

CLASSICS OF BIOLOGY AND MEDICINE — I

The Transplantation of Organs: A Preliminary Communication^a

Alexis Carrel

Hull Physiological Laboratory, University of Chicago, Chicago, Illinois

This operation consists of extirpating an organ, with its vessels, of putting it in another region, and of uniting its vessels to a neighboring artery and vein. If the organ is replaced in the same animal from which it was removed, the operation is called an autotransplantation. If it is placed in another animal of the same species it is called a homotransplantation, while if it is placed in an animal of a different species, the operation is called a heterotransplantation.

The so-defined transplantation completely differs from the well-known experiments of subcutaneous or intraperitoneal grafts of small slices of organs.

LITERATURE

The literature of the transplantation of organs is not extensive.

In 1901-02 I began experimenting with the view of finding a method of substituting a sound organ for a diseased one, e.g., of treating Bright's disease by replacing the diseased kidney by a normal one, or myxedema by transplanting a sound

thyroid gland and securing it a blood supply by arterial and venous anastomosis. These first experiments were made in the Faculty of Medicine of the University of Lyons.

The transplantation of the thyroid gland, with its vessels was performed on a large dog [1]. The right thyroid gland was dissected and its vessels cut. The largest artery and vein were united by a termino-lateral anastomosis to the carotid artery, and the external jugular vein. The circulation was re-established. It was impossible to observe physiologic results, owing to coagulation, which soon occurred, due to the bad aseptic and technical conditions of the operation.

About the same time the transplantation of the kidney was made [2]. The carotid and the jugular of a dog were dissected and prepared for anastomosis. The kidney having been extirpated, with its vessels and its ureter, was put into the cervical wound. End-to-end anastomoses of the renal artery to the carotid and of the renal vein to the jugular were performed. The end of the ureter was united to a small

^a *Editor's note:* Alexis Carrel's pioneering work in experimental surgery, especially in vascular surgery and organ transplantation, earned him the 1912 Nobel Prize in Physiology or Medicine. These two short articles demonstrate his bold yet logical approaches to both the technical and theoretical aspects of organ transplantation. Reprinted from the *Journal of the American Medical Association* 45:1645-1646, 1905.

opening of the skin, located a little above the sternum. On release of the clamps, the circulation was immediately re-established, and seemed thoroughly normal. After a few hours a clear fluid began flowing from the ureter. Permanent results were not observed, on account of septic complications.

In the same year, and prior to this, similar experiments, of which I was then ignorant, were performed by Ullmann [3]. His method was different. He used Payr's tubes for uniting the blood vessels. Definitive results were not observed. In 1903 the same experiment was made by Carl Beek of Chicago, but not published.

In 1905 Floresco [4] continued these experiments. He succeeded in transplanting the kidney into the lumbar region. The urine escaped into the bladder. My technic of anastomosing blood vessels was used with a slight modification. The operation was successful, but the anatomic and physiologic results have not yet been published.

In 1905 several series of experiments were performed by Dr. Guthrie and myself in the physiologic and surgical rooms of the Hull laboratory, in order to study the results of the transplantation of the blood vessels [5] of the heart, of the thigh, of the kidney and of the other glands [6]. I am very glad of this occasion to thank Dr. Stewart for giving me the privilege of performing these researches in his laboratory.

PROBLEMS CONNECTED WITH VISCERAL TRANSPLANTATION

It is impossible to discuss here all the problems which the question or transplantation of organs raises. We will only consider the most important conditions which are necessary to the nutrition of the transplanted organs.

In case of autotransplantation or homotransplantation, the establishment of a good circulation through the anasto-

moses ordinarily renders the operation successful. The life of the transplanted organs depends almost entirely on the circulation. If the vessels become obliterated, gangrene destroys the organ. Obliteration can occur very easily. It may be produced by a great many causes; for instance, injury to the endothelium by the forceps, the needles or the clamps of temporary hemostasis, clots on the perforating stitches, fall of the external sheath in the opening of the vessel, and above all, lack of perfect asepsis.

The ordinary surgical methods of blood-vessel anastomosis have failed to give successful results in the transplantation of organs. At first I used tubes of magnesium or tubes of "caramel," but without good results. Coagulation occurred. Afterward I found a method of suturing which was often successful. By degrees that method has been improved in such a manner that now obliteration almost never occurs. Dr. Guthrie and I, operating together, obtain practically constantly good results. That very important question of technic being settled, autotransplantation and homotransplantation become almost easy.

The problem of the heterotransplantation is much more complicated. It is well known that the serum of an animal in many cases is toxic for the cells of an animal of another species. The aim of these researches being to determine the possibility of transplanting organs from animal to man, that question is very important. Fortunately, biologic laws are not without exceptions. Perhaps the human serum is not toxic for the cells of some animals. We have some reason to think that organs of the anthropoid apes transplanted on man may not be injured by the serum, for the blood of ape and man are inactive toward each other. Besides, it might be possible to use anticytolytic serums. All these points are unknown and must be experimentally studied.

POSSIBLE RESULTS OF VISCERAL TRANSPLANTATION

Only a few of the possible results of the transplantation of organs will be mentioned in this paper. We do not want to discuss here the physiologic applications or the method. They are numerous and of considerable importance. Already we have performed several experiments along this line. For instance, Dr. Stewart and I have transplanted the kidney, with reversal of the circulation, in order to study the modifications of the secretions. With Dr. Guthrie, I transplanted one of the kidneys of a dog into the cervical region, and, on the third day after the operation, made a comparative study of the urine secreted by the transplanted and the sound kidney [7]. I performed also the transplantation of the heart of a dog on the carotid and the jugular of another dog. The heart was beating and the blood circulating through it. Dr. Guthrie and I established an arterial circulation through the right inferior thyroid vein of a dog, which had symmetrical hypertrophy of the thyroid glands. Marked changes occurred. Thus it appears that the reversal of the circulation in only one vein of a gland may alter the physiologic processes. The replantation of the thyroid gland was successfully made [8]. Probably our knowledge of the pancreas, the spleen, etc., may be increased by this method.

From a clinical standpoint, the transplantation of organs may become important. Perhaps it will be possible to treat myxedema, idiocy, etc., by transplanting a sound thyroid gland with anastomosis of the thyroid vessels to suitable arteries and veins. In kidney affections the transplantation of a sound kidney may be of benefit. Perhaps, after a complete amputation of arm, leg, or thigh, it may be possible to replant the limb, or another similar limb, if it is procurable.

A great many experiments on animals must be performed before using that method on man. As yet it is impossible to say whether or not the transplantation of organs will yield practical results. It seems possible, and we hope that it may open new fields in therapy and biology.

ACKNOWLEDGEMENT: *I wish to thank Dr. Guthrie for helping me in the revision of this paper.*

REFERENCES

1. Carrel. Les anastomoses Vasculaires ; leur technique opératoire et leurs indications. 2e Congrès des Médecins de langue française de l'Amérique du Nord, Montreal, 1904.
2. Carrel. La technique opératoire des anastomoses vasculaires et la transplantation des viscères. Lyon Médical, 1902.
3. Ullmann. Experimentelle Nieventransplantation. Wien. klin. Wochft., 1902.
4. Floresco. Conditions de la transplantation du rein. Recherches sur la transplantation du rein. Journal de Physiologie et de Pathologie générale, 1905.
5. Carrel. Anastomoses and Transplantation of Blood Vessels. American Medicine. 1905.
6. Carrel and Guthrie. Transplantation of the Kidney. (To be published); Transplantation of the Inferior Thyroid Vein on the Carotid Artery, in a Case of Goitre. (To be published); Amputation of the Thigh. Replantation. (To be published in the American Journal of the Medical Sciences).
7. Carrel and Guthrie. Functions of a Transplanted Kidney. Science, Oct. 13, 1905.
8. Carrel and Guthrie. Extirpation and Replantation of the Thyroid Gland with Reversal of the Circulation. Science, Oct. 27, 1905.