pressure in Compliant *vs.* Noncompliant Lung during Controlled Ventilation

	Compliant Lung			Noncompliant Lung		
PEEP (torr)	P_{la} (torr)	P_{paw} Up (torr)	P_{paw} Down (torr)	P_{la} (torr)	P_{paw} Up (torr)	P_{paw} Down (torr)
0	5.6 ± 0.6	6.9 ± 0.7	6.7 ± 0.7	6.3 ± 0.8	6.8 ± 0.8	7.0 ± 0.9
5	5.1 ± 0.6	7.9 ± 0.7*	6.1 ± 0.6	5.1 ± 0.8	6.6 ± 0.7	5.6 ± 0.8
10	5.3 ± 0.6	9.6 ± 0.9*	6.6 ± 0.8	5.4 ± 0.7	7.2 ± 0.7*†	6.2 ± 0.7
15	5.5 ± 0.7	13.9 ± 1.0*	9.1 ± 1.0*	6.2 ± 0.6	9.9 ± 0.8*†	8.1 ± 1.0*
20	6.4 ± 0.9	19.6 ± 1.4*	12.5 ± 1.5*	6.7 ± 0.8	14.6 ± 1.1*†	10.4 ± 0.9*

PEEP = positive end-expiratory pressure; P_{la} = transmural left atrial pressure; P_{paw} Up = transmural pulmonary arterial wedge pressure catheter above left atrium; P_{paw} Down = transmural pulmonary arterial wedge pressure, catheter below left atrium.
* $P < 0.01$, significantly greater than P_{la}.
† $P < 0.01$, significantly less than P_{paw} Up in compliant lung.

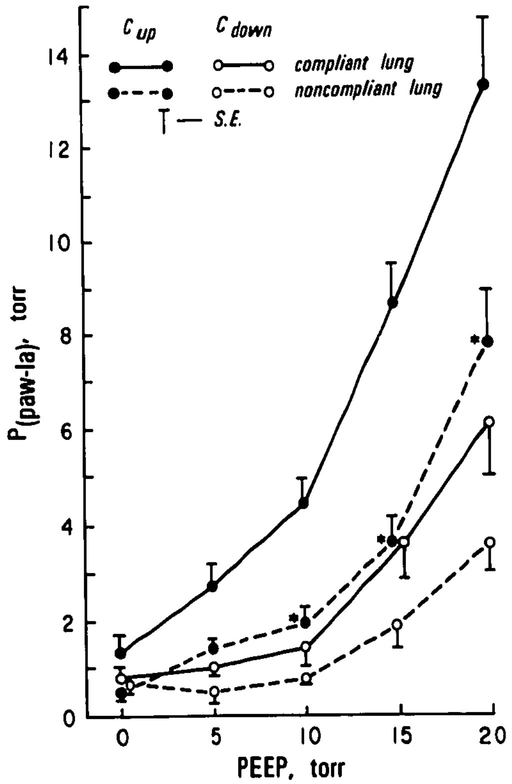

FIG. 2. See figure 1. *$P < 0.01$, significantly less than P_{paw-la} from C_{up} in compliant lung. C_{up} = pulmonary arterial catheter positioned above left atrium; C_{down} = pulmonary arterial catheter positioned below left atrium.

significantly decreased at PEEP ≥ 10 torr compared with PEEP = 0 in compliant and noncompliant lung, but $\dot{Q}_t$ from C_{up} and C_{down} did not differ at any level of PEEP in compliant or noncompliant lung. At PEEP = 0, arterial blood-gas and pH values were Pa_{O_2} = 436 ± 38 torr, Pa_{CO_2} = 38 ± 2 torr, pH = 7.34 ± 0.02, and Pa_{O_2} = 137 ± 29 torr, Pa_{CO_2} = 42 ± 2 torr, pH = 7.31 ± 0.04 in compliant and noncompliant lung, respectively. In view of a normal cardiac output, this corresponds to estimated right-to-left intrapulmonary shunts of 12 and 27 per cent for compliant and noncompliant lung, respectively, at PEEP = 0.

TABLE 4. Pleural and Transpulmonary Pressures in Compliant *vs.* Noncompliant Lung during Controlled Ventilation

	Compliant Lung		Noncompliant Lung	
PEEP (torr)	P_{pl} (torr)	P_{tp} (torr)	P_{pl} (torr)	P_{tp} (torr)
0	−3.0 ± 0.6	3.0 ± 0.6	−2.8 ± 0.4	2.8 ± 0.4
5	−1.2 ± 0.5	6.2 ± 0.5	−0.9 ± 0.4	5.9 ± 0.4
10	0.9 ± 0.6	7.7 ± 1.3	1.4 ± 0.5	8.5 ± 0.5
15	2.9 ± 0.7	12.2 ± 0.7	3.2 ± 0.6	11.8 ± 0.6
20	4.2 ± 0.8	15.8 ± 0.8	4.3 ± 0.7	15.7 ± 0.7

PEEP = positive end-expiratory pressure; P_{pl} = pleural pressure; P_{tp} = transpulmonary pressure.

Discussion

The necessity for P_{paw} to reflect P_{la} accurately during the treatment of critically ill patients is crucial, for if incorrect P_{paw} values are chosen, inappropriate fluid management and use of cardiotonic or vasoactive drugs can occur. The principal findings of this study were that during increasing levels of PEEP, a) spontaneous ventilation afforded complete protection of the accuracy of P_{paw} as a reflection of P_{la}, and b) noncompliant lung afforded moderate protection of the accuracy of P_{paw} as a reflection of P_{la}. Consideration should be given to both of these findings.

During spontaneous ventilation in compliant lungs, although the PA catheter was located above the left atrial level, P_{paw} remained an accurate reflection of P_{la} even with PEEP as high as 20 torr. This contrasts sharply with the large PEEP-induced discrepancy in $P_{paw}-P_{la}$ that occurred during controlled ventilation and high levels of PEEP.

A recent experiment in which P_{tp} (and therefore lung volume) was allowed to increase or was kept constant during progressive increases in PEEP[5] provides a probable mechanism for this dramatic difference. When progressively increasing PEEP was applied and P_{tp} was allowed to increase, changes in P_{pl} were minimal and changes in alveolar pressure caused P_{paw} to become progressively greater than P_{la}. When progressively increasing PEEP was applied and P_{tp} was kept constant, the changes in P_{pl} were large and were equally transmitted to P_{paw} and P_{la} so that P_{paw} always remained an accurate reflection of P_{la}.

In our experiment, we found P_{tp} during controlled ventilation to be always greater than P_{tp} during spontaneous ventilation at each level of PEEP. During spontaneous ventilation, the animals had to increase their efforts to exhale against the higher levels of PEEP, and thereby increased P_{pl} at end expiration. This accounts for the lesser increase in P_{tp} as PEEP increased during spontaneous ventilation compared with controlled ventilation. Under circumstances in which pulmonary compliance is not changing, lung volume is directly related to P_{tp}. The relative distribution of Zones I, II, and III throughout the lung is dependent upon instantaneous lung volume and pulmonary blood volume. Because P_{tp} (and therefore lung volume) increased to a much lesser extent during spontaneous ventilation compared with controlled ventilation, the relative distribution of Zones I, II, and III was minimally changed even though the absolute airway pressure (PEEP being relative to atmosphere) was high at end expiration. We suggest, then, that it is the magnitude of the change in P_{tp} (and therefore lung volume) caused by PEEP that is responsible for the accuracy or discrepancy of the $P_{paw}-P_{la}$ relationship, rather than the absolute magnitude of PEEP. We speculate that at end expiration during spontaneous ventilation with increasing PEEP, if P_{tp} increased to the same extent as during controlled ventilation, a $P_{paw}-P_{la}$ gradient would develop. Additionally, cardiac output during spontaneous ventilation did not decrease significantly until PEEP was 20 torr, which maintained pulmonary blood volume (the second determinant of distribution of lung zones).

We found that increasing PEEP during controlled ventilation caused cardiac output to decrease while P_{la} remained constant, which indicates a decrease in myocardial contractility. The decrease in myocardial contractility may have been caused by an increase in right ventricular end-diastolic pressure, which in turn may have caused a shift in the interventricular septum, which in turn may have caused a change in left ventricular geometry and compliance and left ventricular end-diastolic pressure and therefore, P_{la}.[6–8]

Our results confirm a recent report that demonstrates a PEEP-induced discrepancy in $P_{paw}-P_{la}$ in normal lungs during controlled positive-pressure ventilation with a progressive increase in PEEP when the pulmonary-artery catheter is located above the left atrium.[4] Our results show, however, that in the noncompliant lung the transmission of PEEP to the pulmonary microvasculature was decreased, and therefore the noncompliant lung "protected" to a moderate extent the accuracy of the P_{paw} measurement as a reflection of P_{la}. It is possible that the mechanism of the decreased transmission of PEEP in the noncompliant lung was due to the presence of channels between the tip of the pulmonary-artery catheter and the left atrium that were not exposed to alveolar pressure. Our calculations of right-to-left intrapulmonary shunt are compatible with this hypothesis. Thus, it may be that it is the increase in intrapulmonary shunting of blood that develops with oleic acid- and hydrochloric-acid-induced lung injury and not specifically the decrease in pulmonary compliance that affords the moderate protection of the $P_{paw}-P_{la}$ relationship in the noncompliant lung. In support of this hypothesis, it is possible that pulmonary compliance was in fact decreased in our dogs during controlled ventilation at high levels of PEEP in compliant lungs, and yet a large $P_{paw}-P_{la}$ gradient developed.

For several reasons, our results indicate that a pulmonary-artery catheter tip (which is vertically stationary) can "physiologically ascend" within the lung from Zone III to Zone II and then higher in Zone II as PEEP is progressively increased. First, in compliant lung the progressive divergence of P_{paw} from P_{la} as PEEP increased was greater in C_{up} than in C_{down}. Second, the same relative changes occurred in P_{paw} from C_{up} and C_{down} in noncompliant lung, but to a lesser extent. Third, the difference between the PEEP level (usually 5 torr) that first caused the P_{paw-la} to become significant when comparing C_{up} with C_{down} in both compliant and noncompliant lung approximated the vertical hydrostatic gradient between C_{up} and C_{down} of 5.5 cm.

The accuracy with which the P_{paw} reflects P_{la} during PEEP in the clinical setting, therefore, depends upon several factors. First, our results indicate that the vertical height difference between the pulmonary-artery catheter tip and the left atrium is important. Even when pulmonary-artery catheters have been floated to the most proximal position from which a P_{paw} and PA phasic pressure pattern can be obtained by balloon inflation and deflation, peripheral catheter placements have been reported.[9] Second, our data indicate that the relative amount of controlled positive-pressure ventilation compared with spontaneous ventilation, such as exists during intermittent mandatory ventilation (IMV), is an important consideration. These current findings suggest further studies to determine how variations in the IMV to spontaneous ventilatory rate ratio will affect the $P_{paw}-P_{la}$ relationship, from which a family of curves could be developed for all levels of PEEP. Third, our results indicate that an increase in right-to-left intrapulmonary shunt appears to afford partial protection of the $P_{paw}-P_{la}$ relationship. However, it should be noted that our animal model precluded the development of late pulmonary parenchymal changes such as extensive inflammatory cell infiltrates, formation of hyaline membranes, and early fibrosis. These changes might result in the development of an even greater intrapulmonary shunt and therefore greater protection of the $P_{paw}-P_{la}$ relationship. Fourth, even if the PA catheter tip-to-LA vertical height relationship, the controlled-to-spontaneous ventilatory rate ratio, and the intrapulmonary shunt all remained constant, a decrease in P_{la} (*i.e.*, hemorrhage) could result in the development of a $P_{paw}-P_{la}$ discrepancy. Last, during either controlled or spontaneous ventilation the magnitude of the change in P_{tp} as influenced by PEEP relative to the above-mentioned factors is obviously a determinant of the accuracy of the $P_{paw}-P_{la}$ relationship.

We conclude that the complete protection afforded the $P_{paw}-P_{la}$ relationship by spontaneous ventilation at all levels of PEEP and the partial protection afforded the $P_{paw}-P_{la}$ relationship by a moderate increase in intrapulmonary shunt during increasing levels of PEEP presently increase our confidence in P_{paw} as an accurate reflection of P_{la} in a variety of clinical situations.

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