QUANTITATIVE FUNCTIONAL EVALUATION OF ARTERIOVENOUS ANASTOMOSES IN TRAUMATIC SHOCK

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The most feasible method of evaluating the activity of the arteriovenous anastomoses, it must be considered, is by injecting particles which cannot pass through the capillaries into the arterial system and then determining their content in the venous blood [6, 10]. Instead of the spherical globules of various sorts which have been used for this purpose [10, 11], it was decided to use hens' erythrocytes, the measurements of which were found to be from 10 × 16 to 11 × 17 μ, essentially larger than the diameter of the capillaries in cats, the animals used for the experiments. Because of the short duration of the experiments the antigenic properties of the erythrocytes were disregarded. A 25% suspension of erythrocytes in Ringer's solution was used.

To assess the over-all activity of the arteriovenous anastomoses the coefficient of activity K_{ava} was calculated. It is defined as the ratio between the total number of particles passing into the vena cava (B) and the number originally injected into the aorta (A):

$$K_{ava} = \frac{B}{A}.$$

The value of this coefficient may vary from 0 to 1 (Fig. 1).

The total number of injected particles was determined from the formula

$$A = 10^3 \cdot V_0 \cdot a,$$

where V_0 represents the volume of suspension (in ml), a is the number of particles (erythrocytes) in 1 mm^3 of suspension (determined in a hematological counting chamber).

The number of particles passing into the vena cava was calculated from the formula

$$B = 10^3 \cdot V_m \cdot b_m,$$

where V_m represents the total circulating blood volume (in ml) and b_m the number of particles contained in 1 mm^3 venous blood (mean value from results of blood samples during five recirculations, the time necessary for even distribution of the particles while they remain in active circulation). The value of b_m was calculated by the following formula:

$$B_m = \frac{\Sigma b_n}{n},$$

where Σb_n represents the total content of particles per cubic millimeter in all blood samples taken during five recirculations, and n is the number of these samples.

The first blood sample was taken from the vena cava 15 sec after injection of the suspension of erythrocytes into the aorta (the erythrocyte and leukocyte counts of the experimental animal were carried out with this sample and films were made from it). Subsequent blood samples were taken every 30 sec (7-9 samples altogether). Films were made from these blood samples, and the remaining blood was returned to the animal's circulation. The number of avian erythrocytes in the sample was calculated by the formula

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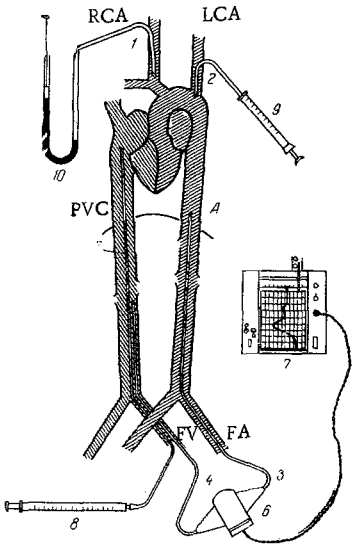

Fig. 1. Scheme of experiment. 1) Cannula for recording arterial pressure; 2) catheter for injecting particles into aorta; 3) incoming catheter of cuvette; 4) outgoing catheter of cuvette; 5) catheter for taking blood samples and injecting dye; 6) cuvette with detector for determining minute volume of circulation; 7) O36M oxyhemograph, adapted for recording dye dilution curves; 8) syringe for taking blood samples or injecting dye; 9) syringe for injecting particles not passing through capillaries; 10) mercury manometer. A) Aorta; PVC) posterior vena cava; FA) femoral artery; FV) femoral vein; LCA) left carotid artery; RCA) right carotid artery.

where b_{100} represents their number per 100 of the experimental animal's own leukocytes and L the number of leukocytes (in hundreds) per mm^3 counted in the first sample.

The erythrocyte suspension was injected into the initial segment of the aorta and blood samples were taken from the mouth of the venae cavae. The arterial pressure, pulse, and respiration were recorded, the minute volume of the circulation and circulating blood volume – by the dye (T-1824) dilution method – were determined, and the number of times that the blood circulated per minute was calculated (see figure).

The resistance to the blood flow due to the precapillaries (the principal vessels determining resistance) was determined from the data for K_{ava}. Taking the total vascular resistance as R, the resistance of the arteriovenous anastomoses as r_{ava}, and the precapillary resistance as r_{pc}, the relationship between them can be expressed by the formula

$$\frac{1}{R}=\frac{1}{r_{pc}}+\frac{1}{r_{ava}}, \tag{1}$$

from which it follows that

$$r_{pc}=\frac{R\cdot r_{ava}}{r_{ava}-R}. \tag{2}$$

Since K_{ava} is an index of the patency of the anastomoses by comparison with the total patency of the vascular system, it may be expressed as the ratio between them

$$K_{ava}=\frac{1}{r_{ava}}:\frac{1}{R}. \tag{3}$$

By transforming this equation we obtain

$$K_{ava}=\frac{R}{r_{ava}},$$

whence

$$r_{ava}=\frac{R}{K_{ava}}. \tag{4}$$

Substituting this last expression in formula (2) and simplifying, we find that

$$r_{pc}=\frac{R}{1-K_{ava}}.$$

The principal hemodynamic indices and the activity of the arteriovenous anastomoses in experimental shock were determined in this manner in 18 experiments on 18 cats. Shock was produced by Cannon's method in unanesthetized animals, and was distinguished into erectile, torpid, and terminal phases. The development of shock in these experiments was similar to that described previously [1-4]. Numerical data describing the shock are given in Table 1.

Table 1. Principal Hemodynamic Indices during Traumatic Shock in Cats

Period of investigation	Pulse (per minute)	Arterial pressure (in mm)	Circulating (in ml/min/kg)	Minute volume of circulation (in ml/min/kg)
Before shock	182±7,7	140±6,5	50±2,5	214±22,8
Torpid phase of shock	187±14,6	68±5,6	34±2,6	119±9,2
	>0,05	<0,01	<0,01	<0,01
Preterminal and terminal phase of shock	146±12,3	36±2,4	30±2,5	78±10,0
	>0,05	<0,02	<0,05	<0,02

Period of investigation	Total peripheral resistance (in dynes·sec·cm^{-5})	Number of circulations of blood (per minute)	Circulation time of blood (in min)	K_{ava}
Before shock	4 320±564	5,7±0,53	0,18±0,017	0,36±0,055
Torpid phase of shock	3 870±715	3,5±0,22	0,28±0,014	0,75±0,103
	>0,05	<0,05	<0,05	<0,05
Preterminal and terminal phase of shock	3 660±850	2,4±0,31	0,42±0,06	0,80±0,067
	>0,05	=0,05	<0,05	<0,05

Note. P^x represents the index of significance of differences determined relative to the preceding period by Van der Waerden's sign test.

The value of K_{ava} in fixed, unanesthetized animals was 0.36 ± 0.055. In ten experiments it was discovered that 25% of the particles 21 μ in diameter passed through the arteriovenous anastomoses in the hind limbs.

In the torpid phase of shock, besides arterial hypotension, a decrease in the circulating blood volume, and a decrease in the minute volume of the circulation, an increase in activity of the arteriovenous anastomoses was observed (see table), probably associated with disturbances of the capillary blood flow characteristic of shock [5, 8, 9]. The total peripheral resistance was almost unchanged. On the other hand, the resistance due to the precapillaries (r_{pc}) rose sharply – to 15,500 dynes · sec · cm^{-5} · kg^{-1} compared with 6750 dynes · sec · cm^{-5} · kg^{-1} in the initial state. No evidence of a lowering of precapillary tone in shock was thus obtained.

In the terminal phase of shock the changes described were more pronounced still, and the value of r_{pc} was 18,300 dynes · sec · cm^{-5} · kg^{-1}.

LITERATURE CITED

1. S. A. Seleznev, Pat. Fiziol., No. 3, 21 (1963).
2. S. A. Seleznev, Byull. éksp. Biol., No. 8, 46 (1963).
3. S. A. Seleznev, The Liver in Traumatic Shock, Author's Abstract of Doctoral Dissertation, Leningrad (1965).
4. O. P. Khrabrova, in the book: Proceedings of a Scientific Conference on "Physiology and Pathology of Cortico-Visceral Relationships and Functional Systems of the Organism," Ivanovo (1965), Vol. 2, p. 442.
5. G. H. Algire and R. M. Merwin, Angiology, 6, 311 (1955).
6. B. Boestroem and W. Schoedel, Pflüg. Arch. ges. Physiol, 256, 371 (1953).
7. M. Clara, Die Arterio-venösen Anastomosen, Wien (1956).
8. H. Frank, New England J. Med., 249, 445 (1953).
9. R. W. Hardaway and D. J. Johnson, Milit. Med., 128, 198 (1963).
10. J. Piiper and W. Schoedel, Pflüg. Arch. ges. Physiol., 258, 489 (1954).
11. M. Prinzmetall, B. Simkin, H. Bergman, et al., Am. Heart J., 33, 420 (1947).