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Title : CIRCULATORY EFFECTS OF ANESTHESIA IN THE DEVELOPING SHEEP. II. ENFLURANE

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Introduction. To determine whether age modulates the cardiovascular effects of enflurane 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 enflurane 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 enflurane 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 enflurane was as follows: for the newborn (N), 2.3 ± 3; for the weanling (W), 2.12 ± 0.3; and for the adult (A), 2.01 ± 0.7. 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 in heart rate from control occurred more frequently in newborns than in adults. For all variables, values for weanlings were similar to those for adults, except for heart rate; these values were more like those for newborns. All animals had greater increases in PVR than in SVR. As an indication 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) heart, kidney; (W) kidney; and (A), kidney. These organ blood flows were reduced less than CO: (N) liver, stomach, skin; (W), liver, skin; and (A) brain, liver, and small and large bowel.

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

	Age	1 MAC	1.5 MAC	1 MAC after 2 hr
HR	N	0.59 ± 0.1	0.67 ± 0.3*	0.66 ± 0.2
	W	0.65 ± 0.1	0.45 ± 0.01*	0.47 ± 0.03*
	A	0.84 ± 0.1	0.79 ± 0.1	0.80 ± 0.1
MAP	N	0.60 ± 0.1	0.48 ± 0.1*	0.59 ± 0.1
	W	0.55 ± 0.1	0.31 ± 0.03*	0.59 ± 0.1*
	A	0.56 ± 0.1	0.46 ± 0.1	0.72 ± 0.1
CO	N	0.59 ± 0.1	0.51 ± 0.2	0.48 ± 0.1
	W	0.56 ± 0.2	0.23 ± 0.01*	0.49 ± 0.1*
	A	0.63 ± 0.1	0.41 ± 0.1	0.49 ± 0.1
$\dot{V}O_2$	N	0.41 ± 0.1	0.48 ± 0.1*	0.31 ± 0.1
	W	0.91 ± 0.4*	-	-
	A	0.56 ± 0.1	0.46 ± 0.2	0.31 ± 0.1
SVR	N	1.19 ± 0.2	1.11 ± 0.4*	1.45 ± 0.3
	W	1.29 ± 0.3	1.33 ± 0.1*	1.28 ± 0.2*
	A	0.98 ± 0.1	1.77 ± 0.5	1.39 ± 0.02
PVR	N	2.13 ± 0.6	2.82 ± 2.1*	2.89 ± 1.2
	W	2.47 ± 1.3	1.42 ± 0.9*	0.87 ± 0.1*
	A	1.62 ± 0.3	3.47 ± 1.8	2.17 ± 0.6

Organ Blood Flows

	Age	1 MAC	1.5 MAC	1 MAC after 2 hr
Brain	N	0.66 ± 0.1	0.96 ± 0.2*	0.58 ± 0.1
	W	0.71 ± 0.1	0.39 ± 0.1*	0.61 ± 0.2*
	A	0.77 ± 0.1	0.64 ± 0.1	0.56 ± 0.1
Heart	N	0.29 ± 0.1	0.24 ± 0.1*	0.21 ± 0.1
	W	0.44 ± 0.1	0.31 ± 0.04*	0.34 ± 0.1*
	A	0.69 ± 0.1	0.49 ± 0.03	0.53 ± 0.2
Kidney	N	0.35 ± 0.1	0.14 ± 0.1*	0.18 ± 0.1
	W	0.30 ± 0.1	0.07 ± 0.03*	0.27 ± 0.02*
	A	0.39 ± 0.1	0.27 ± 0.1	0.55 ± 0.1
Liver	N	1.76 ± 0.7	0.64 ± 0.3*	0.87 ± 0.2
	W	1.5 ± 1.3	0.10 ± 0.01*	0.21 ± 0.03*
	A	5.54 ± 3.0	2.47 ± 1.1	7.08 ± 3.6
Spleen	N	0.67 ± 0.2	-	0.48 ± 0.2
	W	0.43 ± 0.1	0.15 ± 0.03*	0.41 ± 0.02*
	A	0.55 ± 0.3	0.25 ± 0.1	0.41 ± 0.2
Lower muscle	N	0.49 ± 0.2	-	0.75 ± 0.4
	W	0.46 ± 0.1	0.41 ± 0.3*	0.48 ± 0.3*
	A	0.54 ± 0.1	0.35 ± 0.1	0.58 ± 0.2
Upper muscle	N	0.42 ± 0.2	-	0.63 ± 0.3
	W	0.48 ± 0.2	0.35 ± 0.1*	0.42 ± 0.1*
	A	0.53 ± 0.2	0.43 ± 0.2	0.54 ± 0.3
Stomach	N	0.96 ± 0.3	0.99 ± 0.4*	0.94 ± 0.3
	W	0.58 ± 0.1	0.69 ± 0.3*	0.79 ± 0.2*
	A	0.68 ± 0.2	0.48 ± 0.1	0.70 ± 0.03
Small bowel	N	0.56 ± 0.1	0.52 ± 0.1*	0.48 ± 0.2
	W	0.50 ± 0.1	0.43 ± 0.1*	0.73 ± 0.3*
	A	1.19 ± 0.5	0.61 ± 0.2	1.47 ± 0.9
Large bowel	N	0.76 ± 0.2	0.53 ± 0.01*	0.42 ± 0.2
	W	0.64 ± 0.1	0.37 ± 0.2*	0.55 ± 0.01*
	A	0.90 ± 0.2	0.51 ± 0.1	0.65 ± 0.2
Skin	N	0.79 ± 0.2	-	0.71 ± 0.3
	W	0.88 ± 0.5	0.29 ± 0.1*	0.49 ± 0.03*
	A	0.69 ± 0.26	0.40 ± 0.2	0.36 ± 0.1

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