Postural Influence on Lobar Distribution of Blood Flow in Dogs[1] (36406)

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(Introduced by George V. Taplin)

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Over the last two decades, a number of experimental and clinical reports have confirmed a gravitational effect on the distribution of pulmonary arterial blood flow which favors the dependent regions of the lungs. Verification has been provided by a variety of techniques including lobar gas analysis, implanted flow meters and external monitoring of inhaled radioactive gas (1–3). Regional flow patterns have also been obtained with radioactive particles using scintiscanning (4).

In spite of important generic differences between man and dog, the latter is commonly chosen as the experimental model for pulmonary and cardiovascular studies. This creates the need for defining and quantitating as many of the existing hemodynamic variables as possible. Measurements of postural effects on flow through individual lobes have been limited or inconclusive (2, 5, 6). To clarify these effects and to establish a set of normal values for dogs under usual laboratory conditions, postural influence on the lobar distribution of intravenously injected radioiodinated, macroaggregated albumin (MAA) was determined.

Materials and Methods. Twenty-one medium to large mongrel dogs, average weight 20 kg, were selected. Fourteen had some characteristics identifiable as German shepherd. Light anesthesia was obtained by intravenous pentobarbital, approximately 25–30 mg/kg, with the animal prone. Five minutes prior to tracer injection the animal was placed in the desired posture, *i.e.*, right or left lateral recumbent, upright or inverted position[2] or was kept prone an equivalent period of time for the prone studies. A slow injection of specially prepared iodine-131 labeled MAA (100 μCi/3.5 mg albumin, size range 10–90 μ maximum diameter) was made into a leg vein. Two minutes after completion of the injection, the animal was returned to the prone position for 5 min, then killed with a large dose of intravenous potassium chloride. The lungs were immediately removed and blotted dry. The lobes were isolated, weighed, diced, then counted in a large well counter.

Results. The results of postural effects of lobar flow in lightly anesthetized dogs are found in Table I. Values are expressed as "percent flow" (percent of total lung activity in each lobe) and "relative flow per gram" (the ratio of activity per lobe to lobe weight divided by the ratio of total activity of both lungs to total weight of both lungs.) The latter figure allows for comparisons of relative flow independent of tissue mass. Table II gives the weight distribution of the seven lobes.

In the prone, upright, and inverted positions in which the two lungs maintain the same relative relationship, the flows in each lung correlate almost perfectly with the comparable weights. In all positions a gravitational effect is seen. In the prone position the large superiorly placed diaphragmatic lobes have the greatest total flow but the least flow per gram. With the animal upright the apical flow falls to less than 7% of the total flow although these lobes account for approx-

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[2] The inverted posture was not maintained for a full 5 min as the animals were hand held. In addition, in this position they invariably developed respiratory distress and were not in a basal state.

TABLE I. Postural Influence on the Distribution of Pulmonary Arterial Blood Flow Determined from Excised Tissue.[a]

Lobe	Prone		Upright		Inverted		Right lateral		Left lateral	
	Relative flow/g	Percent flow	Relative flow/g	Percent flow	Relative flow/g	Percent flow	Relative flow/g	Percent flow	Relative flow/g	Percent flow
Right Lung										
Apical										
Mean	1.12	18.6	0.26	4.3	1.48	24.5	1.00	18.0	0.72	11.7
Range	1.02–1.24	17.0–21.8	0.08–0.50	1.4–8.4	1.10–2.05	20.1–30.7	0.76–1.09	14.4–23.8	0.39–0.88	5.3–14.6
Cardiac										
Mean	1.32	11.4	0.85	7.2	1.06	9.6	1.26	11.3	0.59	4.9
Range	1.12–1.70	10.5–12.4	0.72–1.01	5.1–9.2	0.95–1.22	8.4–11.5	0.75–1.67	7.4–13.6	0.39–0.77	3.6–6.8
Diaphragmatic										
Mean	0.77	18.4	1.52	37.2	0.76	17.8	1.21	28.9	0.72	17.7
Range	0.72–0.82	17.8–19.3	1.11–1.89	30.4–46.9	0.49–1.06	12.9–25.2	0.94–1.36	24.4–32.8	0.56–0.83	15.0–21.5
Intermediate										
Mean	1.19	10.3	1.28	10.1	0.73	6.8	1.08	8.4	1.14	8.8
Range	1.03–1.40	8.0–13.1	1.09–1.41	8.3–12.2	0.50–0.92	4.9–8.3	0.84–1.26	7.9–8.9	0.99–1.24	8.3–9.7
Total										
Mean	1.02	58.7	1.01	58.8	0.99	58.7	1.12	66.5	0.76	43.0
Range	0.94–1.10	53.9–62.2	0.92–1.05	55.0–61.7	0.97–1.03	57.5–60.4	1.04–1.29	62.9–75.4	0.58–0.85	33.6–48.9
Left Lung										
Apical										
Mean	1.04	10.6	0.22	2.2	1.43	14.1	0.85	8.0	1.05	10.3
Range	0.94–1.14	8.9–12.4	0.07–0.44	0.6–4.8	1.17–1.92	12.8–18.3	0.70–0.96	7.7–8.3	1.04–1.07	8.6–12.2
Cardiac										
Mean	1.50	8.3	0.68	4.4	1.32	7.0	0.75	4.7	1.36	6.7
Range	1.31–1.71	7.4–9.5	0.26–0.94	1.8–7.6	1.09–1.73	5.8–7.6	0.62–0.85	3.5–5.5	1.16–1.86	5.7–7.6
Diaphragmatic										
Mean	0.85	22.4	1.37	34.7	0.80	20.2	0.84	20.8	1.42	39.9
Range	0.64–0.95	17.1–25.7	1.13–1.47	31.4–36.3	0.60–0.90	16.7–22.2	0.54–0.99	13.1–24.1	1.28–1.68	33.0–51.0
Total										
Mean	0.98	41.3	0.99	41.2	1.01	41.3	0.82	33.5	1.33	57.0
Range	0.88–1.08	37.8–46.1	0.93–1.12	38.3–45.0	0.96–1.05	39.6–42.5	0.59–0.93	24.6–37.1	1.20–1.57	51.0–66.4

[a] Five dogs in the Prone group and four each in the remaining groups.

imately 25% of the lung mass. In contrast, with the animal inverted, a much smaller decrease in flow is observed in the nondependent diaphragmatic lobes. This minimal change is probably due in part to an increased cardiac output secondary to the greatly increased respiratory effort encountered in this posture. In the lateral positions, flow changes tend to increase in the dependent lobes and to decrease in the nondependent lobes. Less change is noted in the intermediate lobe which receives its arterial supply from the right main pulmonary artery but which lies partially in the left chest cavity.

The mean weight for the 21 dogs was 20.0 $\pm$ 3.6 kg (range 13–28) with lung wet wt of 139.8 $\pm$ 31.6 g (range 77–205). These values yield an average of 0.70 g lung wt/100 g body wt.

Discussion. The results of this study show a definite postural effect on the distribution of pulmonary arterial blood flow in the dog which favors the dependent lobes. Both the theory and the reliability of measuring regional flow with radioactive particles have been established for MAA and for plastic microspheres (7, 8). The major limitation of this method is the need for obtaining tissue counts for flow quantitation in anatomic subdivisions of the lung. However, external counting or scintiscanning can be used to provide estimates of regional flow changes *in vivo*. Microspheres, because of greater control in particle size and of a more even distribution of radioactivity, may be preferred when precise measurements are required. Likewise, MAA may be advantageous for repeat experiments because they do not permanently block the arteriolar capillary bed. Microspheres made from albumin may be superior to either MAA or plastic microspheres by retaining the desirable characteristics of both (7).

Changes in body posture can cause alterations in cardiac output (2). This parameter was not measured in this study and is not normally taken into consideration in experiments where a single posture is maintained. However, conditions or drugs which increase cardiac output or raise pulmonary arterial

TABLE II. Weight by Percent of Individual Lobes $\pm$ S.D. (Range)

Right lung					Left lung			
Apical	Cardiac	Diaphragmatic	Intermediate	Total	Apical	Cardiac	Diaphragmatic	Total
16.7 $\pm$ 1.6 (13.8–20.5)	9.0 $\pm$ 1.0 (7.3–10.8)	24.3 $\pm$ 1.6 (21.4–27.5)	8.3 $\pm$ 1.1 (6.7–10.2)	58.3 $\pm$ 1.6 (55.6–61.1)	9.9 $\pm$ 1.0 (8.3–11.7)	5.8 $\pm$ 0.9 (3.7–7.3)	26.1 $\pm$ 1.7 (23.1–30.3)	41.7 $\pm$ 1.6 (38.9–44.6)

pressure have been shown to reduce the gravitational effect (9). The reverse is true when output or pressure are lowered.

A set of normal values for lung and lobar weights in dogs is established. The mean value of 0.70 g lung/100 g body wt is somewhat lower than that which has previously appeared in literature (10, 11), but the relative percentage of weight by lobes agrees closely with published measurements (5).

It is concluded that body posture has an important influence on relative flow of blood to the various lobes in canine lungs and these differences must be taken into consideration in many pulmonary and circulatory experiments in which dogs are utilized.

Summary. A study was undertaken in dogs to determine the role of posture on regional pulmonary arterial perfusion and to establish a set of normal values for lobar blood flow in various body positions. Relative flow through each of the seven lobes was measured by *in vitro* tissue counting in five body positions following intravenous injection of albumin macroaggregates. In each position a definite flow gradient was found which favored the dependent lobes. Quantitative results are presented as are values for lung and lobar weights.

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