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THE EFFECT OF LONG-STANDING EXPERIMENTAL ARTERIOVENOUS ANEURYSMS ON THE HEART

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The influence of arteriovenous aneurysms on the central and peripheral circulation has been the subject of a considerable number of monographs and papers. This fact demonstrates the unfailing interest of workers in various countries in this field of pathology. There are several experimental investigations [4-8 and others] which supplement the findings of clinical observations. However, certain features of the complex pathogenesis of the cardiovascular disturbances arising with arteriovenous aneurysms still remain unexplained; in particular the mechanism of development of bacterial endocarditis and endarteritis in the fistula. In the world literature only a few papers have been published on the experimental production of endocarditis in these conditions [10-12].

In the present investigation we set out to study the effect of arteriovenous fistulae on the heart in experiments of long duration (up to one-and-a-half years) using a combined method of investigation. This consisted of radiography of the heart, electrocardiography, determination of the rate of the cardiac rhythm, and pathological-anatomical and histological study of animals dying or killed at different times; other investigations included temperature recording, blood cultures and measurement of the ESR. This method (combined investigation) enables the progress of the changes in the heart of the experimental animals to be observed more fully and comprehensively.

EXPERIMENTAL METHOD

The experiments were performed on 20 dogs weighing 15-20 kg. Arteriovenous fistulae were produced aseptically in the femoral vessels; in 4 animals an anastomosis was produced between the abdominal aorta and the inferior vena cava. The femoral fistulae were produced as a rule in both limbs with an interval of from 2 weeks to 2 months between the operations.

In order to expose the femoral vessels the superficial tissues were divided along the line of the femoral artery. Access to the abdominal aorta and inferior vena cava was secured by a midline incision in the anterior abdominal wall. The loops of bowel were partly displaced upwards and partly eventrated onto a sterile towel thoroughly soaked in warm physiological saline. Linear incisions along the course of the arterial and venous trunks were made easily by the use of an instrument specially made for the purpose – a "vascular probe." This consists of an elongated cone with a pointed apex, on the surface of which a narrow longitudinal groove is made. With a continuous suture the medial border of the incisions in the artery and vein is first sutured, and then the lateral. Altogether 35 functioning arteriovenous fistulae, 1-3 cm in diameter, were produced.

X-rays of the chest were taken in the frontal plane with a portable RU-760 x-ray apparatus, with the heart in the same position relative to the tube of the apparatus. Films were taken before operation, immediately after operation, and then regularly every 10-20 days.

The electrocardiograms were always recorded under the same conditions, in the standing position (in a frame). The action currents of the heart were recorded by 3 standard leads from the limbs by an EKP-4 apparatus with a constant sensitivity of 1 mv = 10 mm. The initial electrocardiographic baseline was established after the total extinction of reflexes to the environment [9]. After the fistula was created, the first electrocardiogram was taken not immediately but after a few days. This avoided abnormalities caused by incidental factors (anesthesia, pain, changes in the position of the body and so on). Subsequent recordings were made periodically, at the same intervals as the x-rays. In the whole combined investigation about 150 x-rays and over 100 electrocardiograms were taken, processed and analyzed.

EXPERIMENTAL RESULTS

At any time of the existence of arteriovenous aneurysms (Fig. 1) the characteristic sound could be heard on auscultation on the site of a fistula – continuous, low pitched, with intensification and raising of the tone during systole; a sensation of fibrillation on palpation corresponded to the bruit. In the femoral anastomoses we observed the rapid development of venous collaterals.

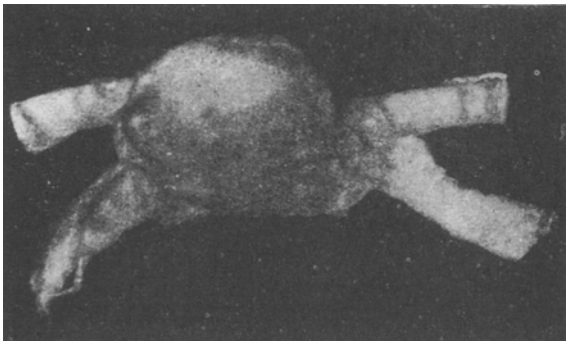

Fig. 1. Experimental arteriovenous aneurysm of the femoral vessels.

In all the experimental animals, changes were observed in the cardiac rhythm, which was increased in rate. With the formation of a second arteriovenous fistula in the same animal, a new rise in the rate of cardiac contractions took place. On compression of the fistula or of the artery leading to it the pulse was slowed (the so-called Dobrovol'skaia's sign). The degree of quickening of the rhythm of cardiac activity increased with increasing diameter of the fistula (see table) and its nearness to the heart. These features observed have a reflex mechanism [1] and are characteristic of the adaptative reaction of the cardiovascular system to the altered conditions of the circulation.

The x-rays obtained showed increase in the heart dimensions, usually developing gradually over a period of several months. Immediately after the formation of the aneurysm it was not possible to find any difference from the original condition (silhouette). The development of this feature was seen more clearly in animals with double femoral arteriovenous fistulae of large size, although the enlargement was observed also in the case of a single femoral fistula (Fig. 2, a, b). In every animal we observed changes in the contour of the heart up to a certain limit. The degree of enlargement, however, was directly proportional to the load on the heart resulting from the development of the pathological anastomoses.

Relationship of the Pulse Rate to the Size of an Experimental Arteriovenous Fistula of the Femoral Vessels

Size of fistula in cm	Pulse before creation of fistula	Pulse after creation of fistula	Degree of pulse quickening (beats/min)
1.5	84	102	18
2.0	95	118	23
2.5	107	140	33

Ligation of the fistula did not cause any noticeable alteration in the size of the heart, which suggested hypertrophy of the myocardium, subsequently confirmed macro- and microscopically. With the development of hypertrophy of the cardiac muscle the pulse always became rather slower. This can be regarded as a favorable prognostic sign, indicating high reserves of power of the heart. In certain dogs with long-standing functioning aneurysms (over a year) the slowness of the pulse was so pronounced that the difference from the preoperative rate was abolished; Dobrovol'skaia's sign was however always present in these cases.

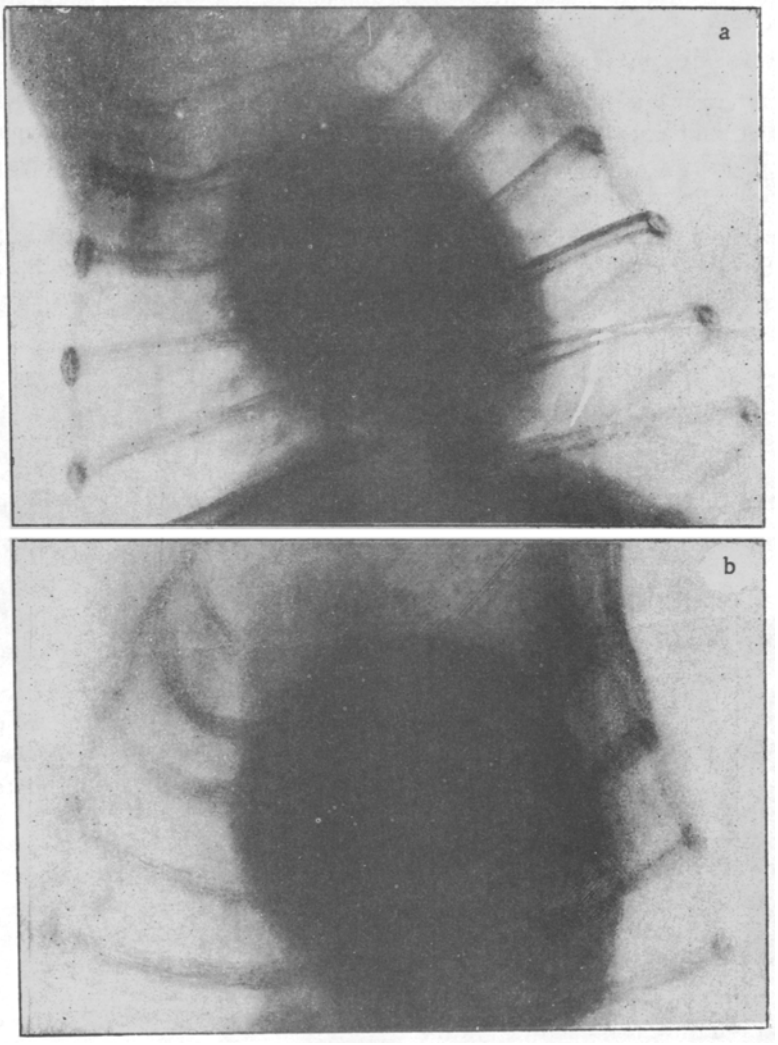

Fig. 2. X-ray of a dog's heart before the creation of an arteriovenous anastomosis (a); x-ray of the heart of the same dog 11 months after operation (b).

By means of electrocardiograms we established considerable changes in the biochemical processes in the cardiac muscle, appearing in even an early stage of the existence of arteriovenous anastomoses, and taking the form of reduction in the voltage and inversion of the T wave. At a later period various animals developed changes which indicated slowing of atrioventricular and intraventricular conduction, and disturbance of excitation in the atria and ventricles. This was shown by lengthening of the P – Q interval, widening of the QRS complex, enlargement and widening, and sometimes smoothing out of the P wave, voltage changes in the R wave, displacement of the S – T interval and deepening of the Q wave. The duration of electrical systole was increased. The direction of the electrical axis of the heart was altered. Investigations over a period of time showed a definite relationship between the magnitude of the changes and the duration of the fistulae, their position and size. Our electrocardiographic results are in agreement with the findings of B. V. Ognev [5].

Comparison of the x-ray and electrocardiographic signs with the results of post mortem examination showed their morphological basis. In animals with profound changes in the elements of the electrocardiogram there were well-marked pathological changes in the heart. The cardiac muscle appeared flabby; the heart was increased in weight, and the walls of both ventricles thickened in comparison with those of animals identical in weight and growth with the experimental ones. Hypertrophy of the left ventricle usually predominated, which corresponded to the rotation of the electrical axis of the heart on the electrocardiograms. Histological examination of the myocardium revealed thickening of the muscle fibers, foci of hemorrhage, edema of the interstitial tissue and cellular infiltrations mainly perivascular in distribution – the appearance of focal and diffuse myocarditis.

In the majority of the dogs valvular abnormalities were found, which were characteristic of bacterial endocarditis; thrombotic deposits on the surface of the folds, areas of fibrinoid necrosis, collections of bacteria and leucocytic infiltration with subsequent increase in the number of lymphoid and histiocytic cells. Lesions of the mitral valve were most common. Less commonly and to a lesser degree the tricuspid and aortic valves were involved in the process. In the heart of these dogs during life, systolic and diastolic murmurs could be auscultated, the character and intensity of which varied. In some animals with long-standing aneurysms, focal nephritis was present; in one case an extensive infarct of recent origin was discovered in the kidney.

In the region of the arteriovenous fistulae a well-defined inflammatory reaction was present, with thickening of the intima, fibrinous deposits, foci of necrosis and cellular infiltration, and a multitude of newly formed vessels. Sometimes endarteritis could be detected at the site of the fistula only, without any visible lesion in the valves of the heart.

In dogs with signs of endarteritis and endocarditis, periodic increases in the temperature were observed, accompanied by increases in the pulse rate and a raised ESR, and blood cultures yielded Streptococcus viridans (by the biological method of N. V. Zhuravskaia [3] and the usual bacteriological method). Blood cultures from the control group of animals were sterile.

The pathogenesis of the cardiac lesions which we observed appears to be as follows. With the formation of an experimental fistula between the artery and vein, part of the arterial blood enters the venous system, leading to an increase in the pressure in the venae cavae and overfilling of the right heart. The animal responds to this sudden change in the conditions of the circulation by a complex reflex mechanism increasing the minute volume by means of quickening of the heart beat. If in each individual case the tachycardia does not exceed the capabilities of the heart (acute cardiac failure often arises), then in the course of time it is compensated to a certain extend by hypertrophy of the myocardium. Since the load on the left heart is greater (to prevent a fall in the peripheral arterial pressure and with overfilling of the right heart), the main hypertrophy affects the left ventricle. The "reorganization" of the cardiovascular system primarily is responsible for the intimate trophic changes in the myocardium, reflected in the changes in the T wave of the electrocardiogram.

The etiology and pathogenesis of bacterial endocarditis and endarteritis are very complex in both man and animals.

Microorganisms constantly enter the blood stream through the mucous membranes, the lungs, the skin and gastrointestinal tract. However, in normal conditions, a developing infection is easily disposed of by the body without the formation of local foci of infection or general septicemia. The arteriovenous fistula and its associated hemodynamic disturbances evidently provide unfavorable conditions for the body to carry out its protective functions. The relatively easy development of bacterial lesions is proved in situations affected by pathological processes. The region of the fistula of an arteriovenous aneurysm, with previous damage to the intima, is most probably a very suitable place for the formation of an inflammatory focus (bacterial endarteritis).

An arteriovenous fistula which is a focus of chronic pathological irritation undoubtedly exerts a neuro-allergic action on the reactivity of the internal membrane of the heart [2]. Furthermore the aneurysm increases the susceptibility of the endocardium (and the myocardium) to infection on account of the overstrain of the cardiovascular apparatus which it causes. Hence on these grounds, and considering the severe strain mainly on the left heart, the more frequent development of the infective process in our experiments on the mitral and aortic valves is accounted for.

The progressive endarteritis of the arteriovenous fistula may play a part as a source of the periodic discharge of bacteria into the blood stream, although it is difficult to discount other portals of infection. Since the aneurysms were created aseptically but blood cultures yielded a growth of Streptococcus viridans, it is most likely that autoinfection takes place.

Our experimental investigations thus confirm the clinical observations of complex changes in the heart arising with congenital and traumatic arteriovenous aneurysms. Bacterial endarteritis develops in the region of the fistula itself. In this way various conditions are created which are favorable to the development of infective endocarditis, even without the deliberate introduction of bacteria. The accompanying bacteremia (Streptococcus viridans) is evidence of the autoinfectious character of the infective process.

The production of infective endocarditis experimentally, by an original method (without previous introduction of microorganisms, damage to the heart valves or sensitization of the animal), approximating the clinical course and pathomorphological and bacteriological features of the chronic bacterial endocarditis of man, opens up wide possibilities for research into this disease in several directions.

SUMMARY

Chronic experiments on dogs with formation of arteriovenous fistulae support clinical observations on the complex changes in the heart which take place in congenital and traumatic arteriovenous aneurysms. Endarteritis appears at the site of the anastomosis. Certain conditions are created favoring the development of septic endocarditis even without the inoculation of bacteria. Associated bacteremia (Streptococcus viridans) permits the assumption that the septic process is autoinfective.

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