PERITONEAL PATCHING OF THE AORTA.¹

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PLATE V.

INTRODUCTION.

The peritoneal patching of an artery consists of substituting for a small part of its wall a patch extirpated from the abdominal wall and composed of peritoneum, sub-peritoneal connective tissue and transverse muscle. This operation was developed with the view of studying two points, surgical and biological, of the problem of regeneration of arteries in mammals. Can an opening through the walls of a large artery be safely occluded by a piece of peritoneum? How can an artery use heterogeneous anatomical elements in order to redintegrate itself, and by what method will the function recreate the organ?

TECHNIQUE.

I developed a technique for the patching of arteries in November, 1905, at the University of Chicago. Afterwards I performed with Dr. Guthrie some arterial grafts of small pieces of veins or arteries. This method was employed for the lateral implantation of small vessels on larger ones. We used it in some experiments of renal transplantations.² It has given also excellent results to Stich and Makkas³ in the transplantation of the thyroid glands. The operation is composed of four stages: preparation of the graft, opening of the aorta and graft, and re-establishment of the circulation.

1. Preparation of the Graft.—A rectangular peritoneal flap is resected, under ether anesthesia, from the antero-lateral wall of the abdomen. It is composed of the peritoneum together with the sub-peritoneal tissues alone, or with the transverse muscle. Then

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the flap is washed in Locke's solution and preserved for a few minutes in vaseline.

2. Opening of the Aorta.—Hemostasis of the aortic segment, upon which the graft is going to be placed, is secured by two Crile forceps, and by ligature or forcipressure of the lumbar collaterals. The anterior wall of the aorta is opened, and a piece of it extirpated. The aortic wall is hard and friable, yet the incisions must be very neat and the edges must not be bruised. Very sharp scissors or a knife must be used. Half of the circumference of the aorta can be removed. The shape of the opening is triangular or oval. As soon as the vessel is opened the blood is washed out, and the edges are covered with vaseline.

3. Graft.—The patch is removed from the vaseline, and with the scissors it is given the same shape and dimensions as the opening of the aorta. It is fixed to the edges of the opening by four equidistant stitches. They are deep through and through stitches. In tying the threads care is taken to approximate accurately the vascular and peritoneal endothelia. If the muscle or the connective tissue overlaps the edges of the peritoneum they must be reduced to the proper length, for it would be dangerous to include them into the line of suture. Afterwards, the graft is completed by a continuous suture of the edges of the patch to the edges of the aortic opening.

4. Reëstablishment of the Circulation.—The lower Crile forceps is removed, while the suture is slightly compressed by a gauze pad. If, after a few minutes, there is still some hemorrhage, a few complementary stitches are added. The upper forceps is then removed and the circulation reëstablished. After that, the muscle is united to the connective tissue sheath of the aorta by a few stitches and the operation is ended.

EXPERIMENTS AND RESULTS.

Three experiments only were performed. In the first one the technique was developed. As I had no assistant, the operation was difficult. The animal died from the anesthetic.

I made the second experiment with Dr. Guthrie at the University of Chicago.
Under ether anesthesia, a small part of the abdominal aorta of a cat was extirpated and replaced by a peritoneal flap taken from the anterior abdominal wall. Five months and five days after the operation the cat was etherized, and the anterior wall of the aorta was closely dissected. The pulsations were normal. At the level of the graft there was no dilatation, but the color was red, for the patch had remained a little transparent; then the abdominal aorta was resected. The limits of the patch became immediately apparent, because the aorta contracted while the peritoneal graft did not. The vessel was cut longitudinally. The intima of the aorta and the internal side of the patch were smooth and glistening.

Histological Examination.—The anatomical specimen was cut transversely and the sections stained with hematoxylin and eosin and Weigert's elastic tissue stain. On the section colored by Weigert's method, the limits of the aortic and peritoneal walls are seen very distinctly, because the elastica of the aorta is very dark, while the patch contains very few elastic fibers. These elastic fibers are very thin and are located along the internal side of the wall. The patch is a little shorter than half the circumference of the aorta. Its ends are accurately united to the vessels (Fig. 1). The hematoxylin-eosin section shows that the peritoneal part of the aorta is as thick as the arterial part. Its appearance is almost the same. The aortic wall is normal. The peritoneal wall may be considered as composed of three parts: adventitia, media, and intima. The adventitia contains several vasa vasorum, and is similar to the aortic adventitia. In the media, no elastic fibers are seen. Its internal part is composed of flat connective tissue cells which assume the appearance of muscular fibers; its middle part is composed of irregular connective tissue cells, and its external part of wavy connective tissue fibers. The intima consists of the more internal part of the media. It is characterized by the presence of a number of very thin elastic fibers.

In the third experiment I transplanted on the aorta of a dog a flap of peritoneum together with a piece of the transverse muscle.

Medium sized, young, white bitch. January 31, 1907, under ether anesthesia, semicircular laparotomy and extirpation of a rectangular piece of peritoneum, subperitoneal connective tissue, and transverse muscle. Resection of a piece of aorta about 12 mm. in length and one-third of the aortic circumference in width. The patch is then sutured to the aortic opening. Suture of the muscle to the connective tissue sheath of the aorta. Reestablishment of the circulation. No hemorrhage. The transplanted flap is thicker than the arterial wall, and bulges above it.

The animal recovers quickly. Pulsations of the femoral remain normal.

November 24, 1908. Etherization. Opening of the abdomen. Pulsations of the abdominal aorta normal. Lumbar peritoneum normal. Dissection of the aorta which is slightly adherent to the vena cava. No evidence of the graft is seen. However, after a close dissection of the anterior wall of the aorta, an elliptical area is seen, the color of which differs slightly from the normal.

*Carrel and Guthrie, Compt. rend. Soc. de biol., 1906, i, 1099.
Peritoneal Patching of the Aorta.

The dimensions of this area cannot be determined, because its limits are not distinct. At its level the caliber of the aorta is absolutely normal. There is not the slightest difference in consistency and thickness of the wall. The circulation is interrupted and the aorta opened. As soon as the vessel is empty of its blood the limits of the patch become immediately apparent because the aorta retracts itself, while the peritoneum does not.

The segment of aorta, on which it is grafted is extirpated, and the circulation is reestablished by a segment of vena cava.

Edema of the hind legs for a few days. Pulsations of the femoral arteries remain normal.


Macroscopic Examination of the Specimen.—On the anterior wall of the resected aortic segment, the peritoneal patch is distinctly seen. Its length is about two centimeters, its width half the circumference of the aorta. Therefore, it is larger than at the time of the transplantation, twenty-two months ago. Its shape is elliptical. On account of the contraction of the aorta it is bent outward. It is a mere cadaveric appearance. Its color, consistency, and thickness appear to be identical with that of the aortic wall. The internal face of the vessel is everywhere smooth and glistening. There is no apparent scar along the line of anastomosis.

Histological Examination.—The vessel is cut transversely at several different levels of the patch. The sections are stained by hematoxylin and eosin, Van Gieson's method and Weigert's elastic tissue stain.

The sections stained by Weigert's method show very accurately the limits of the aorta and of the peritoneal patch. The elastic framework of the aorta is normal and stops abruptly at the point of union with the peritoneum. The union is excellent, the edge of the aorta being slightly bent outward. The peritoneal patch occupies about half the circumference of the aorta. It is almost exactly as thick as the aortic wall. On its internal side a few fine elastic fibers have developed. In the adventitia there is a layer of thick elastic fibers; in the internal part of the media a very large number of exceedingly fine elastic fibers are seen; there is no elastic tissue at all in the external part of the media.

On the sections colored with hematoxylin and eosin the aortic and peritoneal parts of the aorta are hardly discernible. The aorta seems normal, for the peritoneal patch assumes an appearance similar to the aorta (Fig. 2). On both aorta and peritoneum the intima has disappeared. The peritoneal patch is composed of a media and an adventitia. The adventitia contains several vasa vasorum and is identical with the aortic adventitia. The media has the same thickness and almost the same appearance as the aortic media. It is composed of two parts—internal and external. The external part is made of wavy and regular elastic fibers. The internal part consists of regular strata of elongated cells with sacculated nuclei, which look like muscular cells.

The Van Gieson stain shows that they are connective tissue cells. The union between the peritoneum and the aorta is perfect. The muscular fibers are bending themselves outward. At the internal side of the intima elastica elongated connective tissue cells appear; their strata become more numerous and finally substitute themselves for the muscle fiber strata of the aortic wall. There is no scar tissue between the aorta and the peritoneum.
The results of these experiments must be considered from two different standpoints. From a surgical standpoint it is shown that the circulation through the aorta was not modified at all by the substitution of a peritoneal patch for a part of its anterior wall. The operation is not dangerous. The aorta remains normal. There was no danger of embolus because there was no clot on the sutures. It is indicated by the smooth appearance of the line of union of the peritoneum and of the artery. When a small thrombus develops on the sutures the line of union assumes afterwards a scarlike appearance. The results are definitive. Five months after the operation in the first experiment, and twenty-two months after the operation in the second experiment, the animals were opened and the aorta examined directly. The circulation was excellent and the patched aorta was apparently normal.

From an anatomical standpoint the peritoneal patch has adapted itself perfectly to the artery. It has become morphologically identical with the wall of the functioning aorta. When the vessel was examined during the life of the animal it was found that the caliber, consistency and shape of the aorta, together with the thickness of its wall at the level of the patch, were entirely normal. There was only a slight difference in color due, in one case, to the fact that the peritoneum had remained transparent and that, through it, the circulating blood was seen. But, as soon as the circulation was interrupted, the aorta underwent contraction, while the patch did not. Therefore, its limits became immediately very apparent, and it seemed dilated. This apparent dilatation was a cadaveric phenomenon, which appeared when the aorta ceased its function and when the blood pressure was suppressed.

It is very interesting to notice that from a histological standpoint the morphology of the patch has been deeply modified and that its anatomical elements, although unchanged in nature, assumed almost the same appearance as those of the aorta (Fig. 2).

The new wall was composed only of connective tissue. The fibers of the transverse muscle had been absorbed and no smooth muscle fibers had developed. Nevertheless the media looked almost like the aortic media. In the last experiment the internal part of the media was composed of regular strata of connective tissue cells,
Peritoneal Patching of the Aorta.

the appearance of which was identical with that of muscle fibers. It is a case of cellular mimicry. The elastica of the patch differed deeply from the aortic elastica. In both cases the patch contained a very small amount of elastic tissue. In the first experiment after five months there were only a few elastic fibers in the intima of the patch. No elastic fibers were seen in the media and the adventitia. In the second case, twenty-two months after the operation, there were no elastic membranes to be compared with those of the normal aorta. Nevertheless, a diffuse infiltration of the internal part of the media by exceedingly thin elastic fibers was seen. A few larger fibers had also appeared in the adventitia.

The new wall, therefore, differs deeply from the normal one, in spite of its morphological similarity. It does not contain any muscular fibers. The elastic tissue has taken very little development. Nevertheless, the tissues of which the wall is composed, although not thicker than those of the artery, were able to stand the blood pressure without undergoing any dilatation.

CONCLUSIONS.

These experiments show that an artery can regenerate itself by using heterogeneous anatomical elements. The adaptation of the peritoneal patch to the aortic wall was so perfect that the vessel, less than two years after the operation, was absolutely normal. Although the new wall was composed of tissues different from normal, the morphology of the aorta was not modified. By a kind of mimicry the connective tissue cells assumed the appearance of muscular fibers. The mechanism of this perfect morphological redintegration is as unknown as the cause of the persistency of the form, in spite of the ceaseless mutations of living matter. The power of redintegration of an artery renders possible its patching with tissues, which have by themselves very little resistance. It explains why an aorta patched with a piece of peritoneum can function normally twenty-two months after the operation.
Fig. 1.

Fig. 2.
EXPLANATION OF PLATE V.

Fig. 1. Peritoneal patching of the aorta of a cat five months after the operation. The elastic framework of the aorta stops abruptly at the edges of the peritoneal patch.

Fig. 2. Peritoneal patching of the aorta of a bitch twenty-two months after the operation.