VASODILATION OF THE MAIN ARTERIES

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Until recently, the role assigned to the main arteries was that of distributing blood to different parts of the body and in smoothing out the pressure variations in the arterial system arising from the entry of blood at systole.

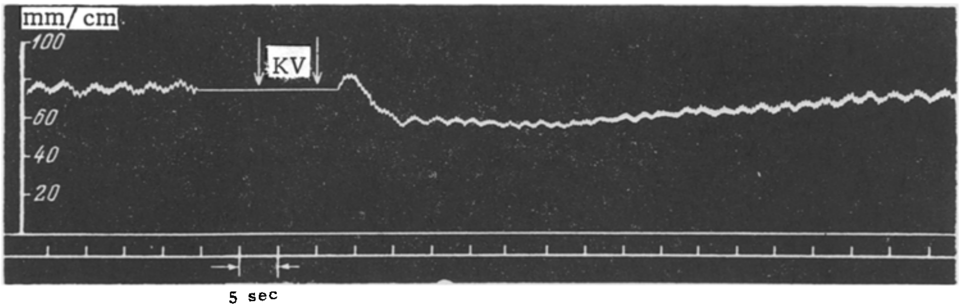

Fig. 1. Curve of the arterial pressure in the femoral artery of a dog after the injection of 35% cardiotrast solution at a rate of 2 ml/sec. KV) Moment of injecting the contrast substance. After a period of rapid fall, the pressure returns to the original level ($1\frac{1}{2}$ min after the end of the injection).

Change in the Lumen of the Arteries (Diameter in mm) of Dog Legs After the Injection of Cardiotrast

No. of dog	External iliac artery		Femoral artery		External muscular artery		Subcutaneous artery	
	injection							
	1	2	1	2	1	2	1	2
1	3,6	4,2	2,9	3,2	1,5	1,8	1,4	1,4
2	4	5	2,8	3,1	2,3	3,5	1,5	1,4
3	3,2	3,8	2,5	2,8	1,2	1,5	1,3	1,3
4	4	5	3,2	3,6	2,0	2,3	2	1,9
5	3,2	4,7	3,1	3,8	1,5	2,5	1	1
6	5	5,5	4,5	5	2	2,8	1,8	1,8
7	4,4	4,8	3,4	3,7	1,3	2,2	1,4	1,3
8	3,6	4,4	3	3,3	1,4	1,6	1,2	1,2
9	4,5	5,2	3,8	4,2	1,0	1,7	1,6	1,8
10	3,8	4,8	3	3,8	1,4	2	1,5	1,6
11	4,8	5,5	4	4,6	2,0	2,6	1,3	1,1
12	4,2	4,9	2,2	2,7	2,0	2,5	1,4	1,3
13	5	5,4	3,8	4,1	1,6	2,2	1,5	1,6
14	4,3	5,5	4,6	4,8	1,6	2,5	1,4	1,2
15	4,8	6	4	5,5	1,8	2,3	1,3	1,1
Mean error	0,086		0,014		0 077			
Degree of significance (probability that effect was not due to chance)	0,99		0,99		0,99			

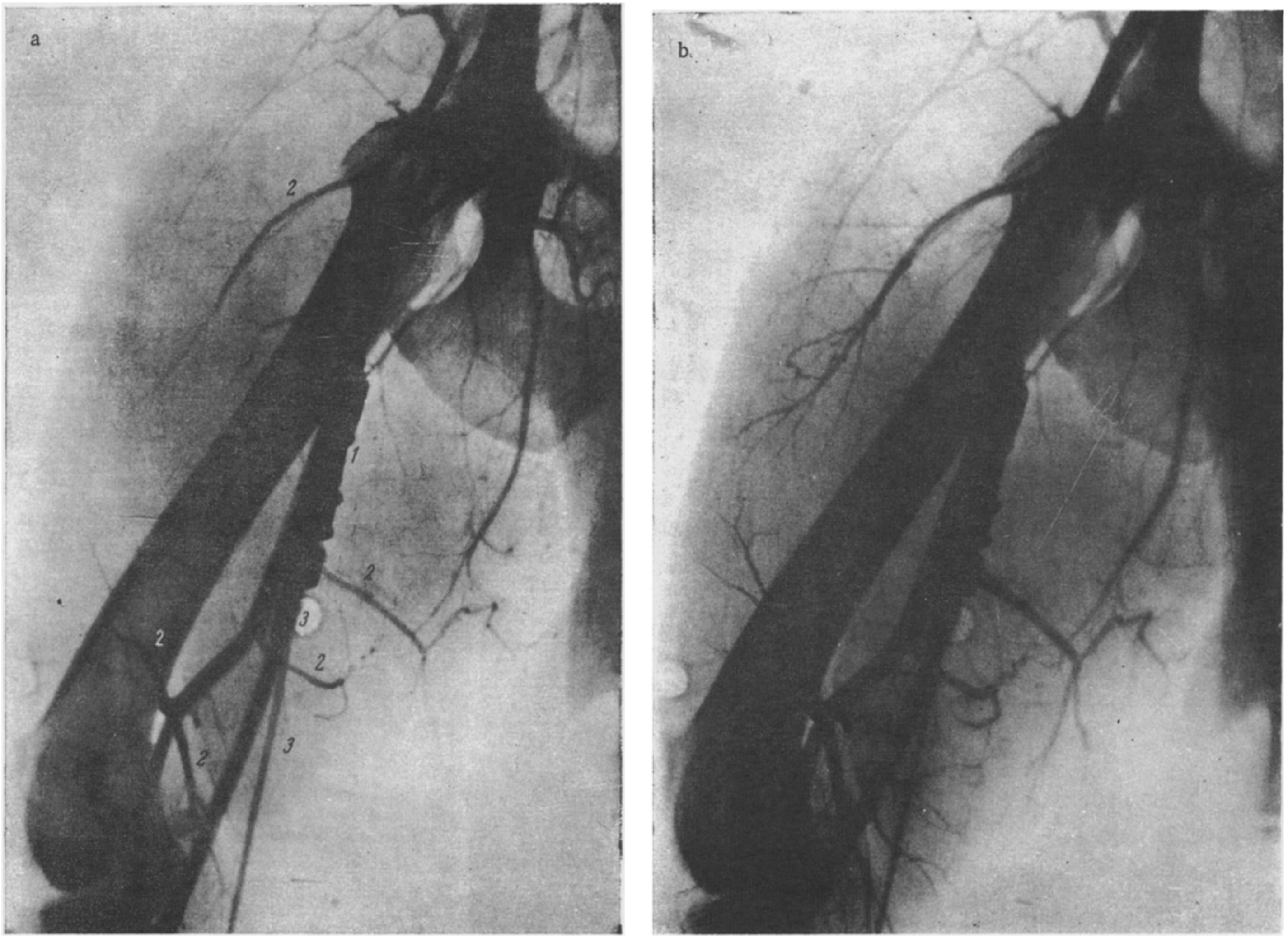

Fig. 2. X-ray picture of the upper leg of a dog, a) after the first injection of cardiotrast; b) after a second injection made after the pressure had returned to its original level ($1\frac{1}{2}$ min after the first injection); the principal vessel (femoral artery) and its muscular branches are considerably dilated, but there is no change in the subcutaneous artery. 1) Femoral artery; 2) arterial branches carrying blood to skeletal muscles; 3) subcutaneous artery.

Our knowledge of the function of the large arteries has been extended by recent results on the influence of alterations in the tension of the arterial walls on blood flow rate. The work of Burton [5], Pappenheimer [8], and Savitskii [1] has shown that while the lumen of an artery remains constant, changes of the elastic tension in the wall are sufficient to increase or decrease the flow through a cross-section of the artery.

There are no results bearing on movements of the large vessels or on their ability actively to change their cross section. Neither is it known in what sequence the changes of the lumen of the different portions of the arterial network takes place, and whether the changes occur in any particular order.

The existing methods of determining the functional mobility of the vascular system, consisting of plethysmography, perfusion of the vessels, oscillography, etc., cannot be applied to changes of the large vessels. Neither do these methods allow a study to be made of the processes of vasoconstriction and vasodilation in the different parts of the arterial system.

The method of angiography by which a study of the vessels is made by means of contrast media opens up great possibilities. The contrast method gives information on the size of the lumen of a particular vessel, and on the architectonics of the vascular plexus of the region to be investigated. The contrast substances themselves have a hypotensive influence [6, 7, 9]. In a study of the vasomotor responses, this feature is of great convenience, because, on this account, a single agent may be injected, and the sequence of changes in the successive portions of a vascular system examined in a series of photographs.

In a number of experiments on 15 mongrel dogs, we used a Soviet brand of the contrast medium cardiotrast to study the functional mobility of the main vessels' and its significance in the process of vasodilation.

METHOD

The dog was fixed on its back and anesthetized with morphine and ether; a needle connected with a mercury manometer was inserted through the skin and into the femoral artery so as to point against the blood flow. After the arterial pressure had been recorded, a three-way tap was used to connect the needle with a syringe containing 35% cardiotrast solution, 1 ml/kg of which was then injected into the artery at a rate of 2 ml/sec. During the injection of the contrast substance, a series of x-ray pictures of the pelvis and both hind limbs were made (four exposures for 2.4 sec). The pressure in the femoral artery was then again recorded. In many experiments the arterial pressure was recorded in both femoral arteries. To find how the lumen of the vessel changed in response to the action of cardiotrast, the contrast substance was injected repeatedly at times determined by the change in arterial pressure in the femoral artery, and further pictures were taken. By means of a loupe (×4) and a transparent scale, measurements of the diameter of the vessel were made on the completed and dried angiograms. The large focusing distance of 95 cm reduced the distortion of the size and shape of the different parts of the arterial system to a minimum.

RESULTS

In all the animals, 3-4 sec after the contrast substance had been injected, the pressure in the femoral artery remained at the original level or else was raised slightly, by 5-6 ml, and this condition was maintained for 5-7 sec. Then the pressure began to fall rapidly, and 15-20 sec after the end of the injection it had fallen on average by 25 to 35% and sometimes by 50% below the original value. The pulse rate increased. The minimum pressure was maintained for not more than a few seconds, after which it began to rise again. Usually, although the fall in the arterial pressure following the injection of 35% cardiotrast lasted 20-25 sec, its return to the original level occurred over a period of 1-1½ min. After this level had been reached, the pressure either remained stable, or else continued to rise for a further time. The pulse frequency fell (Fig. 1). When more concentrated solutions of 50-70% cardiotrast was injected, recovery of the arterial pressure was more prolonged, taking 2½-3½ min.

After the pressure had returned to its original value and became stabilized, the same amount of cardiotrast was again injected, and a further series of x-rays taken. The first series shows the passage of the contrast substance from the main arteries into the smaller branches. In all the photographs, the size of the lumen remains unchanged. After passing through the arteries for 3-4 sec, the cardiotrast appears in the veins. A comparison of the two series of pictures showed that at the time when the arterial pressure returned to its original value (after its depression), the main arteries of the limbs (iliac and femoral arteries) and their branches supplying the skeletal musculature were greatly dilated.

Figure 2 shows two pictures from one experiment, and the dilation of the large arteries of the limbs is clearly seen. At this time the vascular plexus appears more branched, due to the penetration of the contrast substance into the dilated small vessels. As can be seen from a comparison of the two series of pictures, the contrast substance then reaches the small arterial branches more rapidly, and the whole plexus is seen to be filled, even in the first exposure, and its density increases in the subsequent frames.

In many of the experiments, the second injection of the contrast substance was made and the x-ray pictures taken at the moment when the pressure had fallen maximally, i.e., 20-30 sec after the first injection. Under these conditions there was not only a dilation of the small arterial vessels, but the lumen of the femoral and iliac arteries also changed. As has already been pointed out, dilation of the principal arteries was observed also $1\frac{1}{2}$-2 min after injection of the cardiotrast. As our experiments with repeated pictures showed, the chief arteries remained dilated for 6-10 min.

The question then naturally arose as to whether the vasodilation and reduction of pressure was a consequence of the increased pressure in the vessel at the moment that the large volume of up to 15 ml of contast substance was forcibly injected. Control experiments in which the same volume of physiological saline was injected at the same rate, both before and after the cardiotrast injection, showed that under these conditions there was no dilation of the vessels; therefore, cardiotrast has a special action (see Fig. 1c).

We have therefore seen that under the influence of cardiotrast both the main arteries and the small arterial branches dilate. The small arteries are affected first, and the principal arteries later.

It can be seen from the table that in all experiments in which cardiotrast is injected without exception, at the time the arterial pressure returns to normal the vessels are dilated. A statistical treatment of the results of measurements of the lumen of the vessels made from the angiograms showed that there was a significant difference in their diameter between the first and the second cardiotrast injections.

It is important to note that not all the large arteries dilate under the influence of cardiotrast. Arteries supplying the skin and the supporting tissue of the lower leg do not dilate, as can be seen from the behavior of the subcutaneous artery, the a. saphena (see Fig. 2 and table).

The vasodilator effect of cardiotrast appears to be associated with its cholinomimetic action, which is characteristic of other contrast substances containing iodine (diodrast and diodone), which resemble cardiotrast structurally [2, 6, 9]. It has been shown that in its action diodrast resembles acetylbetamethylcholine [6].

Some authors [7] consider that contrast substances containing iodine act directly on the muscular elements of the vascular walls, leaving them paralyzed for a certain time. Cardiotrast does indeed have this effect on the small arteries (arterioles) which supply skeletal muscle. In the last three years it has been convincingly shown [3] that nerve fibers of two kinds supply the vessels of skeletal muscles, sympathetic adrenergic vasoconstrictor, and sympathetic cholinergic vasodilator fibers.

As has been demonstrated above, the vasodilator action of cardiotrast affects first of all the small arterial branches, and then spreads backwards to the larger arteries and main vessels. It is not easy to explain this fact without further experiments, although we can make some suggestions.

It is known that the large arteries have their own vascular plexus (vasa vasorum), and therefore all humoral influence on the muscular elements of the main arteries are brought about through these vessels. However, the nutrition of the walls of the small vessels is from the blood flowing directly through them. If we maintain that the vasodilator agent acts directly on the muscular wall of the vessels, then we would expect the nutritional arrangements to explain the fact that the main vessels dilate somewhat later than do the arterioles and small arteries.

There is an alternative interpretation, as follows. Dilation of the main vessels is a reflex response which results from the primary dilation of the arterioles, and originates from the corresponding angioreceptors.

The features we have observed of the response of the different portions of the vascular system to a vasodilator agent are related to the local blood supply of the femoral arterial system. At the present time, it is difficult to assess the hemodynamic significance of the mobility of the main vessels. On this account, the results presented deserve all the more attention, and further study.

SUMMARY

An angiographic study was made of the vasodilator action of cardiotrast on the limbs of 15 dogs. Besides the dilation of a large number of small arterial branches supplying the skeletal muscles, there was also a noticeable enlargement of the lumen of the main (femoral and iliac) arteries. No dilation was observed in the arteries supplying the skin. The different reaction of the vessels supplying muscle and skin is attributed to their different innervation.

Dilation of the lumen occurs first in the small arterial branches, and later in the main arteries. The possible mechanism of the vasodilator effect produced by cardiotrast in general, and on the main arteries in particular, is discussed.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.