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EFFECT OF THE DURATION OF PRECEDING ISCHEMIA AND THE MASS OF ISCHEMIZED TISSUE ON THE STATE OF THE CLOTTING AND ANTICLOTTING SYSTEMS OF THE BLOOD IN TOURNIQUET SHOCK

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Experiments on 80 rabbits showed that inclusion of previously ischemized limbs in the circulation is accompanied by an increase in the clotting potential of the blood and by inhibition of fibrinolysis in the early stages after removal of the tourniquets, followed by hypocoagulation and activation of fibrinolysis. These changes depend on the duration and mass of the previously ischemized tissues. The authors consider that these disturbances in tourniquet shock lead either to the risk of intravascular thrombosis or to hypocoagulation followed by secondary fibrinolysis.

KEY WORDS: ischemia; tourniquet shock; coagulation; fibrinolysis; blood clotting system.

Tourniquet shock is a serious pathological condition which frequently causes death of patients. The severity of its course is directly dependent on the duration of ischemia and the mass of ischemized tissue. Tourniquet shock, like other forms of shock, is based on disturbances of the microcirculation that are closely linked with changes in the state of the blood clotting system and fibrinolysis [12, 14]. The role of disturbance of the state of these systems in the development of tourniquet shock has not been adequately studied, and data on the problem are contradictory [1, 5, 8].

The object of this investigation was to study the state of the clotting and anticlotting systems of the blood in the early period of tourniquet shock and its dependence on the duration of previous ischemia and the mass of ischemized tissue.

EXPERIMENTAL METHOD

Experiments were carried out on 80 rabbits weighing 2.5-3 kg. Tourniquets were applied to the limbs 30 min after subcutaneous injection of morphine hydrochloride (0.3 ml of the 1% solution/kg body weight). The degree of ischemia was monitored by determining the electrical excitability of the muscles. Blood was taken in all experiments from the marginal vein of the ear before and 1, 2, 3, and 5 h after removal of the tourniquets. To study the effect of the duration of previous ischemia on the state of the systems to be tested three series of experiments were carried out in which tourniquets were applied to the fore- and hindlimbs on one side for periods of 1, 6, and 9 h. To determine the effect of the mass of ischemized tissue, two series of experiments were carried out in which tourniquets were applied to one hind limb or to the fore- and hindlimbs on one side for identical periods of ischemia, namely 6 h. Three series of experiments acted as controls: 1) intact animals, 2) animals with tourniquets applied to the fore- and hindlimbs on one side for 6 h and not subsequently removed, 3) animals with tourniquets applied to the fore- and hindlimbs on one side for 6 h but with preservation of the blood flow along the main trunk vessels (the tourniquets were applied beneath previously exteriorized vascular bundles). The clotting and anticlotting systems of the blood were studied in rela-

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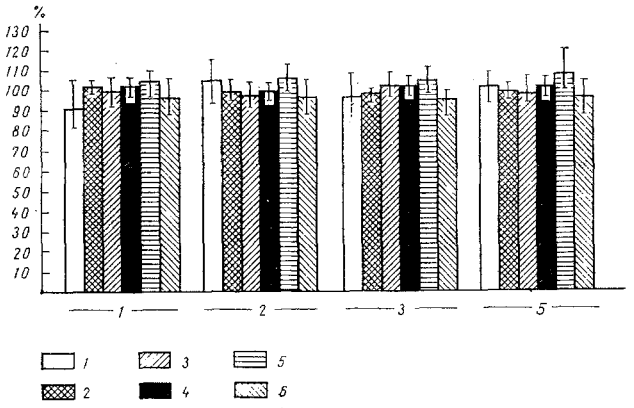

Fig. 1. Ischemia of two limbs for 1 h, after removal of tourniquets. Here and in Figs. 2 and 3: 1) blood clotting time; 2) plasma heparin tolerance; 3) prothrombin activity; 4) fibrinogen concentration; 5) fibrinase activity; 6) time for lysis of clot of euglobulin fraction of plasma. Abscissa, time after removal of tourniquet (in h); ordinate, value of indices of clotting and anticlotting systems of blood (in % of control taken as 100%).

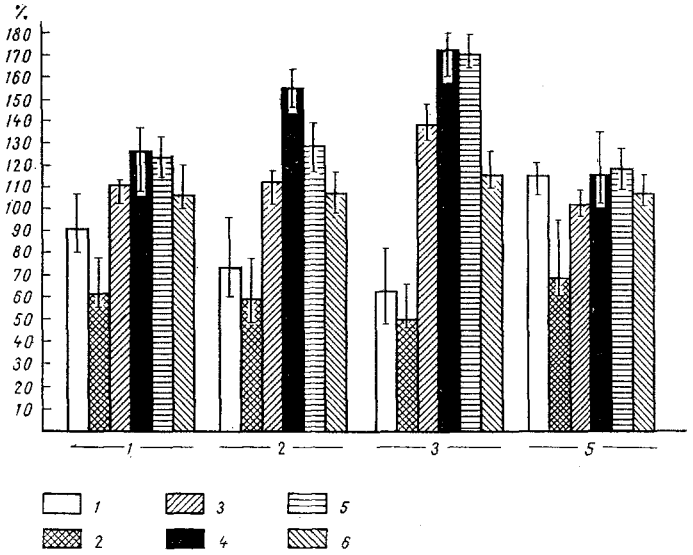

Fig. 2. Ischemia of two limbs for 6 h, after removal of tourniquets.

tion to the following indices: the blood clotting time (by means of the N-333 coagulograph), the plasma recalcification time (Bergerhof and Roka), the plasma heparin tolerance (Sigg), the free heparin time (Sirmai), prothrombin activity (Quick's method in Kudryashov's modification), the fibrinogen concentration (Rutberg), the degree of pathological fibrinogen B (Cummine and Lyons), fibrinase activity (Sigg and Duckert's method in the modification of Baluda, Zhukova, and Rukozenkova), the degree of the thrombotest (Ita's method in Kotovshchikova's modification), and fibrinolytic activity (Kowalski, Kopek, and Niewierowski).

The results were subjected to statistical analysis [13].

EXPERIMENTAL RESULTS

In control experiments the blood clotting system of the intact animals after repeated sampling underwent changes in the direction of hypercoagulation, but the changes were not statistically significant. After ischemia of two limbs for 6 h without subsequent removal of the tourniquets, the hypercoagulation trend became more distinct in character. For instance, the fourth blood sample showed significant differences from the results of the previous series of experiments with respect to the following parameters: plasma recalcification time ($P < 0.01$), fibrinogen concentration ($P < 0.05$), degree of pathological fibrinogen B ($P < 0.001$), and fibrinase activity ($P < 0.05$).

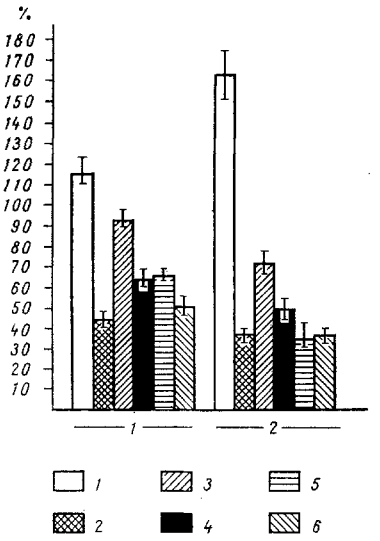

Fig. 3. Ischemia of two limbs for 9 h, after removal of tourniquets.

In the series of experiments in which the blood flow was maintained along the trunk vessels a tendency toward hypercoagulation also was observed, and it was most marked 5 h after removal of the tourniquets. The blood clotting time was reduced by 11.7% ($P < 0.05$) and the plasma recalcification time by 15.3% ($P < 0.02$). Prothrombin activity was increased by 17.5% ($P < 0.01$) and fibrinase activity by 49.5% ($P < 0.01$). The degree of the thrombotest was noticably increased, but the changes were within the limits of physiological variation. Fibrinolysis was activated by 11.8% ($P < 0.01$).

After ischemia of two limbs for 1 h the changes in the blood systems were small and consisted of a reduction of the free heparin time by 10.3% by the second hour and a small increase in the degree of pathological fibrinogen B (Fig. 1).

Marked changes took place in the blood clotting and fibrinolysis systems after ischemia of two limbs for 6 h, and the changes were phasic in character (Fig. 2). A state of hypercoagulation was observed as early as 1 h after removal of the tourniquets, and it reached a maximum by the third hour. Fibrinolytic activity was sharply inhibited at the same time.

However, 5 h after removal of the tourniquets the coagulation potential was reduced, and this was reflected in an increase in the blood clotting time, and the return of the prothrombin index, plasma recalcification time, and free heparin time to close to their initial values. The fibrinogen concentration ($P < 0.01$), the degree of the thrombotest ($P < 0.001$), and the degree of fibrinogen B ($P < 0.01$) remained significantly high. Fibrinolytic activity was inhibited by a lesser degree.

On removal of the tourniquets after ischemia of two limbs for 5 h, blood could be obtained only during the first 2 h; later it could not be obtained because of severe vasoconstriction. The results of analysis of blood samples obtained during the first 2 h showed a sharp increase in the blood clotting time and plasma recalcification time (by 55% after 2 h). There was a parallel decrease in the fibrinogen concentration and fibrinase activity, whereas fibrinolytic activity was considerably increased (Fig. 3).

Changes in the blood clotting and fibrinolysis systems after ischemia of one limb for 6 h were similar to those in the series with ischemia of two limbs for 1 h.

Recirculation in the limbs with their blood flow maintained via the main trunk vessels caused no marked changes in the blood clotting and fibrinolysis systems as was the case when two limbs ischemized for 6 h were included in the circulation. In the latter case phasic changes were observed: increased procoagulant activity, inhibition of the anticoagulant component, and inhibition of fibrinolysis 3 h after removal of the tourniquets, with the consequent risk of development of thrombosis [4], and defined as the thrombotic state of hemostasis [10]. The greater the mass of previously ischemized tissue, the more serious this risk. Subsequently a tendency toward hypocoagulation was observed, possibly on account of a reflex humoral response [6]. However, changes after prolonged ischemia (of two limbs for 9 h) were qualitatively different in character. The increase observed in the plasma recalcification time, the decrease in plasma heparin tolerance, and the sharp decrease in the fibrinogen concentration with a simultaneous quickening of lysis of the euglobulin clot,

were possibly dependent on the appearance of activators of fibrinolysis in the blood or a natural reaction of the anticlotting system to the appearance of thromboplastins in the blood, which occurs in any form of trauma [7, 9, 10]. The manifestiations of a hypercoagulation [1, 8] or hypocoagulation tendency [5], noted by other workers, are evidently connected with differences in the intensity of the previous ischemia. Deaths arising from tourniquet shock, depending on the duration of ischemia and the mass of ischemized tissues, are probably to some extent due to disturbances of the blood clotting and fibrinolysis systems [2, 3, 14].

Inclusion of previously ischemized limbs in the circulation thus causes marked changes in the blood clotting and fibrinolysis systems that are expressed as a primary hypercoagulation reaction and an increased risk of thrombosis, followed by transition to hypocoagulation; if, however, the ischemia was of long duration (ischemia of two limbs for 9 h) it was expressed as a primary reaction of hypocoagulation with secondary fibrinolysis.

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