MINUTE VOLUME, PERIPHERAL VASCULAR RESISTANCE, AND CIRCULATING BLOOD VOLUME IN EXPERIMENTAL TRAUMATIC SHOCK

O. P. Khrabrova

UDC 617-001.36-092.9-07:616.12-008.1-072.7

Insufficient attention has been paid to the study of changes in the hemodynamics in traumatic shock.

Investigations [9, 15] of the minute volume (MV) of the circulation and the arterial pressure in patients with traumatic shock have shown that the changes in these parameters are not always parallel, and that the changes in MV are not always proportional to the changes in the level of the arterial pressure. L. L. Shik and co-workers [8] showed that in some types of shock with a high arterial pressure the MV is low, and the shock then runs a severe course.

In the present investigation the changes in the MV, the general peripheral vascular resistance, and the circulating blood volume were investigated at different periods of experimental and traumatic shock.

EXPERIMENTAL

The experiments were conducted on cats. Shock was produced by Cannon's method by crushing the soft tissues of the thigh. To estimate the severity of the shock the arterial pressure, the pulse and respiration rates were recorded. In one group of experiments the circulating blood volume was studied, and in the other group, the MV and the general peripheral vascular resistance.

The circulating blood volume was determined by injecting 2 ml of a 0.25% solution of Evans' blue into the inferior vena cava. The circulating blood volume was calculated on the basis of determination of the concentration of the dye in the plasma in conjunction with the hematocrit index.

The MV was determined by the dye (Evans' blue) dilution method, generally accepted at the present time. The solution of the dye (0.25%) in a volume of 1 ml was injected through a catheter into the orifice of the venae cavae. The dilution curve was plotted with the aid of a type 036M oxyhemograph, modernized by the author. This apparatus was used to determine the MV in investigations by other authors [2, 14]. The detector of the apparatus was fitted to a special cuvette, made of methacrylate and tied into the femoral artery and vein. The cuvette was used so as to make the experimental conditions as identical as possible.

The peripheral vascular resistance was calculated by the usual formula [1, 3, 5, 10, 11].

EXPERIMENTAL RESULTS

The following phases of traumatic shock were distinguished: erectile, torpid, and terminal. The torpid phase was subdivided into three periods: the beginning, the period of stabilization, and the end [4].

In the course of 67 experiments, as the shock developed a gradual decrease was found in the blood volume, coinciding as a rule with a change in the arterial pressure (see table).

In moderately severe shock comparison between the circulating blood volume and the arterial pressure showed a linear relationship satisfactorily described by an equation of the type $y = f(x-a)$. Relationships of this type have been described by the author previously [7]. By the use of this relationship it could be deduced that the vascular changes were small in moderately severe shock. In severe shock no direct relationship could be obtained between the changes of arterial pressure and the circulating blood volume.

In the next series of 52 experiments the MV was determined and the peripheral vascular resistance calculated. As a rule in the experiments to study the MV the shock was severe and ended with death of the animals.

Laboratory of Pathological Physiology, I. I. Dzhanelidze Emergency Aid Research Institute, Leningrad (Presented by Academician V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 63, No. 6, pp. 21-23, June, 1967. Original article submitted October 29, 1965.

Minute Volume, Circulating Blood Volume, Peripheral Vascular Resistance, and Arterial Pressure at Different Periods of Development of Traumatic Shock (M ±m)

Index	Initial data	Phase of shock			
		torpid			terminal
		beginning	period of stabilization	end	
Minute volume (in ml/min/kg body wt.)	227±17,4	69±5,7	192±18,7	132±13,4	84±9,4
Circulating blood vol. (in ml/kg body wt)	56±2,6	47±2,3	44±2,4	34±2,2	27±3,1
Peripheral vascular resistance (dyn/sec/cm^{-5})	15 679±124,9	16 960±138,5	9 804±79,6	8 046±67,3	6 095±61,8
Arterial pressure (in mm Hg)	140±9,4	45±3,8	85±5,8	52±3,7	21±2,7

With the development of traumatic shock, a considerable decrease in the MV was observed by the beginning of the torpid phase—to 69 ml/min/kg body weight. In the period of stabilization of the shock the MV increased, coming close to its original value, but then progressively fell again (see table). As the animal's condition worsened and the MV diminished, the projection of the descending part of the dilution curve became relatively longer than the projection of its ascending part, leading to disturbance of the usual ratio between them (1 : 1.7).

Analysis of the results obtained by determination of the MV, the circulating blood volume, and the arterial pressure showed that at the beginning of development of shock the changes in these indices follow a parallel course, but this pattern is disturbed in the period of stabilization of the shock. In this period the arterial pressure rises slightly and the MV increases, but the circulating blood volume remains unchanged. The MV thus, is maintained at a fairly high level, not by a change in the circulating blood volume, but as a result of the bringing of other mechanisms into play, and especially an increase in the heart rate, which averaged at this time 200-240 beats per min.

In the later periods of development of shock (at the end of the torpid phase and in the terminal phase) the changes in these three indices once more followed a parallel course.

At the beginning of the torpid phase, i.e., at a time when the arterial pressure was falling sharply and both the MV and the circulating blood volume were diminishing, the peripheral vascular resistance was increasing (see table). With a further aggravation of the traumatic shock the peripheral vascular resistance gradually fell.

The changes in the principal hemodynamic indices are thus determined by the period of development of shock, and they follow a parallel course only in profound shock, whereas in the early periods of development of the process the changes in these indices may take place in opposite directions.

From the results obtained, it is concluded that the changes in the circulating blood volume and in the peripheral vascular resistance follow a different pattern in different parts of the vascular system.

LITERATURE CITED

1. L. V. Vesel'nikov, Kardiologiya, No. 5, 74 (1962).
2. R. S. Vinitskaya, Byull. éksp. Biol., No. 3, 114 (1965).
3. V. L. Karpman, In: Modern Methods of Investigation of the Functions of the Cardiovascular System [in Russian], Moscow (1963), p. 125.
4. S. A. Seleznev, Byull. éksp. Biol., No. 8, 46 (1963).
5. V. I. Struchkov, A. V. Vinogradov, and V. A. Sakharov et al., Grudnaya Khir., No. 5, 46 (1960).

6. V. M. Khayutin, Fiziol. Zh. SSSR, No. 3, 338 (1963).
7. O. P. Khrabrova, In: Proceedings of a Scientific Conference on the Problem: Physiology and Pathology of Cortico-Visceral Relationships and the Functional Systems of the Organism [in Russian], Ivanova, 2 (1965), p. 442.
8. L. L. Shik, R. S. Vinitskaya, and A. N. Kuznetsova et al., In: The Pathological Physiology of the Cardiovascular System [in Russian], Tbilisi, 1 (1964), p. 125.
9. J. Cohn and M. Luzia, J.A.M.A., 190 (1964), p. 891.
10. J. J. Deyle et al., J. Lab. clin. Med., 43 (1953), p. 29.
11. O. Frank, cited by V. L. Karpman.
12. A. Gerola, G. Bassi, and R. Dringoli et al., Boll. Soc. ital Biol. sper., 39 (1963), p. 82.
13. A. Groom and S. Rowlands, Phys. in Med. Biol., 3 (1958), p. 138.
14. P. Hetzel, H. Swan, and J. Arellano et al., J. appl. Physiol., 13 (1958), p. 92.
15. L. Makk and P. Johnson et al., Am. J. Surg., 108 (1964), p. 757.
16. C. Rothe and E. Selkurt, Am. J. Physiol., 207 (1964), p. 203.
17. H. Wood, Circulat. Res., 10 (1962), p. 371.
18. B. Lweifach, Fed. Proc., 20 (1961), p. 18.