ROLE OF THE INITIAL HEMODYNAMIC STATUS AND RATE OF BLOOD LOSS REPLACEMENT IN POSTRESUSCITATION CIRCULATORY CHANGES AND MORTALITY OF ANIMALS

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The role of initial hemodynamic heterogeneity in the formation of postresuscitation circulatory disturbances remains virtually unstudied, although there are both direct and indirect indications of possible correlation between them [2, 7]. Meanwhile, as a result of recent original data [1, 4, 6], traditional ideas on the rapid correction of the patient's or animal's blood deficit, the high arterial blood pressure, and the sudden centralization of the circulation as being unequivocally positive reactions during resuscitation, have been made more precise and, to a certain extent, revised [5].

The aim of this investigation was to study changes in the central hemodynamics (CHD) and survival rate of animals after clinical death and their dependence on the initial hemodynamic status, the rate of blood loss replacement, and the use of deligandized albumin (Albosorb), which possesses not only a hemodynamic effect, but also at the same time an enhanced detoxicating effect [3, 8].

EXPERIMENTAL METHOD

Chronic experiments were carried out on 43 anesthetized (trimeperidine 8 mg/kg and pentobarbital 5-10 mg/kg) dogs weighing from 12 to 47 kg. The animals were subjected to clinical death for 10 min by exsanguination (57.2 ± 3.2 ml/kg body weight). The duration of clinical death was 8.6 ± 70 min. The animals were revived by intraarterial injection of blood with adrenalin. If necessary, indirect cardiac massage and electrical defibrillation of the heart were carried out. There were three groups of experiments: in group 1 (12 experiments) the lost blood was completely replaced during cardiac resuscitation or in the course of 3-5 min after restoration of cardiac activity; in group 2 (17 experiments) the volume of incompletely replaced blood loss (10-15 ml/kg) was made good by intravenous injection of blood in the course of 40-50 min after restoration of cardiac activity; in group 3 (14 experiments), against the background of incompletely replaced blood loss (10-15 ml/kg) a solution of Albosorb (7-10 ml/kg) was injected by intravenous drip over a period of 20-25 min, followed by injection of the remaining blood. Before blood loss and between 10 min and 6 h after revival, the cardiac output (CO) was measured by the thermodilution method. The systemic arterial pressure (BP), the pulmonary arterial pressure (PAP), and the heart rate (HR) were recorded. The cardiac index (CI), stroke index (SI), and total peripheral resistance (TPR) were calculated. The saturation, partial pressure, and concentration of oxygen and the hemoglobin concentration were determined in arterial and mixed venous blood. The total oxygen consumption (QO_2) of the animal was calculated.

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TABLE 1. Postresuscitation Changes in Hemodynamics Depending on Initial Hemodynamic Status, Rates of Blood Loss Replacement, and Final Results of Resuscitation

Group	Parameter	Result of resuscitation	Initially	Postresuscitation period			
				10–30 min	1 h	3 h	6 h
1	CI, ml/kg·min	Survived (9)	147,3±13,1	196,5±18,8	156,6±25,1	74,5±13,7*	68,8±8,9*
		Died (5)	121,4±7,0	115,6±10,6	125,2±17,1	68,4±8,1*	67,5±5,8*
	SI, ml/kg·min	Survived	2,85±0,20	1,45±0,16*	1,31±0,18*	1,11±0,24*	0,52±0,20*
		Died	1,93±0,12	0,97±0,14*·	1,00±0,18*	0,68±0,09*	0,53±0,12*
	BP, mm Hg	Survived	96±4	128±4*	101±4	120±7*	132±8*
		Died	114±4	124±4	107±4	118±5	136±8
2	CI, ml/kg·min	Survived (9)	108,9±14,7	82,4±4,5	99,1±8,1	69,4±6,2*	61,2±4,9*
		Died (8)	99,5±9,5	67,2±5,9*	75,1±5,8·	54,5±3,2*	72,7±10,9
	SI, ml/kg·min	Survived	2,03±0,13	0,58±0,06*	0,95±0,18*	0,84±0,11*	0,53±0,12*
		Died	1,34±0,14·	0,43±0,02*	0,53±0,02*··	0,44±0,06*··	0,45±0,06*
	BP, mm Hg	Survived	116±8	124±5	118±6	119±7	129±5
		Died	121±4	112±5	105±8	99±8*	104±9·
3	CI, ml/kg·min	Survived (8)	138,4±12,6	132,3±14,0	167,1±12,5	130,5±18,8	103,7±23,1
		Died (6)	120,8±14,5	137,4±14,7	169,1±26,1	100,2±7,7	124,3±15,5
	SI, ml/kg·min	Survived	2,18±0,19	0,87±0,14*	1,28±0,14*	1,26±0,21*	0,86±0,17*
		Died	2,19±0,19	0,96±0,19*	1,24±0,18*	0,71±0,09*··	0,57±0,16*
	BP, mm Hg	Survived	100±5	116±8	111±5	113±5	130±15
		Died	104±8	125±7	119±5	104±9	120±17

Legend. *$p < 0.05$ compared with initial value, $p < 0.05$ compared with corresponding value in subgroup taken for comparison; number of animals given in parentheses.

EXPERIMENTAL RESULTS

Analysis of changes in CHD after resuscitation showed that CI in groups 1 and 3 were significantly higher in the first 10-30 min and after 1 h than in group 2 (140.9 ± 16.1, 160.5 ± 20.0, and 100.2 ± 11.3 ml/kg·min respectively). By the 3rd hour the blood flow in all groups was reduced (in group 1 to 72.2 ± 6.9, in group 2 to 74.7 ± 6.8, in group 3 to 121.2 ± 16.2 ml/kg·min). However, in the experiments with Albosorb it did not fall below its initial level, and between 3 and 6 h it significantly exceeded the blood flow in the comparison groups.

Despite the significantly greater blood flow in group 1 than in group 2, the QO_2 level during the first 10-30 min after the beginning of resuscitation did not differ significantly. Only after 1 h was the greater blood flow in group 1 accompanied by a higher QO_2 (7.30 ± 0.78 and 4.55 ± 0.67 ml/min·kg respectively). However, in response to injection of Albosorb, the increase in perfusion was accompanied by increased oxygen consumption at the early stages of resuscitation also.

Comparison of the degree of changes in CI and SI in the period from 3 to 6 h with that observed toward 1 h and the initial values revealed a significantly more marked inhibition of them if the total blood loss was replaced rapidly. In the latter case (group 1), moreover, the decrease in blood flow was accompanied by the earlier (after 3 h) development of secondary arterial hypertension and an increase in TPR.

Thus the level of perfusion during the first hour after resuscitation depends directly on the completeness of restoration of the blood loss. Meanwhile rapid injection of all the blood, while increasing the blood flow in the early stages, is not accompanied by an increase in its nutritive properties, does not prevent delayed hypoperfusion, and may possibly accelerate the development of this process. An infusion of Albosorb, against the background of a moderate blood deficiency, abolishes early hypoperfusion (observed in the case of slow replenishment of the blood loss), increases the oxygen consumption, and prolongs the phase of relative normalization of the circulation in the early postresuscitation period.

Despite the hemodynamic differences discovered, the results of resuscitation, whether interpreted by the early indicators of recovery (heart, respiration, corneal reflexes) or by the final outcome, were about the same in all three groups. The mortality rate of the dogs (in the first three days) was 50, 47, and 43% respectively.

Analysis of the parameters of the hemodynamics studied in surviving and dying animals in groups with rapid and gradual return of the blood showed differences (Table 1). Within each group SI before death was significantly higher in the former than in the latter. During resuscitation and within the first hour the dying animals exhibited less severe volume and pressure hemodynamic reactions than the more resistant animals. In group 1 this was reflected in the absence of an increase in the values of CI at the 10th-30th minutes and BP at the 10-15th minutes after the beginning of resuscitation

compared with the initial values in animals which died, and in lower values of SI in them during the same period. In group 2, it was reflected in a decrease in CI and BP relative to the initial values in animals which died between the 10th-30th minutes, and higher values in those surviving for a long time. At the stage of 1-3 h after resuscitation, lower values of SI in animals which died compared with the survivors were observed only in the experiments of group 2, with gradual replacement of the blood loss.

This dependence established between the initial level of SI and the end result of resuscitation raised the question of assessing the efficacy of rates of return of blood (after restoration of cardiac activity) in animals with an identical initial hemodynamic status. For this purpose, 6 animals were chosen from group 2 with an initial SI of between 1.58 and 2.33, i.e., the same as in the 6 dogs of group 1 which died. It was found that despite the significantly lower level of perfusion (84.0 ± 4.0 compared with 115.6 ± 10.6 ml/kg·min) and of SI (0.57 ± 0.06 compared with 0.97 ± 0.14 ml/kg·min), only one animal died in the period between 10 and 30 min. The difference in the results of resuscitation was highly significant ($p < 0.025$) and indicated that the method of gradual correction of a small blood deficit is more effective for resuscitation in the case of a low initial SI within the limits specified.

Analysis of the state of CHD in dying and surviving dogs, when Albosorb was used for treatment showed that, unlike the first two groups, whatever the end result of resuscitation the animals did not differ in values of their CHD parameters, either in the initial state or during the first hour of the recovery process (Table 1). Not until the 3rd hour was a sharp fall of SI and a more marked reduction of CI observed in the dying animals compared with the previous stage of observation. Consequently, treatment with Albosorb abolished the effect of the initial SI on the results of resuscitation. However, just as in group 2 also, the prognostic significance of a low SI 3 h after resuscitation remained negative.

Thus the final results of resuscitation, like the hemodynamic changes during the first hour after resuscitation, correlate closely, independently of the rates of placement of the lost blood (after the resumption of cardiac activity), with the initial value of SI, the latter evidently reflecting the functional state of the cardiovascular system at the moment of clinical death (the reaction to anesthesia, to immobilization stress, and so on). The effect of the initial value of SI on the course of the postresuscitation period is realized in the intensity and adequacy of the hemodynamic response during the first hour after resuscitation. With average values of the initial SI, maintenance of a moderate blood deficiency, gradually corrected toward the first hour of the postresuscitation period, is accompanied by improvement of the survival rate of the animals, compared with that observed after rapid replacement, which is evidently accompanied by the earlier formation of secondary circulatory disturbances. Rapid replenishment of the blood loss did not adversely affect the result of resuscitation only in dogs with a high initial SI.

Treatment with Albosorb abolishes the association between the initial level of SI and the result of resuscitation, but preserves the prognostic value of this parameter 3 h after resuscitation.

LITERATURE CITED

1. A. Ya. Evtushenko and L. A. Shalyakin, Anest. Reanimatol., No. 2, 31 (1986).
2. I. A. Gundarov, "Comparative characteristics of the hemodynamics of different types of circulation in healthy subjects, and in persons with a borderline level of arterial pressure and with labile arterial hypertension," Author's Abstract of Dissertation for the Degree of Candidate, Moscow (1982).
3. G. S. Mazurkevich and A. I. Tyukavin, Fiziol. Zh. SSSR, No. 5, 575 (1985).
4. N. P. Metal'nikova, I. O. Zaks, S. I. Khanyuchenko, et al., Anest. Reanimatol., No. 4, 48 (1990).
5. V. A. Negovskii, A. M. Gurvich, and E. S. Zolotokrylina, Postresuscitation Sickness [in Russian], Moscow (1987).
6. L. A. Shalyakin, Ischemia: Pathophysiological and Pharmacologic Aspects [in Russian], Kemerovo (1989), p. 14.
7. N. V. Edeleva, Anest. Reanimatol., No. 6, 50 (1987).
8. T. E. Emerson, Crit. Care Med., 17, No. 7, 690 (1989).