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Title : CIRCULATORY EFFECTS OF ANESTHESIA IN THE DEVELOPING SHEEP. I. HALOTHANE

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Introduction. To determine whether age modulates the cardiovascular effects of halothane anesthesia, we studied chronically prepared sheep and lambs.

Methods. Eighteen animals were grouped by age into three groups of six: "newborns" were 5-10 days old at the time of study; "weanlings" were 5 1/2 - 6 1/2 weeks of age; and "adults" were young, non-pregnant sheep. For each age group, we determined MAC for halothane in a standard fashion. We used an ear clamp as the stimulus, controlled ventilation, and measured end-tidal anesthetic concentrations with a Beckman LB_2 infrared gas analyzer. We then prepared the animals for study by surgically implanting polyvinyl catheters into the left atrium, main pulmonary artery, and descending aorta. Three to five days later, we performed cardiovascular studies while the animals were awake and anesthetized at 1 and 1.5 MAC halothane in oxygen. After 2 hr, we repeated measurements at 1 MAC. We measured or calculated values for circulatory variables (table 1) at each anesthetic concentration. After making these hemodynamic measurements, we measured regional blood flows by injecting 15 μ radioactive microspheres into the left atrium and collecting a reference sample from the aorta for measurement of cardiac output (CO). At each anesthetic concentration, blood gases were taken to ensure constancy of ventilation and adequacy of oxygenation, and to determine the arteriovenous oxygen content difference.

Results. MAC for halothane was as follows: for the newborn (N), 1.07 ± 0.01; for the weanling (W), 0.95 ± 0.08; and for the adult (A), 0.83 ± 0.2. All circulatory data and changes in organ blood flow are given in Table 1.

Discussion. Newborn and adult sheep demonstrated dose-related changes in all measured variables. Reductions from control occurred more frequently in newborns than in adults for the following variables: HR, MAP, and CO. Values for weanlings were similar to those for adults, except for CO; these values were more like those for newborns. Adults had greater increases in PVR than did newborns. As an indication of redistribution of blood flow, we compared changes in blood flow for each organ with change in CO for each anesthetic level. These organ blood flows were reduced more than CO: (N) stomach; (W) stomach; and (A), kidney, upper muscle. These organ blood flows were reduced less than CO: (N) liver, upper muscle; (W), liver, upper muscle, large bowel; and (A) brain, heart, liver, lower muscle, stomach, and small and large bowel.

Table 1. Circulatory Changes (Fraction of Awake Control ± SEM) with Halothane Anesthesia

	Age	1 MAC	1.5 MAC	1 MAC after 2 hr
HR	N	0.83 ± 0.1	0.71 ± 0.1	0.87 ± 0.2
	W	1.14 ± 0.2	1.17 ± 0.2	1.23 ± 0.2
	A	1.11 ± 0.1	0.99 ± 0.2	0.95 ± 0.1
MAP	N	0.76 ± 0.1	0.61 ± 0.04	0.75 ± 0.1
	W	0.95 ± 0.1	0.77 ± 0.1	0.98 ± 0.1
	A	1.0 ± 0.1	0.88 ± 0.04	0.95 ± 0.1
CO	N	0.61 ± 0.1	0.44 ± 0.04	0.67 ± 0.1
	W	0.47 ± 0.02	0.45 ± 0.02	0.55 ± 0.1
	A	0.78 ± 0.2	0.86 ± 0.2	0.90 ± 0.3
$\dot{V}_{O_2}$	N	0.76 ± 0.1	0.52 ± 0.1	0.60 ± 0.1
	W	0.65 ± 0.1	0.73 ± 0.1	1.27 ± 0.1*
	A	-	-	-
SVR	N	1.33 ± 0.2	1.40 ± 0.1	1.15 ± 0.1
	W	1.60 ± 0.3	1.37 ± 0.3	1.51 ± 0.7
	A	1.53 ± 0.3	1.23 ± 0.3	1.43 ± 0.3
PVR	N	1.42 ± 0.2	1.26 ± 0.2	1.20 ± 0.1
	W	2.14 ± 0.7	1.03 ± 0.1*	0.81 ± 0.1*
	A	1.82 ± 0.4	2.47 ± 0.1	2.42 ± 0.7

Organ Blood Flows

	Age	1 MAC	1.5 MAC	1 MAC after 2 hr
Brain	N	0.52 ± 0.1	0.43 ± 0.04	0.47 ± 0.1
	W	-	-	-
	A	1.48 ± 0.4	0.89 ± 0.3	1.11 ± 0.2
Heart	N	0.52 ± 0.1	0.33 ± 0.1	0.61 ± 0.01
	W	0.35 ± 0.04*	0.26 ± 0.03*	-
	A	1.00 ± 0.2	0.56 ± 0.2	0.76 ± 0.1
Kidney	N	0.53 ± 0.03	0.37 ± 0.04	0.49 ± 0.1
	W	0.55 ± 0.1	0.42 ± 0.1	0.51 ± 0.03
	A	0.67 ± 0.1	0.65 ± 0.1	0.58 ± 0.1
Liver	N	0.96 ± 0.3	1.66 ± 0.6	3.40 ± 2.0
	W	1.23 ± 0.4	0.82 ± 0.03	0.74 ± 0.1
	A	2.04 ± 0.7	1.45 ± 0.3	1.32 ± 0.4
Spleen	N	0.59 ± 0.1	0.35 ± 0.1	0.52 ± 0.1
	W	0.49 ± 0.1	0.43 ± 0.1	0.44 ± 0.1
	A	0.72 ± 0.1	0.60 ± 0.1	0.44 ± 0.1
Lower muscle	N	0.68 ± 0.2	0.32 ± 0.1	0.56 ± 0.1
	W	-	0.19 ± 0.1	0.62 ± 0.3
	A	1.41 ± 1.1	1.24 ± 0.8	2.32 ± 1.0
Upper muscle	N	0.86 ± 0.3	0.39 ± 0.1	0.99 ± 0.3
	W	2.12 ± 1.4*	0.85 ± 0.5*	1.21 ± 0.1*
	A	0.43 ± 0.1	0.49 ± 0.1	0.97 ± 0.3
Stomach	N	0.45 ± 0.1	0.37 ± 0.1	0.58 ± 0.1
	W	0.37 ± 0.03*	0.29 ± 0.1*	0.21 ± 0.0*
	A	1.52 ± 0.7	0.87 ± 0.3	1.34 ± 0.4
Small bowel	N	0.71 ± 0.18	0.49 ± 0.1	0.87 ± 0.2
	W	0.54 ± 0.2	0.59 ± 0.03	0.40 ± 0.1
	A	1.15 ± 0.2	1.10 ± 0.2	1.11 ± 0.1
Large bowel	N	0.74 ± 0.04	0.54 ± 0.04	0.73 ± 0.1
	W	0.81 ± 0.1	0.61 ± 0.01	0.71 ± 0.2
	A	1.20 ± 0.4	0.86 ± 0.1	1.04 ± 0.2
Skin	N	0.65 ± 0.1	0.42 ± 0.1	0.67 ± 0.2
	W	-	-	-
	A	0.73 ± 0.2	0.47 ± 0.03*	0.55 ± 0.03*

*n = 2. N = newborn; W = weanling; and A = adult.