MICROCIRCULATORY CHANGES IN TISSUES SURROUNDING A GUNSHOT WOUND

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To study changes arising in tissues surrounding gunshot wounds, as a rule clinical-anatomical criteria have been used until now [7, 9].

Gunshot wounds give rise to complex disturbances of the hemodynamics and, in particular, of the microcirculatory system, the state of which reflects adequacy of the tissue blood flow [6]. It is with the aid of the microcirculatory system that the body performs the transport function of its cardiovascular system and carries out transcapillary exchange, maintaining tissue homeostasis [3, 8]. Changes in the microcirculatory bed arise sooner and disappear later than the clinical manifestations of the disease or complication [2, 5], and they characterize most reliably the degree of tissue viability [4].

The aim of this investigation was to study the state of the microcirculation in muscle tissue surrounding a gunshot wound.

EXPERIMENTAL METHOD

The microcirculation in tissues surrounding a gunshot wound was assessed by means of a radionuclide method, involving tissue radiometry, a scanographic study, and intravital contact microscopy. A gunshot wound of the soft tissues of the hind limb in the middle third of the thigh was inflicted experimentally (under intravenous hexobarbital anesthesia: 60-80 mg/kg body weight) from a distance of 2.5 m from a Makarov pistol with a 9-mm caliber bullet. The experiments were carried out on 924 Chinchilla rabbits weighing from 2.9 to 3.3 kg. The radionuclide investigations consisted of the creation of a depot of radioactive material in the muscle tissue surrounding the gunshot wound, followed by recording its resorption. First, 0.1-0.2 ml of an isotonic solution containing sodium iodide with ^{131}I-radioactivity of 0.074 MBq (energy 0.364 MeV, $T_{1/2}$ 8.06 days) was injected into muscle tissue to a depth of 1 cm. The initial level of activity of the radionuclide in the depot thus created and the degree of its subsequent retention in the tissues were measured by means of a RK-1 radioxenometer. Radioactivity was measured as the number of pulses (the arithmetic mean of two radiometric measurements, with counting for 15 sec). The initial level of activity of the radionuclide in the tissue depot was taken as 100%. The ^{131}I preparation was injected into the muscle tissues 6 h after wounding at different distances from the edge of the gunshot wound: every 1 mm for the first 0.8 cm, every 2 mm between 0.8 and 2.8 cm, and every 10 mm between 2.8 and 9.8 cm. The tissue depot of the radionuclide created at the above points was studied radiometrically 15 min after injection of the isotope, and 6 h, and 1-3, 5, 7, 9, and 14 days after wounding (44 tests at each point). In the next series of experiments, for a closer study of the state of the zones of the microcirculatory disorders, the loss of activity of the radiopharmaceutical ^{131}I preparation from the tissue depots was determined 5, 10, 15, 20, 30, 60, and 240 min after its injection. In 14 animals a scanographic study was made of the region of the gunshot wound. An eluate of the generator radiopharmaceutical indium-113M (energy 0.393 MeV, $T_{1/2}$ 100 min) in a dose of 15 MBq was injected intravenously into the test animal 6 h, and 1-3, 5, 7, 9, and 14 days after wounding of the soft tissues of the hind limb, and 10 min later the tissues surrounding the wound were scanned on a "Scinticart-M" scanner ("Gamma," Hungary) with nine-color shading recording. A focusing collimator was used and the scanning speed was 0.5 m/min. The state of the microcirculation in the tissues surround

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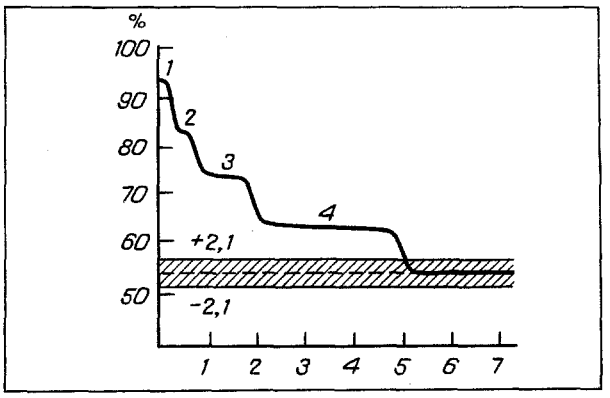

Fig. 1. Content of ^{131}I radionuclide in muscle tissue at different distances from edge of wound canal 15 min after injection of isotope. Abscissa, distance from edge of wound canal (in cm); ordinate, content of isotope in tissues (in % of initial level). 1-4) Zones (levels) of microcirculatory disorders. Continuous horizontal lines indicate region of change of parameter in intact animals.

ing the gunshot wound was assessed visually by means of intravital contact microscopy, by the dark field method on a "Lyumam-K1" research contact microscope. After gunshot wounding the skin, subcutaneous connective tissue, and fascia on the medial surface of the thigh were divided longitudinally down to the muscles through the wound canal, with exposure of the muscles by retraction of the skin with ligatures. The muscle was irrigated with isotonic solution warmed to 38°C. The arterial and venous portions of the vascular bed of the femoral muscles and movement of blood in them were investigated from the edge of the gunshot wound to 6-8 cm in all directions, 1 and 6 h and 1-3, 5, 7, 9, and 14 days after wounding. The experiments were carried out on 80 rabbits, with 10 in each series.

During evaluation of the state of the microcirculation, vascular, intravascular, and perivascular changes were analyzed: visually, by photographs, and on the screen of a videomonitor.

EXPERIMENTAL RESULTS

Analysis of the tissue radiometry data showed that four zones of microcirculatory disorders, differing in the level of retention of the radiopharmaceutical in the tissue depot (Fig. 1), were formed statistically significantly ($p < 0.05$) at different distances from the wound canal. For instance, 6 h after wounding, in the first zone, the boundary of which lay within 0.6 cm of the wound edge, the level of radioactivity 15 min after creation of the tissue depot of the isotope was 92.7 ± 0.5%, in zone 2 (from 0.3 to 1.4 cm) it was 83.4 ± 0.3%, in zone 3 (from 0.4 to 2.8 cm) 73.2 ± 1.3%, and in zone 4 (from 0.7 to 6.8 cm) it was 63.2 ± 1.2%. These results are evidence that 6 h after wounding, virtually no microcirculation was present in the soft tissues of zone 1, immediately next to the wound canal, in zone 2 it was grossly disturbed, in zone 3 the disturbances were moderate in character, and in zone 4, changes in the microcirculatory system were not significant. The time course of resorption of sodium-131 iodide from the tissue depots revealed microcirculatory changes in different directions in zones 2-4 of the gunshot wound. In zone 2, for instance, progressive worsening of the microcirculation was observed in the tissues until complete cessation of the blood flow on the 7th day after wounding. If wound healing followed an uncomplicated course, the microcirculation in zone 3 was gradually restored and normal values were reached toward the end of the 2nd week after wounding. In the muscle tissue of zone 4 the normal microcirculation was restored by the 7th day after wounding.

The scanographic studies of the tissues surrounding the gunshot wound revealed a distinct gradient of distributions of indium-113M, confirming the zonal distribution of the microcirculatory disorders found by tissue radiometry. Each zone was distinguished by a different level of accumulation of the indium isotope. For instance, 6 h after wounding, the level of radioactivity in zones 1, 2, 3, and 4 was 410 ± 36, 520 ± 29, 650 ± 78, and 780 ± 42 pulses/sec respectively. In the tissues surrounding the gunshot wound, three, two, and one levels of accumulation of the radioisotope indium-113M were identified after 3, 7, and 14 days respectively (Fig. 2).

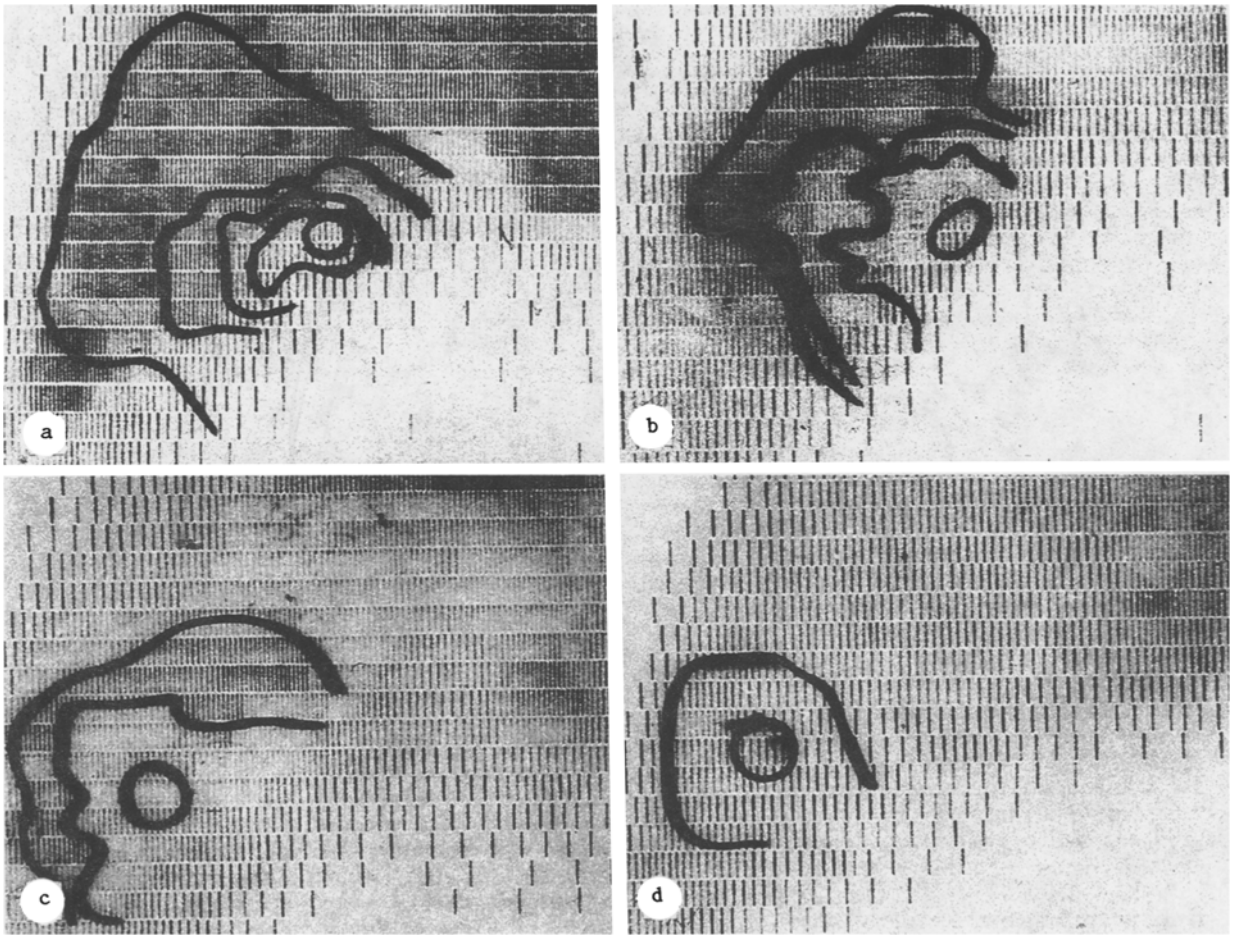

Fig. 2. Scanograms of gunshot wound of soft tissues of rabbit thigh 10 min after intravenous injection of indium. a) 6 h after wounding: four zones of accumulation of indium radionuclide in tissues surrounding gunshot wound clearly determined, b) 3 days after wounding: three levels of indium accumulation can be detected in the wound tissues, c) 7 days after wounding: two levels of indium accumulation can be identified, d) 14 days after wounding: one level of indium accumulation can be identified (the boundaries of the levels of distribution of indium and projection of the wound canal indicated by application for clarity).

Biomicroscopic investigations revealed microvascular changes in the neighborhood of the gunshot wound. In zone 1, against the background of destroyed muscle fibers and hemorrhages, fragmented microvessels packed with erythrocytes, in which no blood flow was present, could be observed (Fig. 3a).

In zone 2, weakly differentiated muscle fibers were identified with evidence of edema, caused by disturbance of vascular permeability. The blood vessels in all divisions of the microcirculatory bed were in a state of dilatation, which was especially marked in the venules. The blood flow was greatly retarded and in some fields of vision it was pendulumlike, or stasis was observed. Thrombus formation and diapedesis of erythrocytes were noted in the postcapillary vessels (Fig. 3b, c).

In zone 3 constriction of the afferent vessels was observed with an increase in the linear velocity of the blood flow in them. The blood flow in the capillaries and postcapillary vessels was retarded considerably. Arterial blood leaked into the venous part of the microcirculatory bed along arteriovenular shunts, by-passing the capillary network. Under these circumstances the postcapillary vessels became highly tortuous, their lumen was enlarged, and the velocity of the blood flow fell (Fig. 3d, e).

In zone 4 there was a very small decrease in the nutritive and increase in the juxtacapillary blood flow (Fig. 3f).

Later changes in the microcirculation in the zones of the gunshot wound thus distinguished were in different directions. For instance, toward the 3rd day after wounding irreversible changes were observed clearly in zone 2: dilatation of all the vessels with absence of the blood flow and with thrombus formation, and necrosis of muscle tissue.

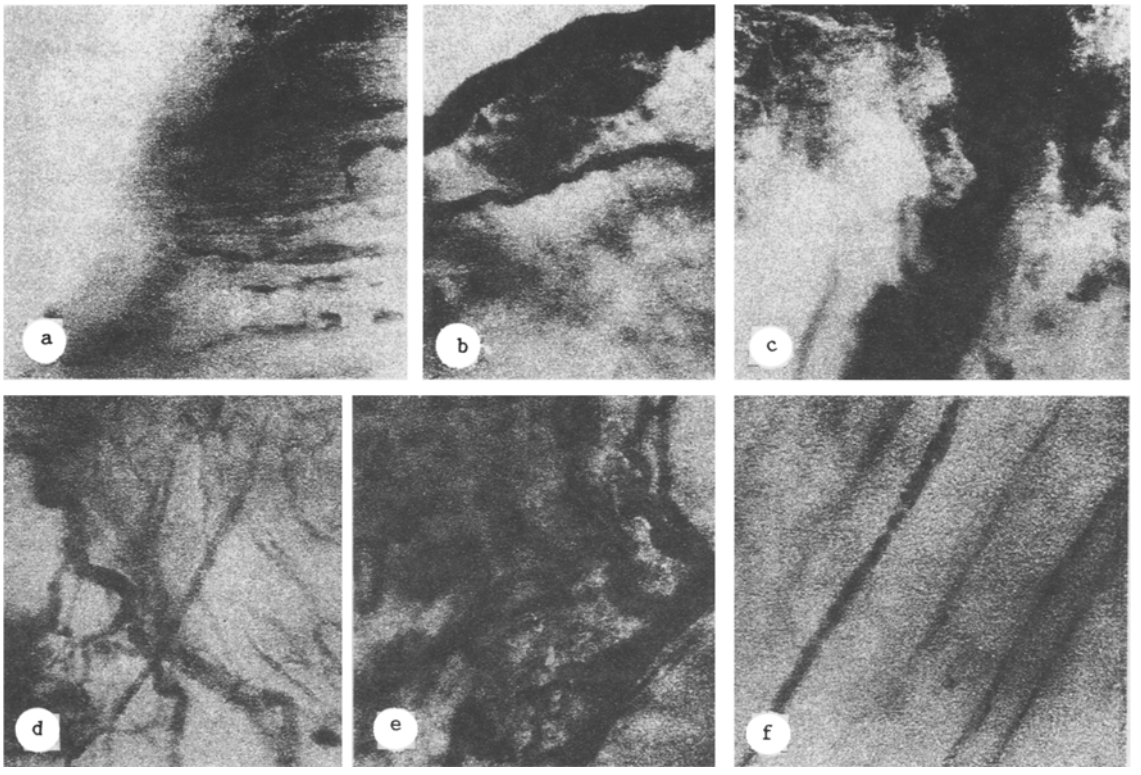

Fig. 3. Characteristics of microcirculatory disorders in tissues of gunshot wound studied by biomicroscopy. a) Fragmented muscle capillaries, b) dilated venule with paravasal hematoma, c) grossly dilated venule with deformed walls and initial signs of thrombus formation, d, e) tortuosity of microvessels, f) slow movement of erythrocytes along muscle capillaries. 100×.

In zone 3 changes in the microcirculation were determined by the presence or absence of complications in the course of wound healing. With an uncomplicated course, by about the 14th day normalization of the microcirculation was observed against the background of a progressive development of granulation tissue, with the formation of new microvessels. If the course was complicated, the blood flow in the microvessels was slowed down to stasis, with subsequent formation of microthrombi and with necrosis of the perivascular tissues.

In zone 4 changes in the microcirculation did not show any clearly defined trend and were reversible in character. Toward the end of the 1st week the diameter of the microvessels came close to normal and the blood flow in them became homogeneous. With the development of granulation tissue (4th-5th days after wounding) a network of newly formed microvessels was observed.

It can be concluded from analysis of the data that four zones of tissue damage are formed in the neighborhood of a gunshot wound, which we described as follows: zone 1 of primary necrosis (destruction), distinguished by complete cessation of the microcirculation, 2) a zone of secondary necrosis, distinguished by a well marked reduction of the microcirculation and its progressive worsening, or even complete cessation on the 3rd day after wounding, 3) a zone of reactive-destructive changes, distinguished by a moderate disturbance of the microcirculation and its restoration provided that the course of wound healing is uncomplicated toward the 14th day after wounding, and a fourth zone of reactive changes, with trivial disturbances of the microcirculation and with its restoration by the 7th day after wounding.

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EFFECT OF ARTERIAL BLOOD LOSS ON MYOELECTRICAL ACTIVITY OF THE PYLORIC SPHINCTER AND DUODENUM

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KEY WORDS: blood loss; pyloric sphincter; duodenum

Blood loss is a stress factor leading to the formation of gastric and duodenal ulcers [3, 9, 13-15]. Arterial blood loss leads to considerable release of catecholamines [8, 9, 15], which mainly inhibit the motor function of the gastrointestinal tract [1, 2, 5, 7, 12] and participate in ulcer formation [4, 6, 13]. Meanwhile the influence of this stress factor on the motor function of the pyloroduodenal zone (that most prone to ulcer formation) has not been finally elucidated. The aim of this investigation was to study changes in electrical activity of the smooth muscles of the pyloric sphincter and duodenum under the influence of arterial blood loss.

EXPERIMENTAL METHOD

Chronic experiments were carried out on six male rabbits weighing 2.6-3.2 kg. Two weeks before the experiment, silver loop electrodes were implanted into the smooth muscles beneath the serous membrane of the pyloric sphincter and duodenum, by the method described previously [10, 11]. Electrical activity of the smooth muscles of the pyloroduodenal zone was recorded on an encephalograph with recording speed of 7.5 mm/sec and with time constant of 0.3 sec. The rabbits received an ordinary diet (vegetables, oats, hay) and were used in the experiments without any preliminary restrictions of food taking. The right common carotid artery was exteriorized in the neck 1 week before the experiments, into a skin bridge 2-3 cm long. Blood loss was produced by puncturing this vessel in animals immobilized in the supine position by the method in [3]. The blood loss amounted to about 5, 10, and 25% of the total blood volume, and its duration was 2 min. Electrical potentials of the smooth muscles of the sphincter and duodenum were recorded for 1 h before, during, and for 1 h after blood loss. The frequency of bursts of action potentials of the smooth muscles of the pyloric sphincter and duodenum was analyzed before and after blood loss, and the pulse rate (as a parameter of activation of the adrenergic system) was analyzed on the basis of the electrocardiogram. The statistical significance of differences was determined by Student's test, with a 95% level of significance.

EXPERIMENTAL RESULTS

Arterial blood loss (5, 10, and 25% of the total blood volume) gave rise to a biphasic change in electrical activity of the smooth muscles of the pyloric sphincter and duodenum. Phase I of the action of arterial blood loss was manifested by inhibition of activity of the pyloroduodenal zone, phase II by its gradual recovery, depending on the volume of blood lost.

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