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REGIONAL REDISTRIBUTION OF BLOOD IN UNANESTHETIZED RATS AFTER BLOOD LOSS

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Relative changes in local blood volume in 46 vascular regions of the body after moderate and severe blood loss are described. Moderate blood loss caused a redistribution of blood from the skin of the chest and hind limbs, most organs of the abdomen and pelvis, the muscular and bony tissues of the abdomen, pelvis, and limbs to the brain, heart, lungs, kidneys, stomach and to the muscles of the head and neck. After severe blood loss the changes were similar but the blood volume in the kidneys and stomach was reduced; a relative increase in the blood volume in the muscular and bony tissues of the thorax also was observed. The intensity of the redistributive response to severe blood loss was less than to a moderate blood loss.

KEY WORDS: regional redistribution of blood; intravascular blood reserve; blood loss.

Changes in the general and regional circulation play an important role after blood loss [5, 6, 9]. Fluctuations in regional blood volume are determined mainly by changes in the lumen of the capacitive levels and they reflect the functioning of the dynamic intravascular blood reserve [3, 7, 10, 12]. To detect mobilization of the intravascular blood reserve it is clearly necessary to record changes in the relative blood volume in many different parts of the vascular system simultaneously. The response will be manifested more clearly if the mechanisms of regulation of the circulation are unchanged by anesthesia or by forcible fixation.

The regional redistribution of blood after blood loss was studied in this investigation with allowance made for the demands mentioned above.

EXPERIMENTAL METHOD

Four days before the experiments were carried out on male rats weighing 190-240 g, a polyethylene catheter was inserted into their external jugular vein and its end was brought out onto the head. Twice a day the catheter was washed out with physiological saline containing heparin so that at the beginning of the experiment the animals were accustomed to the manipulations; food was taken away from the cages for 18-20 h before the experiment. Blood was taken from an incision in the tail in a volume equivalent to 18.0 ± 1.82% of the total circulating blood volume (CBV) over a period of 5-7 min (moderate blood loss) or to 38.1 ±1.91% of the CBV over a period of 7-12 min (severe blood loss). A mixture of red blood cells tagged with ^{51}Cr and of albumin-^{131}I was injected through the catheter 20 min after bleeding and, after they had become uniformly mixed

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TABLE 1. Regional Redistribution of Blood in Unanesthetized Rats after Blood Loss without Forcible Fixation (M ± m)

Part of body	Vascular regions	Control		Blood loss	
		Amount of blood, mg/g	% of CBV/% of weight	% of CBV/% of weight, loading of first factor	
				18.0±1.82% CBV	38.1±1.91% CBV
Head	Skin	24±2,10	0,45±0,028	+0,315	—0,085
	mm. masseter	25±3,41	0,44±0,059	+0,409	—0,252
	Brain	27±3,41	0,44±0,046	+0,736	+0,239
	Carcass	34±2,01	0,62±0,047	+0,224	—0,113
Neck	Skin	23±2,98	0,48±0,061	+0,326	+0,376
	mm. levator auris longus	21±2,41	0,40±0,046	+0,455	+0,026
	Salivary glands	32±4,91	0,71±0,146	+0,336	—0,057
	Carcass	29±2,54	0,56±0,066	+0,555	+0,377
Chest	Skin	21±3,14	0,33±0,034	—0,708	—0,335
	mm. rectus thoracis	17±2,24	0,34±0,066	—0,036	—0,315
	Heart (muscles)	211±16,3	3,65±0,312	+0,810	+0,497
	Lungs	392±40,7	6,49±0,630	+0,736	+0,569
	Carcass	35±4,00	0,57±0,027	+0,036	+0,450
Abdomen and pelvis	Skin	13±3,23	0,22±0,038	—0,283	—0,038
	mm. rectus et obliquus abdominis	15±1,60	0,31±0,034	—0,349	—0,151
	Liver	378±28,8	6,81±0,358	—0,064	—0,134
	Small intestine	36±3,49	0,71±0,093	—0,380	—0,626
	Large intestine	30±3,32	0,53±0,038	—0,588	—0,188
	Stomach	53±5,47	0,88±0,078	+0,584	—0,377
	Kidneys	192±17,8	3,41±0,233	+0,409	—0,463
	Adrenals	174±19,6	3,47±0,322	+0,274	+0,235
	Spleen	329±66,5	6,89±1,211	—0,536	—0,346
	Pancreas	81±17,4	2,21±0,414	—0,179	—0,458
	Urinary bladder	56±4,17	1,01±0,182	+0,166	—0,621
	Testes	32±4,05	0,47±0,026	—0,662	—0,376
	Carcass	26±3,01	0,46±0,034	—0,657	—0,529
Forelimbs	Skin	23±3,87	0,42±0,034	—0,004	+0,014
	mm. biceps	19±3,15	0,37±0,064	—0,022	—0,230
	Humeri	38±3,17	0,73±0,067	+0,138	+0,005
	Carcass	27±3,17	0,48±0,047	—0,616	—0,604
Hind limbs	Skin	23±5,68	0,48±0,099	—0,674	—0,779
	mm. gastrocnemeus	18±2,38	0,36±0,052	+0,146	—0,442
	Femora	44±4,86	0,84±0,077	+0,361	—0,237
	Carcass	22±2,28	0,41±0,048	—0,657	—0,590
Tail		17±3,35	0,37±0,069	—0,251	—0,144

in the circulation, 0.7 ml of a saturated KCl solution also was injected. The cadavers of the rats were frozen to −20°C in the course of 2 h, blood samples were taken by dissection of the tissues, and their radioactivity was determined. Since the ratio between the radioactivity of the indicator of the blood cells and the total activity of the indicator mixture injected was equal to the individual hematocrit index of the circulating blood, the level of indication of the whole blood could be determined from the total radioactivity of the sample [1]. The muscular and bony tissues left in each part of the body after removal of the samples of skin and the weighed samples of muscles and internal organs were described as the "carcass." Special experiments showed that the time for uniform mixing in the control and after moderate blood loss was 10 min for labeled red cells and 3 min for the plasma. After severe blood loss the corresponding times were 20 and 6 min.

Special experiments also showed that agonal and postmortem redistribution of blood were virtually identical in the experimental and control animals. The regional redistribution of blood was characterized by the relative index: % of CBV/% of weight [2]. Statistical analysis of the results was carried out by correlation and factor analysis by the method of chief components [4]. An essential feature of the factor analysis was factorization of the correlation matrix of the changes in features, suggested by one of us. The M-22 computer was used for quantitative analysis of the data.

EXPERIMENTAL RESULTS AND DISCUSSION

CBV for the control rats was 55±1.79 mg blood/g body weight. After average blood loss CBV was reduced to a mean value of 46±2.91 mg (P 0.02), about equivalent to the volume of blood lost. Under these circumstances, however, the hematocrit index also fell from 42.4±1.01 to 37.4±1.14 (P 0.01). After severe blood loss CBV was reduced to a mean value of 39.1±1.37 mg/g, but this reduction was less than the volume of blood lost.

Loadings of the first factor characterizing the relative changes in blood volume in the experimental animals compared with the controls are given in Table 1. The statistically significant ($P < 0.05$) factor loading in absolute value was greater than or equal to 0.360. A + and − sign denotes a probable increase or decrease in the local blood volume.

The results of the investigations showed that moderate blood loss causes a redistribution of blood from the skin of the chest and hind limbs, from most of the abdominal and pelvic organs, from the carcass of the abdomen and pelvis, and from the carcasses of the limbs to the brain, heart, lungs, kidneys, stomach, and also to the muscles of the head and neck. After severe blood loss the response was very similar, but the relative blood volume in the kidneys and stomach was reduced and no redistribution of the blood into the vascular regions of the head was present. Meanwhile a relative increase in the blood volume of the thoracic carcass was observed. The intensity of the redistributive response to severe blood loss was lower than to moderate blood loss. This is shown by the lower weighting of the first factor and also by the smaller difference in the weightings of the first and second factors after severe blood loss. After moderate blood loss the weighting of the first factor was 23.0%, of the second 9.7%, and of the third 8.4%, whereas after severe blood loss the corresponding values were 17.8, 10.3, and 8.7%.

The results confirm information to the effect that the blood volume after blood loss is reduced mainly in the internal abdominal organs [9, 11] and they contradict the view that blood is mobilized from the lungs [8]. In the present experiments there was not only a relative, but actually an absolute increase in the blood volume in the lungs ($P < 0.02$).

It is interesting that the redistribution of blood after blood loss took place not only into the internal organs, but also into the musculature of the head, neck, and chest. Fluctuations in the blood volumes in the internal organs of the abdomen and pelvis, on the one hand, and of the chest, on the other hand, were reciprocal in character and the fluctuations in the regional blood volumes in the vessels of the skin and muscles in different parts of the body and in certain organs of the "splanchnic" regional exhibited functional heterogeneity.

The results of this investigation suggest that after blood loss the intravascular blood reserve is mobilized and utilized in vitally important organs as well as in the musculature of the anterior part of the body, the functional activity of which must evidently have some special significance.

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