Title: PHASIC VARIATION IN PULMONARY CAPILLARY PRESSURE MEASURED BY TIME-CONTROLLED ARTERIAL OCCLUSION

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Introduction. Pulmonary capillary pressure (Pc), the major determining factor of pulmonary water filtration, has been measured using isogravimetric method, pulmonary venous occlusion (PVO) techenique[1] and pulmonary artery occlusion (PAO) technique[2]. Although PAO technique has been successfully applied to obtain Pc in intact lung, if Pc has significant pulsation, measured Pc may only represent the pressure at the moment of occlusion, but not the pressure averaged over an entire cardiac cycle. To test whether there is significant phasic variation in Pc, we designed an experimental model so as to control the timing of PAO. We extended PAO analysis to obtaining the longitudinal distribution of pulmonary vascular resistance and compliance as well as Pc determination.

Methods. Six mongrel dogs (10-20.5Kg) were anesthetized with pentobarbital sodium and ventilated mechanically. Left thoracotomy was performed and a Millar catheter-tip pressure transducer was placed at the left lower lobe (LLL) PA. After excision of the left upper lobe, an electromagnetic flow probe and PA clamp device were placed at the left main PA. This device can occlude PA within 20msec with a variable delay after R spike on an electrocardiogram (ECG). While ventilation interrupted at end expiration, PAO pressure profile was acquired for 15 sec using 10 bit A/D converter, together with the preceding 5 sec of phasic PA pressure (Pa). We obtained the solution of PAO pressure on the condition that Cc>>Ca: $Pa(t)=a_1e^{-k1t}+a_2e^{-k2t}+Pv$, where $k_1=1/RaCa$, $k_2=1/RvCc$, by mathematically analyzing the theoretical model of the pulmonary circulation (Fig.1). Pc at the moment of occlusion was calculated as $(1-k_2/k_1)a_2+Pv$. The Pc, k_1 and k_2 averaged over an cardiac cycle and the total vascular resistance, calculated as (mean Pa - Pv)/flow to LLL, were used to determine Ra, Rv, Ca and Cc. A least-square curve fit was obtained using Gauss-Newton method and the goodness of fit was excellent with a correlation coefficient>0.99.

Results. The time-controlled PAO device provided the reproducible PAO decay curve with minimal interference. Superimposing the set of PAO curves obtained with various delays after R spike demonstrated the characteristic shapes of the individual curves (Fig.2). Pc's plot, calculated from these curves, vs. cardiac cycle shows phasic variation as large as 35% of the difference between mean Pa and Pv (Fig.3). Mean Pa, Pv, Pc, and time constants of PAO curves were averaged over an cardiac cycle and shown in Table 1. The longitudinal distributions of pulmonary vascular resistance and compliance were Ra/Rv 6:4 and Ca/Cc 1:10 (Table 1).

Discussion. Our results obtained by the time-controlled PAO method demonstrated the pulsation in Pc. The magnitude and partition of pulmonary vascular resistance and compliance were comparable to those obtained by PVO technique,[1] validating this type of analysis. Measurement of Pc is important in patients with ARDS[2] or pulmonary edema, since in these conditions pulmonary capillary wedge pressure may differ significantly from true Pc. Although maximum pulse pressure was 3 torr in our experiment, this could become much larger in pulmonary hypertension and the problem of PAO timing may become clinically important. It is concluded that our experimental model provides a useful tool to investigate hemodynamic properties of vascular bed in in-vivo lung lobe.

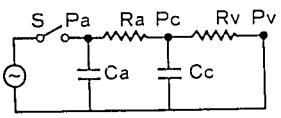

Fig.1 Ra, Rv :arterial and venous resistances. Ca, Cc : arterial and capillary compliances.

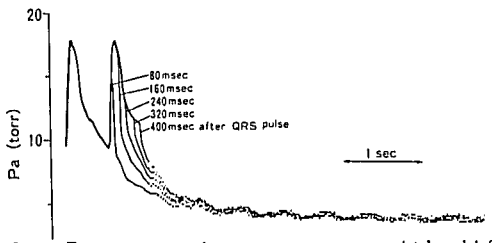

Fig.2 Pressure decay curves with different occlusion timing superimposed. Numbers indicate the occlusion time in msec after R spike on ECG.

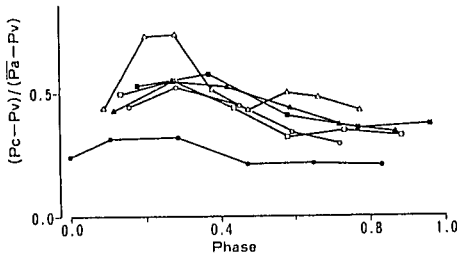

Fig.3 Capillary pressure(Pc) during cardiac cycle. Pc was normalized by (mean Pa - Pv). The abscissa indicates fractional time in one cardiac cycle, 0 and 1 corresponding to end-diastole of PA. Each symbol represents different dogs.

$\bar{Pa}$(torr)	$\bar{Pv}$(torr)	$\bar{Pc}$(torr)	time constant(sec) fast	slow
14.0±1.1	4.8±1.2	8.6±0.9	0.14±0.03	1.13±0.25
Ra(torr·s/ml)	Rv(torr·s/ml)	Ca(ml/torr)	Cc(ml/torr)	
1.5±0.3	1.2±0.3	0.10±0.02	1.03±0.19	

Table 1 Calculated parameters (mean ± SE)

References.
1. Linehan JH, Dawson CA, Rickaby DA :Distribution of vascular resistance and compliance in a dog lung lobe. J Appl Physiol 53:158-168,1982
2. Collee GG, Lynch KE, Hill RD, Zapol WM :Bedside measurement of pulmonary capillary pressure in patients with acute respiratory failure. Anesthesiology 66:614-620,1987