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REVASCULARISATION IN PART OF A LIMB REPLANTED AFTER HAVING BEEN CUT BONE DEEP

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In 1947, one of us (LADÁNYI) succeeded in suturing back a digit after it had been cut off 10 minutes earlier in an accident. In the possession of antibiotics this problem of regeneration seemed and subsequently proved to be solvable. In our Department we have succeeded in 20 cases to replant digits cut off partially or totally within 2 hours of the accident and without suturing blood vessels and nerves.

The more important it is to study this problem in detail since blood vessels supplying the digits are of such a calibre that it appears impossible they may be sutured by means of the present vascular suture apparatuses in use. Nor is the present surgical technique adequate for uniting by suture blood vessels of such a small calibre. Therefore, in such cases, replantation without suturing blood vessels is the method of choice.

In an effort to elucidate the theoretical basis of the procedure that had proved practicable, animal experiments were carried out in order to make a closer study of the regeneration processes taking place in the replanted region.

In this paper we wish to deal exclusively with the development of a new vascular supply in a canine limb cut to the bone and replanted. The results of arteriographic studies and the evaluation of India ink experiments in vivo, will be presented and discussed below.

Method

In the course of three years 22 dogs were subjected to a series of experiments. Under intravenous or intraperitoneal anaesthesia the canine fore limb was transected bone-deep about 3 cm above the joint corresponding to the wrist in man. During operation the fore limb was compressed by means of a rubber band applied above the joint corresponding to the elbow. Skin and fascia were circularly transected. Tendons were transected between sutures applied previously. Likewise, the muscles were cut between catgut sutures, together with the blood vessels and nerves. The arteries were not tied. Inside the wound the periosteum was circularly cut in a line with the incision and then pushed apart ½ cm both proximally and distally. After that, the interosseous membrane, too, was transected.

In these experiments we did not cut the bone, because a total interruption of bone continuity would have necessitated the use of plaster casts, which in turn would — in the earlier stage — have made a step-by-step observation of the vascularisation process impossible. Experiments on totally detached limbs are now in progress.

The time required for cutting and carefully replanting the part of the limb varied from 20 to 25 minutes. If 10 to 15 minutes after transection the appropriate soft tissue layers were brought together carefully by means of previously placed sutures, they were found to unite and heal.

Experimental

In this paper an account is given of 20 (out of a total of 22) cases, in which limbs transected to the bone were replanted within an hour and healed by means of the above method. In each one of these cases all the nerves and vessels were undoubtedly cut and in none of them were they subsequently sutured. In the course of the experiments two out of the 20 animals died due to intercurrent disease. Thus the evaluation of revascularisation was based on the results obtained in 18 dogs with successfully replanted limb parts.

Series A. Serial arteriographic examinations were carried out during periods varying from 1 week to 5 months after operation. Under Evipan anaesthesia an incision was made in the medial aspect of that region which corresponds to the arm. The brachial artery was thus exposed and an intramuscular cannula was introduced into it. Joduron of 70 per cent was then injected into the artery and at the same time serial radiograms were taken (Figs.1, 2, 3, 4, 5, 6). The radiograms were taken 1, 2, 3, 6 and 8 weeks after operation. Fig. 6 shows the situation at 5 months.

Series B. The other technique employed for the follow-up of revascularisation was the modified Spalteholcz supravital India ink method. Under Evipan anaesthesia the thoracic cavity was opened by a longitudinal incision made in the midline of the sternum. The pericardium also was opened exposing the heart apex, which then was cut off by scissors. Through this opening a metal cannula $^1/_2$ cm in diameter (bearing a tap) was introduced into the aorta, across the left ventricle. Except for the aorta, the great vessels were ligated with double thick silk and the aorta was fastened to the cannula. After that India ink was injected under pressure to fill the vessels of the still living animal (Kis 2). After treatment with Gauetherian oil, sections were made, and the scar line of replantation was carefully examined (Figs. 7 and 8).

Discussion

An evaluation of the results of the animal experiments revealed that in 20 of the 22 cases the part of the canine fore limb, replanted without vascular suture within 1 hour after it had been cut, united distally at a length of about 6 cm from the line of incision. In the first phase nutrition occurred probably by diffusion. By the end of the first week the contrast medium still flooded the tissues in the line of the incision and it appeared to have no preformed route of transfer from the proximal into the distal part. Later at the site where the blood

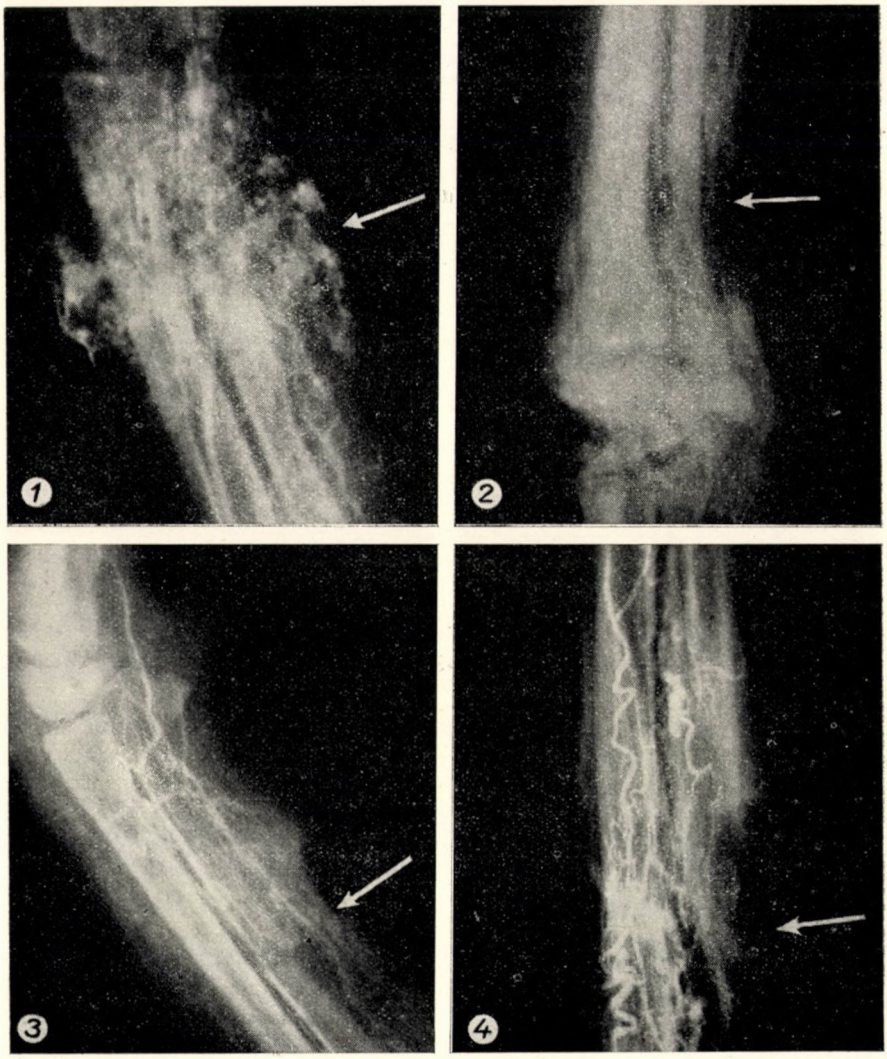

Fig. 1. Arteriogram made one week after replantation. It can be seen that the proximal main vascular trunk fills well and is interrupted in the line of replantation. A fine network of blood vessels is developing in that area. The contrast medium has left the vessels and appears in the tissue spaces. Distal to this area a very narrow vascular network is developing

Fig. 2. Arteriogram made two weeks after replantation. The main vascular trunk is interrupted in the line of replantation. Both proximally and distally abundant vascularisation hardly extending beyond the joint corresponding to the wrist can be seen. As compared to Fig. 1. there is no extravasated radiopaque medium

Fig. 3. Arteriogram made three weeks later. Most of the rich, fine vascular network meets the distal vascular stump

Fig. 4. Six weeks after operation. The main vascular trunk and the distal stump communicate through an abundant vascular network

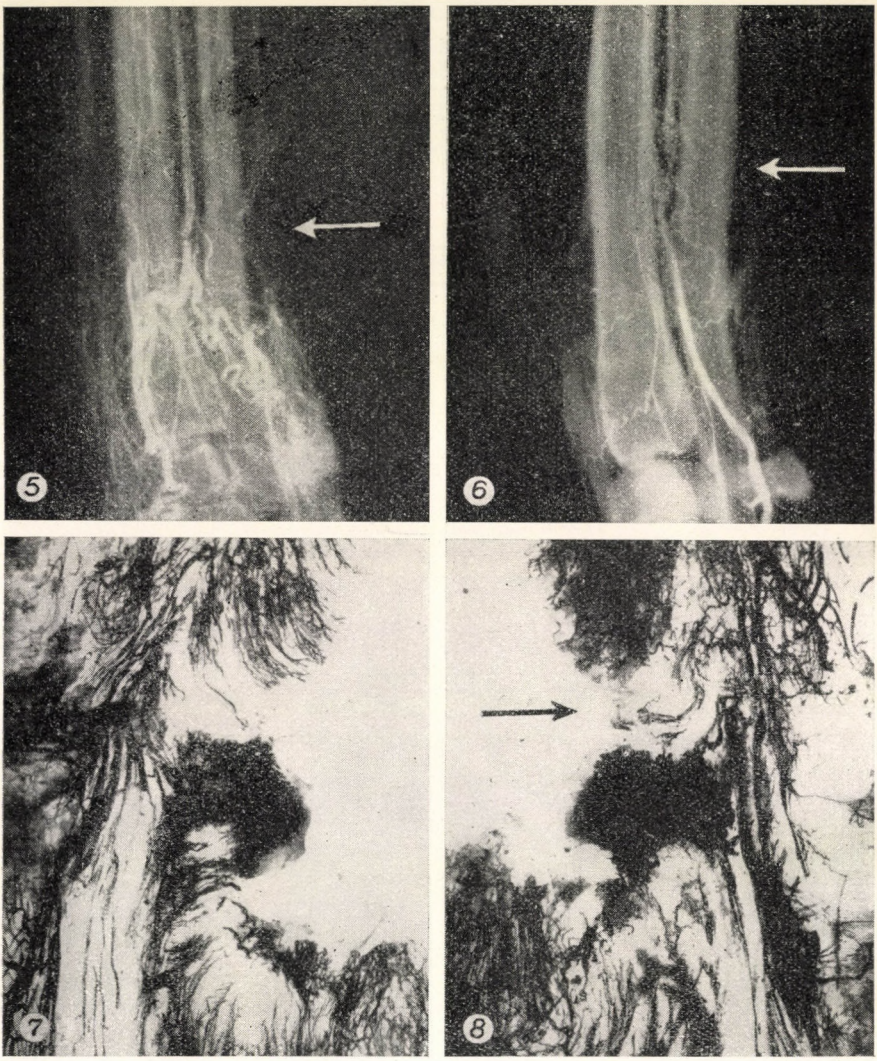

Fig. 5. Eight weeks after replantation. Good arterial filling, also distally

Fig. 6. Five months after replantation. The proximal and distal vascular trunks communicate through a network of vessels in an area about 1 cm in length. The blood supply to the distal part is carried now in a smaller number of vessels of large diameter and not by way of the fine network as before

Fig. 7. Four weeks after operation. India ink preparation. Large numbers of tortuous, thin vessels are seen. Proliferating, superimposed vascular buds are abundant. There is a rich vascularisation also in the distal part, partly reaching the vessels from the proximal part

Fig. 8. Six weeks after operation. India ink preparation. Along the created part of the replantation line a communication has been established between the two vascular systems

vessels had been cut a fine, rich and very tortuous vascular network developed. This new vascular network appeared at first along greater vessels and subsequently in other areas of the granulation tissue, as it was clearly seen in the sections.

In the sections made from specimens of India ink injection, superimposed masses of new proliferating vascular buds were to be seen. Distally and proximally to these some new vascular networks became observable, showing partial unification after 4 weeks and an almost complete unification after 6 weeks.

It is obvious from both the arteriograms and the preparations made after the India ink injection that the newly formed vascular network provided for an ample connection between distal and proximal vessels as early as 4 to 6 weeks after operation.

It was interesting to see how the vascular buds had started to grow from both the proximal and distal trunks in a direction opposite to that of blood flow. The buds of the proximal trunk were striving to achieve unification with a higher regeneration potency. The sections indisputably showed that both proximally and distally the new vascular networks had been connected with the main vascular trunks.

There are still numerous open questions regarding revascularisation, especially as far as regeneration is concerned. In regeneration experiments undoubtedly little attention has been paid to peripheral circulation, and it is thought that these problems should from now on be approached from new angles. We believe that by elucidating a minor — as yet not examined— aspect of the problem, we have contributed evidence that may prove useful for those concerned with research in this field.

Summary

The revascularisation of limbs transected bone-deep and replanted without suturing blood vessels has been examined in the dog. A new vascular network developed distally to the line of incision. By the techniques employed it could be clearly demonstrated that from 4 to 6 weeks after operation a new vascular connection has been established between the distal and proximal parts.

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РАЗВИТИЕ КРОВОСНАБЖЕНИЯ ПЕРЕРЕЗАННОЙ ДО КОСТЕЙ И ЗАШИТОЙ ОБРАТНО ЧАСТИ КОНЕЧНОСТЕЙ

Й. ЛАДАНЬИ и ДЬ. ТОМПА

Авторами было исследовано новообразование сосудистой системы в перерезанной до костей и зашитой обратно без сосудистого шва конечности собак.

В дистальном направлении от линии разреза образуется новая сосудистая система. С помощью метода авторов образование сосудистой сети между дистальной и проксимальной частями как правило хорошо можно проследить в 4–6 недели после вмешательства.

NEUBILDUNG DER BLUTVERSORGUNG BIS ZUM KNOCHEN INZINDIERTEN UND ZURÜCKGENÄHTEN EXTREMITÄTEN

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In bis zum Knochen inzindierten und ohne Anwendung von Gefässnaht wieder angenähten Extremitäten von Hunden wurde das sich neubildende Gefässsystem untersucht.

In distaler Richtung von der Schnittlinie bildet sich ein neues Blutgefässsystem. Mit Hilfe der von den Autoren empfohlenen Methode lässt sich im allgemeinen in der 4—6 Woche nach dem Eingriff das vom distalen zum proximalen Teil durchgehende Gefässnetz gut beobachten.

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