REMOTE RESULTS OF THE REPLANTATION OF THE KIDNEY AND THE SPLEEN.¹

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The technique of the transplantation of organs has been very much improved and simplified in the course of the experiments made during the last two years at the Rockefeller Institute. The grafting of a kidney or a spleen on the renal or the splenic vessels has become an easy and safe operation. Vascular or ureteral complications occur very exceptionally, and, after the operation, the animals remain generally in good health. From a surgical standpoint the problem of the graft of organs can be considered as having been solved.

But, from a biological standpoint, no conclusion has thus far been reached because the interactions of the host and of its new organ are still practically unknown. The study of these interactions was very difficult because the complications which followed the operation were of widely different kinds.² In most cases it could not be ascertained whether the cause of the accidents was biological or surgical, and biological causes were sometimes held responsible for accidents due merely to a fault of technique. Therefore, it was necessary to develop a method making it possible to determine the relative importance of the biological and surgical factors in the evolution of transplanted organs.

This method consisted merely in using a technique the details of which were identical whether the organ was grafted on the same animal or on another animal of the same species. Should an organ, extirpated from an animal and replanted into its owner by a certain technique, continue to functionate normally and should it cease to functionate when transplanted into another animal by

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²Carrel, Jour. of Exper. Med., 1908, x, 98.
the same technique, the physiological disturbance could not be considered as brought about by the surgical factors. The changes undergone by the organ would be due to the influence of the host, that is, to biological factors.

The experiments were divided into two series. In the first series, made in 1908, the kidneys or the spleen from a dog were extirpated on the same animal. The experiments of the second series were performed seven months ago. They consisted in extirpating a kidney from a dog and transplanting it into another dog by the same technique as that used in the first series. The present article deals only with the first series of operations, while the experiments of the second series will be published later.

Two points had to be elucidated by the first series of experiments. (1) Can an organ which underwent section of its vessels and of its nerves, a complete interruption of its circulation, and a perfusion with Locke’s solution, functionate normally for a very long period of time? (2) What is, then, its anatomical condition?

To the first question is given a positive answer by the following experiment. On February 6, 1908, the left kidney of a bitch was extirpated, washed in and perfused with Locke’s solution and re-plant. The circulation was reestablished after having been interrupted for fifty minutes. Fifteen days afterwards the right kidney was removed. The animal remained in perfect health. In June, 1909 this bitch was pregnant and gave birth to eleven pups. In December she again had three pups. To-day, twenty-three months have elapsed since the operation and she is still entirely healthy. Therefore, it is certain that the operation in itself does not interfere at all with the functions of the organ for almost two years at least.

Four other experiments have been performed in order to study the second, point that is, the anatomical condition of the organ.

Experiment I.—Exirpation and replantation of the left kidney. Ether Anesthesia. Middle-aged Irish terrier. November 22, 1908, extirpation of the left kidney, which is put into a jar of Locke’s solution and perfused. The kidney is

\[ \text{Carrel, Arch. f. klin. Chir., 1909, lxxxviii, 372.} \]

\[ \text{All the operations were made under ether anesthesia.} \]

\[ \text{The first part of this observation has been published in the Arch. f. klin. Chir., loc. cit.} \]
replanted into the peritoneal cavity. Suture of the renal artery and vein. Re-establishment of the circulation after an interruption of about fifty minutes. Suture of the ureter and of the peritoneum.

The animal remains in good health and is sent to the farm.

September, 1909. Animal becomes sick.

October 14, 1909. Death.

Autopsy.—Very large dilatation of the stomach. Stenosis of the pylorus by fibrous adhesion to the liver. Both kidneys are normal. The left kidney does not show any evidence of having been extirpated and replanted. It presents exactly the same appearance as the right kidney. The renal vessels are carefully dissected. The perivascular connective tissue does not present any abnormality. The caliber of the vessels is normal and the location of the anastomoses cannot be detected. The anterior wall of the vein is cut longitudinally and the linear scar of the anastomosis is easily seen. On longitudinal opening of the artery, no evidence of anastomosis is found. Nevertheless, by careful examination, the point of union can be located by a very slight difference of color in a point of the intima. The scar has become practically invisible. The ureteral anastomosis also is perfect.

Experiment II.—Extirpation and replantation of the left kidney. Ether anesthesia. Large young black dog. February 1, 1909, extirpation of the left kidney, which is perfused with Locke's solution. Then the kidney is put back into the abdomen. Suture of the vessels, the ureters and the peritoneum. Re-establishment of the circulation after an interruption of forty-six minutes.

The dog remains in excellent health.

April 21, 1909, the dog is killed in a fight with other dogs.

Autopsy, eight hours after death. The kidneys are normal. There is no evidence of the operation. Nevertheless the location of the anastomoses is detected by a slight adhesion of the vein to the artery. Longitudinal opening of the vessels: linear scars and no modification of caliber. From both standpoints, microscopical and histological, there is no difference between the left and the right kidney. They are entirely normal.

Experiment III.—Extirpation and replantation of the spleen. Ether anesthesia. Medium sized white and black dog. February 4, 1908, ligature and section of the gastro-splenic vessels, which are abnormally large; ligature and section of the omentum. Dissection and section of the splenic artery and vein which are abnormally small. The spleen is removed and deposited in a jar of Locke's solution.

Replantation of the spleen and suture of the vessels. The lumen of the artery is only one-half millimeter wide, and the suture is difficult. Nevertheless, the circulation is re-established normally. The spleen is very red and its volume is increased.


Experiment IV.—Extirpation and replantation of the spleen. Ether anesthesia.
February 24, 1908. Large yellow dog, in poor health. Splenic vessels are normal. Extirpation of the spleen which is washed in and perfused with Locke’s solution. The spleen is replaced into the peritoneal cavity, and the vessels and nerves are sutured. Reestablishment of the circulation after an interruption of forty-four minutes. The spleen becomes immediately very red and contracted, and after a few minutes its size becomes very much larger than normal.

June 21, 1909. The dog is fat and in excellent health. Ether anesthesia. Exploratory laparotomy. No adhesions. Spleen has regained its normal size. Splenic peritoneum is whitish in some places. On dissection of the vessels, no evidence of anastomosis is found.

November 4, 1909. The dog died accidentally at the farm. Autopsy.—Spleen in the same condition as in June, 1909. The anastomoses of the vessels cannot be located. Longitudinal opening of the artery and vein. No scars are seen. The specimen is placed into a jar of formalin. After a short time two transverse, whitish bands appear on the internal surface of the vessels, and indicate the location of the anastomoses. There is no visible scar on the intima. The whitish lines are due probably to a slight sclerosis of the adventitia.

Histological Examination.—Sclerosis of the capsula. Spleen normal.

In four experiments three positive results were obtained. The disappearance of the spleen in Experiment III was due to the occlusion of the artery, which occurred doubtless a short time after the operation. The method is not responsible for this accident. For it is known that such a small vessel cannot be sutured with many chances of success. In that case the end to end suture ought to have been given up, and the union performed by an aortic patch.

In the three other experiments the anatomical condition of the vessels and of the organs was studied a long time after operation.

The renal artery and vein were dissected and opened two months and twenty-one days after the operation in Experiment II. The location of the anastomoses could be detected by very slight thickening of the perivascular connective tissue and by a slight adhesion of the posterior wall of the renal vein to the artery. On the intima of both vessels was a very narrow, circular scar. It is shown by the result of Experiment I that eleven months after the operation the scars of the anastomoses had become almost invisible. The renal vessels and the perivascular connective tissue were absolutely normal, and the anastomoses could not be located. After opening of the vein a linear scar was seen. But the intima of the artery
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did not show any scar at all, and the anastomosis could be located approximately only by a slight difference of color of the wall at one point. The suture of the splenic vessels in Experiment IV has given still better results. On the fresh specimen, and after having been opened, the splenic vessels did not show any evidence of ever having been cut transversally. No scar at all was seen. Under the influence of formalin a slight change in color appeared which permitted the location of the anastomoses. It can be considered as certain that these results of the suture of the renal and splenic vessels are definitive.

The anatomical conditions of the replanted organs, kidney or spleen need not be described, for they are entirely normal.

The five experiments mentioned in this article demonstrate that the section of the vessels of the spleen and kidney of a dog, the section of their nerves, the suspension of their circulation for about fifty minutes, and their extirpation and perfusion with Locke's solution do not modify their functions and their anatomical condition when they are replanted on the same animal. These results have been observed for a long time after the operation and can be considered as definitive.

If some changes in the functions and in the structure of the kidneys occur when grafted with the same technique on another dog, it will be permissible to assume that the lesions produced are due to the influence of the host on its new organ. Six dogs, whose left kidneys were replaced seven months ago by left kidneys extirpated from other dogs, are actually living and in good health. They will be used next year for the study of the interaction of the organ and its new owner, and for determining, in some measure, the hypothetical practical value of the transplantation of organs.