EFFECT OF NORADRENALIN ON THE DISTRIBUTION OF THE CIRCULATION IN TRAUMATIC SHOCK

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To evaluate the circulatory disturbances in traumatic shock it is important to know not only the changes in the output of the heart, the peripheral resistance of the blood vessels, the arterial pressure, and other general indices, but also the relationship between the blood supply to the different organs—the distribution of the circulation. The role of the blood vessels of the different organs in the storage of blood during shock has received considerable study [1-3, 9]. However, the relationship between the blood flow in the various organs in this condition has been investigated much less thoroughly [4, 10, 13, 14].

In 1964, Ekholm, Erikson, and Skoglund [12] proposed an experimental method of assessing the circulation based on roentgenography of animals after adminstration of 25% thorotrast in a dose of 5-10 ml/kg. In their experiments, which were carried out on cats, the blood vessels and vascular territories remained constantly contrasted for 1 h, after which the contrast material began to accumulate in certain organs in higher concentration than in others.

It was decided to use this method to assess the distribution of the circulation in shock and after administration of noradrenalin to shocked animals.

EXPERIMENTAL METHOD

The experiments were carried out on 24 cats weighing from 2.5 to 4.5 kg. Shock was produced by Cannon's method—by traumatization of the soft tissues of the thigh by 180-200 blows with a rubber-tipped hammer weighing 700 g. To assess the severity of the shock, the arterial pressure, pulse, and respiration were recorded on a kymograph, and the defensive, corneal and pupillary reflexes were studied.

The contrast material was 50% cardiotrast (diodine, SPOFA, Prague), which was injected intravenously in a dose of 4.5-5 ml/kg. The injection of the contrast material and the subsequent roentgenography were carried out in control experiments 60-90 min after preparation of the animal for the experiments with shock—in the fully developed, torpid phase, and in the experiments with administration of noradrenalin (in control conditions and during shock) immediately after starting the injection of the drug.

Roentgenography of the whole animal (including the head and the lower limbs) was carried out periodically: before and 1-2, 10, 30, 60, 90, and 120 min after injection of the contrast material. Film of type RM-1 (size 18×24 cm) with a sensitivity of 250 units was used for roentgenography. The apparatus used was the URDD-10 (distance from tube to object 110 cm, voltage 40-45 kV, current 60-80 mA, exposure 0.15-0.25 sec).

Noradrenalin hydrotartrate (Ukrainian Institute of Experimental Endocrinology) was injected intravenously in Ringer's solution in a dose of 1-2 μg/kg body weight/min (estimated as base) for 20-30 min.

EXPERIMENTAL RESULTS

The injection of a large dose of contrast material in the control experiments led to rapid and fairly uniform filling of the blood vessels with the material: after 1-2 min the abdominal viscera showed up as a general homogeneous shadow, and the borders between them could not be distinguished. The reason for this was evidently the filling of the blood vessels of the abdominal wall muscles with contrast material. The heart and great vessels also were clearly outlined (Fig. 1, A). The roentgenographic picture was similar 10 min later (Fig. 1, B).

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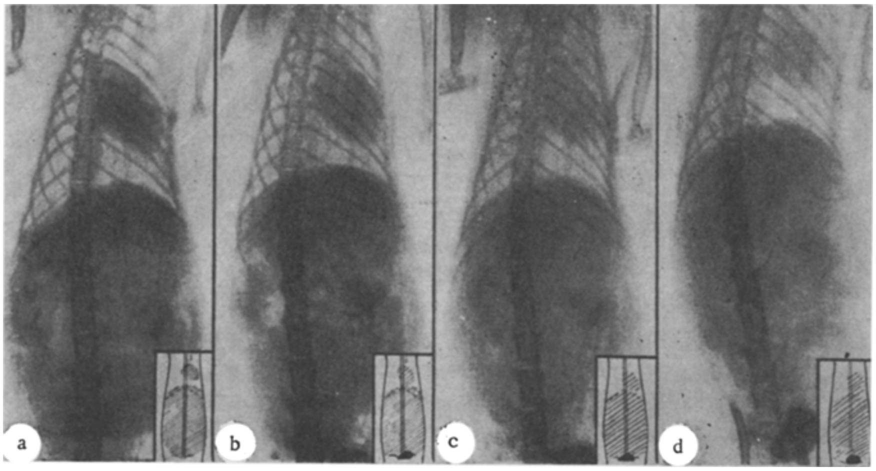

Fig. 1. Roentgenograms of an animal after saturation of the cardiovascular system with contrast material in control experiments. a) immediately after injection; b–d) 10 and 120 min later.

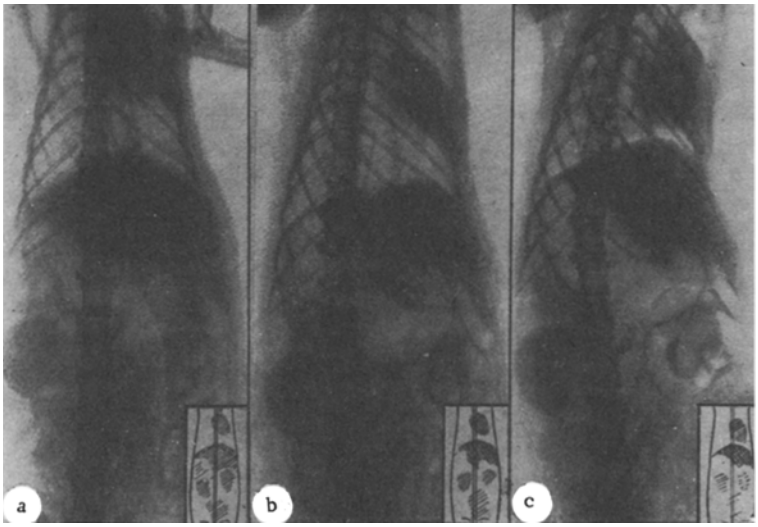

Fig. 2. Roentgenograms of an animal after saturation of the cardiovascular system with contrast material in the torpid phase of shock: a) immediately after injection; b and c) 10 and 60 min later.

In the later roentgenograms, taken 30, 60 and 120 min after injection, the abdominal viscera showed up an equally intense shadow, and the heart shadow had become more sharply defined (Fig. 1, c, d). This demonstrated that the contrast material continued to circulate in the blood vessels of the abdominal viscera in approximately equal amounts. In the control experiments the cardiotrast gradually began to be excreted by the kidneys, and after 15-30 min it could be detected in the urinary bladder, in which appreciable amounts of the contrast material were seen at the next examination after 60 min (Fig. 1, b–d).

After saturation of the cardiovascular system with contrast material by the method of Ekholm and his co-workers [12], the quantity of the substance in a given organ depends on the number of actively functioning vessels (capillaries), and not on the velocity of movement of the blood, so that a more or less uniform distribution of the contrast material in the control animals demonstrates a uniform distribution of the blood flow.

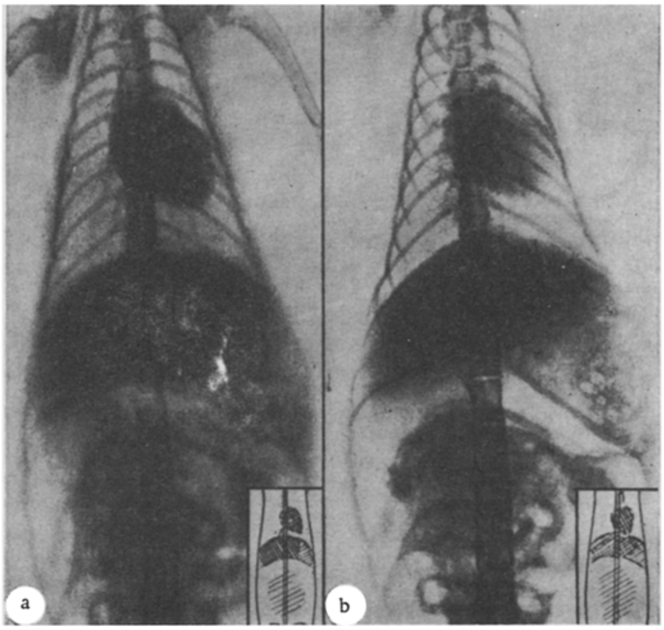

Fig. 3. Roentgenograms of an animal after saturation of the cardiovascular system with contrast material in experiments in which noradrenalin was given during shock: a) immediately after injection; b) 30 min later.

The picture was different in traumatic shock, which followed a consistent course in the present experiments [5-7]. In the torpid phase the shock was characterized by general inhibition of the animals' reactions, by their weak reaction or absence of reaction to nociceptive stimulation, by arterial hypotension, and by a rapid pulse and respiration, sometimes irregular. Several periods could be distinguished in the development of the torpid phase [6, 7].

Injection of the contrast material in the torpid phase of traumatic shock, in a dose equivalent to that given in the control experiments, led to uneven filling of the visceral vessels with the material; it was concentrated in the liver and heart, and to a lesser degree in the kidneys (Fig. 2, a). On the roentgenograms taken after 10 min the central parts of the liver, the heart, the great vessels, and the kidneys were not always outlined perfectly clearly and the intensity of the shadow of the two kidneys was not identical. After 30-60 min the picture remained approximately the same as after 10 min (Fig. 2, c).

In the torpid phase of traumatic shock some degree of centralization of the contrast material was thus observed (irregular filling of the vessels of the different organs), corresponding in all probability to the "centralization" of the circulation, because the content of contrast material in a given organ when the the saturation method is used is determined (as stated above, by the number of actively functioning capillaries in them. The blood supply to the heart, the liver, and even the kidneys still appeared satisfactory when the blood flow in the intestine and skeletal muscles was very small. In the control animals, 60 min after the injection, the amount of contrast material in the heart and great vessels had been reduced, but in shock, on the other hand, it remained at an adequately high level.

It could be supposed that the intensity of the visceral shadows in the roentgenogram would depend also on the restriction of elimination of the contrast material in the conditions of shock, but such a suggestion is really applicable only to the absolute, and not to the comparative intensity of the shadows, which characterizes the distribution of the blood flow.

The differences in the distribution of the circulation were still more clearly defined after administration of noradrenalin to the shocked animals. In these experiments the contrast material, injected immediately after the infusion of noradrenalin began in the torpid phase of shock, was immediately concentrated in the central portions of the liver and heart (Fig. 3, a). On the roentgenograms taken 10-30 min after the beginning of injection of noradrenalin, the heart, the central parts of the liver, and the blood vessels of the lungs were contrasted (Fig. 3, b). In these conditions even the peripheral parts of the liver evidently received only a very poor blood supply.

The circulation in the liver in normal conditions may be of two types – diffuse and centralized [11]. In shock, especially after administration of noradrenalin, the circulation was of the second type. The results of these experiments confirmed the authors' earlier hypothesis [8] that the increase in arterial pressure observed following administration of noradrenalin in the conditions of shock cannot be regarded as evidence of an improvement in the hemodynamics: it may be associated with an increase in the tone of the vessels and in the resistance to the blood flow through collateral channels in certain vitally important organs.

The results of experiments with saturation of the blood stream with roentgenographic contrast material thus suggest that in the conditions of traumatic shock a marked "centralization" of the circulation takes place. The administration of noradrenalin not only does not abolish this centralization, but may even intensify it.

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