EXPERIMENTAL RESULTS IN THE USE OF DEAD FASCIA GRAFTS FOR HERNIA REPAIR

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Recently the use of dead material as grafts in the repair of anatomical defects has created widespread interest. This has been due principally to the work of Nageotte and Sencert. These authors have reported the transplantation of pieces of tendon preserved in alcohol or formalin to repair defects in living tendon. Their work has been extensive and their results excellent. A short review of their work, and of events leading up to it, is essential as a preliminary to the recounting of the work reported in this paper.

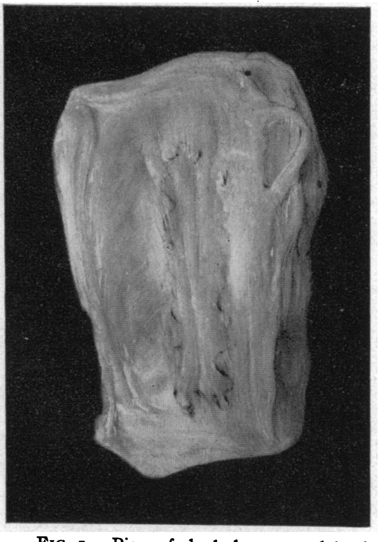

Fig. 1.—Piece of alcohol-preserved dead fascia grafted into the fascia lata of a dog. Removed six months after operation. The black silk sutures indicate the position of the graft.

Before taking up the experimental and clinical work of Nageotte and Sencert, it is desirable to consider a theory of the nature and origin of connective tissue formulated by Nageotte in 1916, and which forms a basis for his subsequent experimental work. For many years there have been in existence two main theories as to the origin of the connective tissues: (1) The exoplasm theory, held principally by Hansen, Mall, Szily, Studnička, and Laguesse. There are several variations of this theory, but, in general, its adherents claim that connective tissue is formed from transformed portions of protoplasm—the exoplasm, which comes from a syncytium of mesenchyme cells. (2) The cellular secretions theory, held principally by Merkel. This theory claims that early syncytium of the mesenchyme cells secretes an amorphous gelatinous non-living ground substance in which the connective-tissue fibres form. In contradistinction to these two theories, Nageotte believes that albuminoid coagula are first formed by the humors of the organism or from the parenchyma cells and that these coagula are no more living than the coral of polyps; that the problem of origin is the same as that of formation of blood plasma. This fundamental substance (substance fondamentale) is not amorphous, but composed of elementary collagen fibrils (fibrille collagène élémentaire). These elementary collagen fibrils give rise to collagen fibres, and connective tissue is formed by the penetration of fibroblasts into the meshes of fibres. The distinctive feature of Nageotte's theory is that he insists upon the fundamental non-living character of all the connective-tissue substances.

In this connection, the work of Baitsell (1915-16) is most interesting. This worker observed the direct transformation of fibrin clot into connective-tissue fibres. Later, tissue cells wandered in, did not digest the fibres, but by their movements caused a division of the large bundles into smaller ones. These cells were rounded when they first appeared but later assumed the typical elongated spindle shape of fibroblast cells. There was no evidence of a later attempt of these cells to form new fibres. After further work (1917), Baitsell showed that the transformation of the fibrin clot was brought about by a fusion and consolidation of the fine elements of which it was composed. In 1921, he showed that the connective tissue in amphibian embryos is formed from a ground substance secreted by the embryonic cells before there is any syncytium of mesenchyme cells. This work tends to lend support to Nageotte's theory.

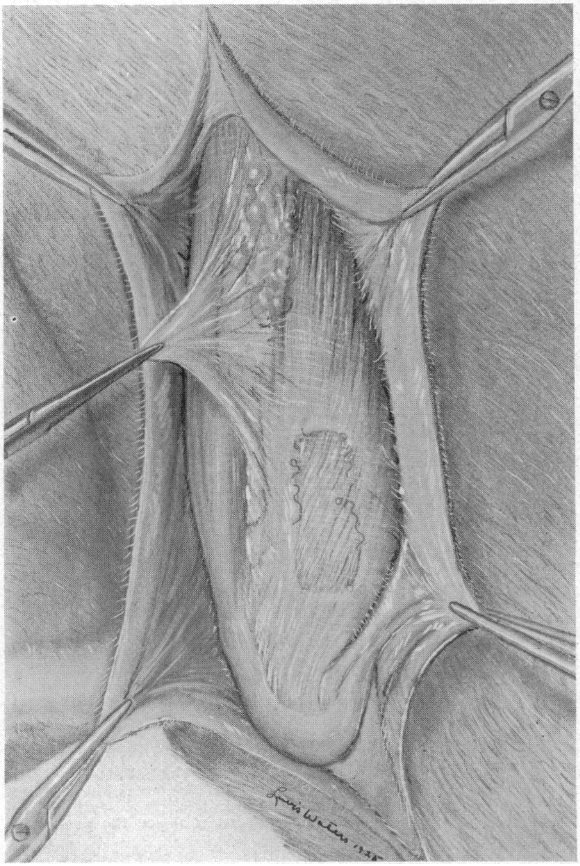

FIG. 2.—Piece of dead fascia from a cat grafted into the fascia lata of a dog. Four months after operation. The difference in thickness of the graft and surrounding fascia is not due to absorption, but to a difference in the original thickness of the structures in the two different species.

Nageotte (1919), described the transformation of dead inclosed protoplasm (dead cartilage cells) into collagenous substance. In 1920, he describes a similar "metamorphism" of the fibrinous network.

In 1917, Nageotte published his first experimental work on the use of "dead grafts." Since then, numerous papers have come out amplifying and enlarging his results and conclusions. He proceeds on the assumption that if connective-tissue substances are inert coagula formed from living cells, one would not expect grafts of dead tissues to act as foreign bodies and produce phagocytosis; the reaction to "dead" fibres should be the same as that to "living" ones. The results of his experiments tend to give approval to his theory of the nature and origin of connective tissues. He transplanted pieces of tendon killed by alcohol or formalin and found that these attached themselves promptly to the connective apparatus of the living tendons which received them. The dead graft takes, and becomes adherent; soon it is impossible to determine its limits because the union between the dead and living tissue has effected itself to perfection. Microscopic examination likewise shows that the implanted tendon blends with the living tissue until no line of demarcation can be detected. After the dead protoplasm has been carried off by the migratory cells, new fibroblasts from the host flock into the persisting connective-tissue framework of the graft, and establish themselves in the place of the old inhabitants; circulation becomes established by the growing in of small vessels from the host, and in time it is actually impossible to tell that the graft had been dead when it was implanted. Nageotte calls this process the "reviviscence" of the graft; the dead graft has in fact become alive again!

FIG. 3.—Dead fascia graft into the fascia lata of a dog. Drawing five months after operation.

When pieces of dead cartilage are transplanted into the ear of a rabbit the morphology of the graft makes impossible the invasion of fibroblasts from the living tissues. However, the graft remains in place, unaltered and adherent, but not encysted.

The only phagocytosis which one is able to observe is that which is necessary for the removal of dead protoplasm. The persistence of the grafts is not simply an example of "aseptic tolerance." For in such cases, the foreign body is immediately surrounded by macrophages, and more slowly isolated by fibrous encystment: in a word, the so-called aseptic tolerance is accompanied by reactions which show clearly the intolerance of the tissues with regard to the foreign body.

Leriche and Policard object to the term "dead graft," claiming that in a graft, the continuity of the personal life of the transplant is preserved. Polettini and Bonnefon object to the term "reviviscence." However, these objections seem to be only matters of terminology.

Besides grafts of dead cartilage and tendon, Nageotte also grafted, with

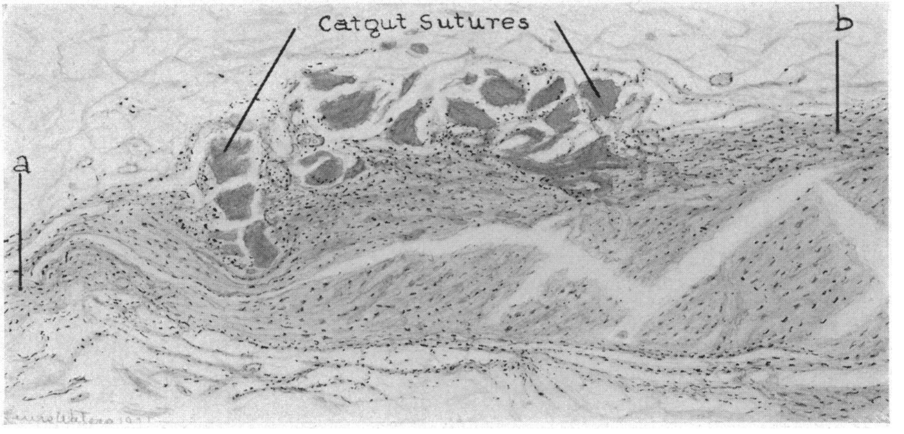

FIG. 4.—Microscopic drawing showing union of dead and living fascia. Four months after operation. a. Living fascia of host. b. Dead graft.

success, segments of dead arteries and nerves. Attempts at grafting dead arterial segments were made by Levin and Larkin in 1909, without success. They got thrombi, and necrosis and calcification of the implant. Carrell, in 1910, got similar results with dead arterial segments—the graft acted as a foreign body and the tissues of the host reacted by building a wall of connective tissue around it. Klotz, Permar, and Guthrie in 1923, reported the successful transplantation of devitalized, formaldehyde-fixed vessel segments, but remarked that there was a subsequent tendency to fusiform dilatation of the transplant due to loss of muscle tissue and elastic fibres.

Support is given to Nageotte's theories and results by the previous work of several authors, which tends to show that any graft is only relatively "alive." Bonnefon, after several years' researches (1913 *et seq.*) on living cornea grafts, opposes the hypothesis of the integral survival of grafts. He presents a series of histological facts which demonstrate the partial or total disintegration of the transplant and its regeneration by the graft carrier. The dead cells of the graft are replaced by living cells of the host, and the union of the graft to the host is effected by the growing in of fibroblasts from the host. Ribbert, Marchand, and Salzer had also previously expressed the view that in corneal grafts the cellular elements of the grafts disappear and are replaced by others from the host. In similar vein, Villard, Tavernier, and Perrin, in 1911, expressed the view that vessels preserved a long time in the icebox do not live really, but that one grafts only their elastic skeleton, susceptible at all times of being invaded by cellular elements, which, derived from the graft carrier, furnish it a vitality sufficient to permit it to assure the continuity of the vessel on which it is implanted.

Some observations of Nageotte along the same line are most interesting. He draws a comparison between living and dead grafts and takes, for an example of comparison, a piece of living tendon graft. In such a graft three distinct phenomena occur: (1) the texture of the tissue introduced attaches

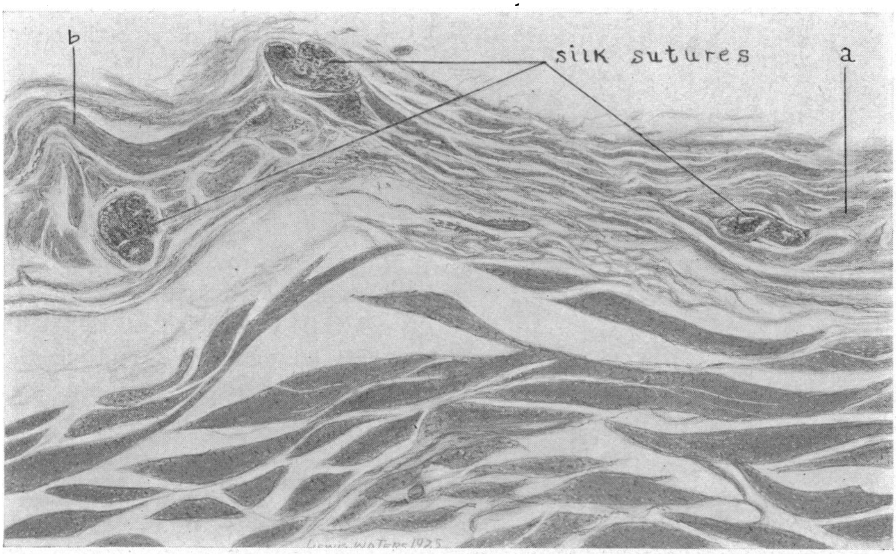

FIG. 5.—Microscopic drawing showing union of dead and living fascia. Four months after operation. a. Living fascia of host. b. Dead graft.

itself to that of the host; (2) a new vascular network is installed; and (3) the cells, for a moment altered, are rehabilitated in their former integrity. If a piece of dead tendon is inserted, what are the modifications of the process? Only the third phenomenon shows a variation: the dead cells are replaced by living cells. The final results are identical. Are there not all possible intermediaries between living and dead grafts? In living grafts kept in the icebox are not a large percentage of the cells dead?

Several workers have achieved excellent surgical results using the methods of Nageotte and Sencert. Nageotte and Sencert themselves, in 1918, reported the bridging of gaps of 3 or 4 cm. in tendons on the palmar surface of the wrist with tendons from a dog that had been preserved in alcohol for one month. Good result. Also Sencert, in 1918, reported the use of a dead nerve of a calf to bridge a gap of 2 cm. in a median nerve. The continuity of the nerve was established with no scar formation, as revealed by a subsequent operation. The report was made too early to be sure of the final outcome, but the result was encouraging, as there was beginning functional restoration. Walther

(1919), grafted 17 cm. of a young calf nerve preserved in alcohol in the radial nerve of a soldier. Good result. Auvray (1919), bridged a gap of 3 or 4 cm. in the tendon of a thumb with dead animal tendon. Good result. Dustin (1919), twice successfully grafted dead nerve of a calf in man. Jalifier (1920), implanted tendons taken from the leg of a calf or dog six to fifty days before. These were used to repair defects in the hand in five cases. Fairly good or very good functional results were reported. A few months later, Jalifier reported the repair of injured nerves with grafts of dead nerves in seventeen cases. Results doubtful. Busacca (1920), grafted dead nerves and tendons. Christophe (1923), successfully grafted an entire patella, with its quadriceps and patellar tendons, that had been preserved in 80 per cent. alcohol for three days, into the knee of a soldier who had lost his patella from a gunshot wound four months before. The grafted patella was obtained from another soldier who died from a head injury. The functional result was excellent, and a röntgenogram made four years after the operation showed a normal knee. Christophe also transplanted alcohol-fixed dead bone to repair defects in the radius and in the ulna with excellent results. Durand (1919), and Delorme (1919), observed and commented favorably upon the work of Nageotte and of Sencert. Regoli (1922), Regard (1923), and Weidenreich (1924), have successfully repeated the experimental work of all of these authors.

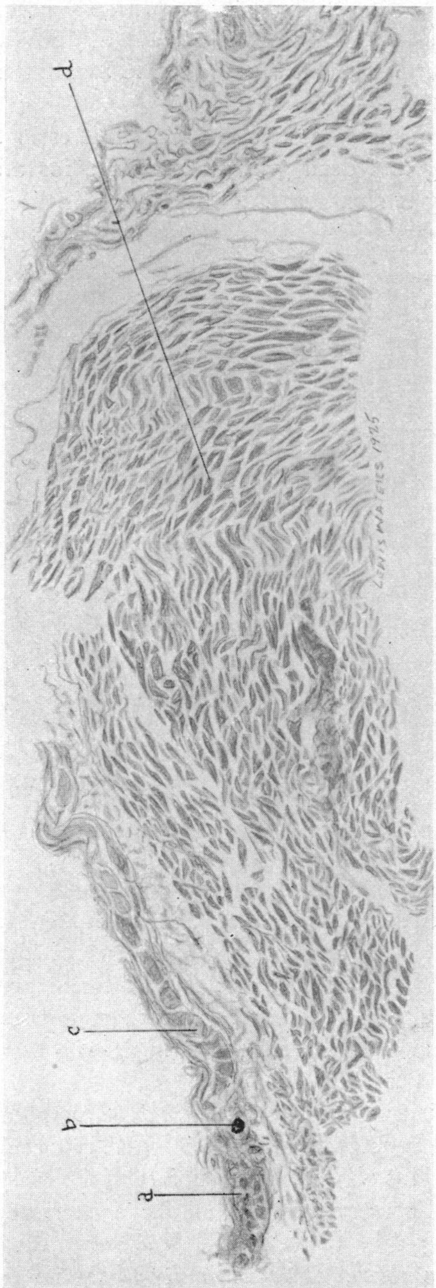

FIG. 6.—Low-power drawing of cross-section of dead fascia graft. Four months after operation. a. Living fascia of host. b. Silk suture. c. Dead graft. d. Muscle.

Nageotte and Sencert state that when a gap in a nerve is repaired by a graft of dead nerve, the healing which takes place is entirely without scar formation or the formation of neuromata, which often occurs when a severed nerve is sutured. In this connection the recent work of Barthélemy (1920) is most interesting. This author calls attention to the fact that after nerves are injected with alcohol or osmic acid for neuralgia, the pain stops, but returns in about the same length of time as is required for nerve regeneration. He, therefore, did a series of experiments on dogs to determine just what happens when nerves are thus injected with alcohol or osmic acid. He found that after the injections, the nerves first degenerate and then regenerate. The regeneration always occurs entirely without scar formation or the formation

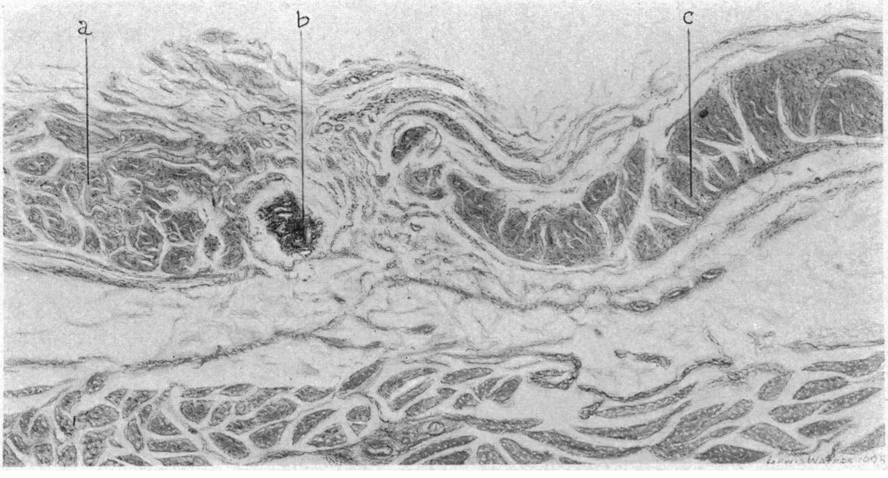

FIG. 7.—Enlarged drawing of a small portion of Fig. 6, showing point of union of dead and living fascia. a. Living fascia of host. b. Silk suture. c. Dead graft.

of neuromata. This tends to substantiate the work of Nageotte and Sencert.

The above-mentioned results have stimulated the author to undertake a series of experiments with a view to determining just what could be done with dead fascia grafts in the repair of hernias. We started out with a two-fold aim: First, to determine what becomes of dead grafts of fascia when transplanted among living tissues; and, secondly, if it should be found that the dead grafts survive, to determine whether hernias could be successfully repaired with them.

In order to solve the first part of our problem, namely to determine the fate of dead grafts when transplanted, we performed twenty-one operations on dogs and cats. The materials used in these operations were pieces of fascia that had been preserved in 70 per cent. alcohol for varying periods of time (three to seventy-five days). The fascia lata and the sheath of the rectus were the principal sources of the dead grafts. Some of the grafts had been previously taken from the same animal (autografts); others were taken from other animals of the same species (isografts); and still others were taken from a different species—grafted from cat to dog, or from dog to cat (zoografts). The usual method of procedure was to cut a rectangular opening in either the sheath of the rectus or the fascia lata and to repair this defect with a piece of dead fascia cut to fit the opening. The thigh proved to be the site of choice for the operation, as the fascia lata is not adherent to the underlying muscle as is the case with the sheath of the rectus. The dead graft was sutured in place by continuous sutures of fine black silk. Catgut was tried but was found not to be as satisfactory as silk for holding the graft in place. The subcutaneous tissue and skin were then sutured over the emplaced graft.

These animals were sacrificed in from two to seven months after operation, and the grafts with the surrounding fascia removed for microscopic section. In a few cases in which the graft was too small to fit the fascial defect, the edge of the graft had pulled away from the edge of the fascia to which it had been sutured. However, in nearly all cases, the graft had remained in place and the living fibres had so intermingled with those of the dead tissue that it would not have been possible to tell where one stopped and the other began, except for the row of black silk sutures. Examples of this are shown in Figs. 1, 2 and 3. In no cases were there evidences of absorption of the grafts. Microscopically the same intermingling of fibres is seen (Figs. 4, 5, 6 and 7). Furthermore living cells can be seen to have wandered in among the dead fibres, so that the former dead graft is now, in effect, living tissue.

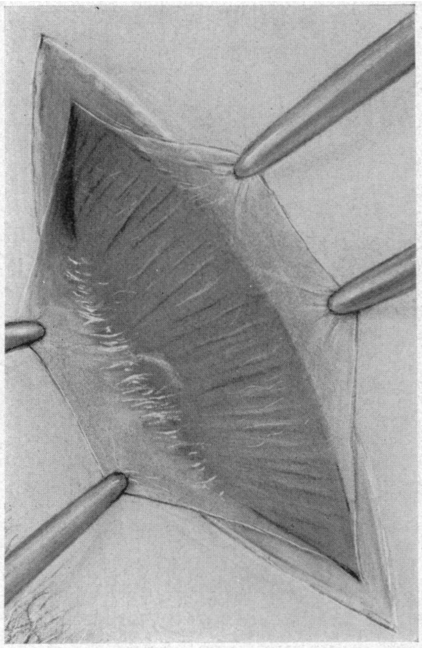

FIG. 8.—Suture of internal oblique muscle to Poupart's ligament in a dog, by the method of Gallie and Le Mesurier, but substituting dead strips of fascia lata for their "living sutures." Four months after operation.

From the foregoing, and the work of the other authors quoted above, it appears that dead fascia used as grafts can be counted upon to remain in place and to do the same work as the living grafts ordinarily used for the same purposes. Why then can not dead strips of fascia lata be used in the new operations of Gallie and Le Mesurier for hernia, instead of their "living sutures"? Would it not simplify their procedure a good deal to be able to take their suture material out of a jar in the operating room rather than to have to perform an additional operation in order to get this material? In order to try out this simpler procedure, we sutured the internal oblique muscle to Poupart's ligament in two dogs, using strips of dead fascia lata as suture material, and employing the technic advocated by Gallie and Le Mesurier. As pointed out by the author in a previous communication, the internal oblique muscle forms a greater angle with Poupart's ligament in the dog than in man. Therefore, it requires more tension on the tissue to bring these two structures into apposition by suture in the dog than in man. In spite of this, and the use of strips of *dead* fascia as suture material, we got the firmest sort of dense fibrous union of the muscle to the ligament in both of our operations (see Fig. 8). In fact the union was much firmer and accompanied by much denser adhesions than that previously reported when silk or catgut was used as suture material.

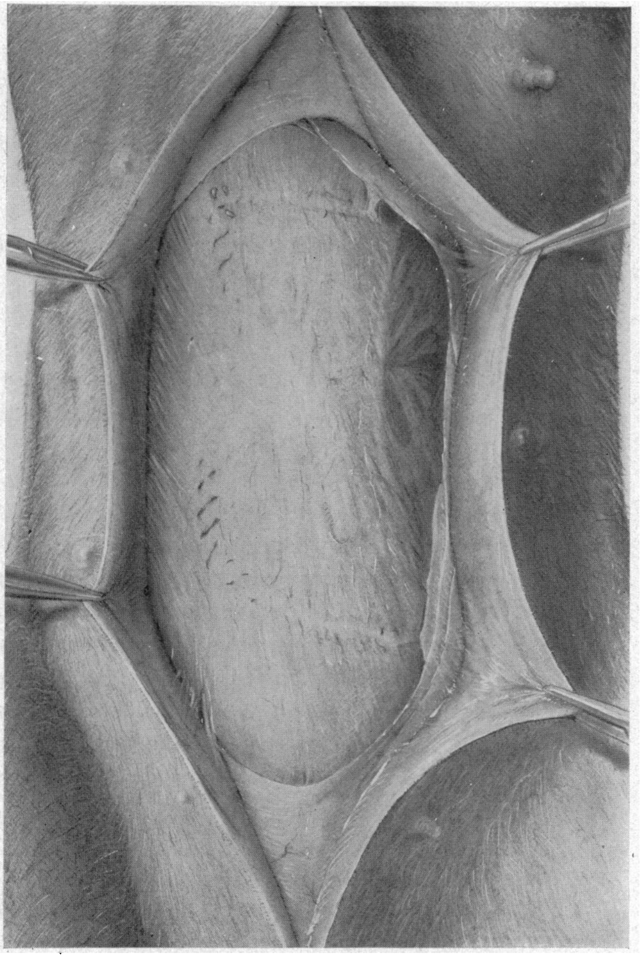

FIG. 9.—Repair of large ventral hernia in a dog with a piece of alcohol-preserved fascia lata of an ox. Five months after operation.

We next undertook to produce large ventral hernias in dogs, and then to repair them by the use of large grafts of dead fascia. A ventral hernia is hard to produce in a dog, as any defect made in the abdominal wall tends to repair itself by an excessive growth of fibrous tissue. We early noted that when the external sheath of the rectus was removed for subsequent use as a dead graft, that subsequent operation or autopsy showed the defect to be repaired by a dense overgrowth of fibrous tissue much stronger than the original rectus sheath. We also learned by repeated attempts at hernia production that a wide excision of abdominal wall was necessary, and so came to employ the following procedure: Three or four inches of the rectus muscle on both sides were excised, including both the external and internal rectus sheaths. The peritoneum was opened with a large crucial incision, and left open. The subcutaneous tissue and skin were then sutured over this opening. The result was a large bulging ventral hernia.

In a few weeks this hernia was repaired with a large piece of dead fascia. Various materials were tried, including the submucous coat of the pig's bladder, the pericardial sac of the ox, and the fascia lata of the ox. The last named material proved most satisfactory, as it is tougher and has practically no give to it. The operation was conducted in this manner: The skin was opened, and any excess fibrous tissue that had grown across the defect in the abdominal wall was removed, leaving only a very thin layer of subcutaneous tissue between skin and peritoneum. The sheath of the rectus, bordering the defect above and below, and the external oblique, bordering it on the sides, were then exposed. The graft of dead fascia was then placed so as to overlap the edges of the defect and sutured in place. Above and below it was sutured to the sheath of the rectus, and on the sides to the fascia of the external oblique muscle and the external oblique muscle itself. Fine black silk doubled was used as the suture material. The buttonhole stitch was tried, but the ordinary continuous suture proved better. The subcutaneous tissue and skin were then sutured over the graft. The dogs thus operated upon were sacrificed in from four to six months after operation. Figure 9 shows a typical result. The hernia was completely cured, and the dead and living fascia would have been indistinguishable, except for the line of suture.

In the foregoing experiments, fascia from several different species were transplanted into other species indiscriminately, and with no ill effect. Heteroplastic grafts took just as well as homoplastic ones. Other workers with dead grafts have had the same experience. It is well known that this is not true of living grafts. The possible explanation is that the preservation of the graft in alcohol or formalin eliminates the antagonistic action of foreign sera. Occasionally, however, certain dead heterogenous grafts appear to be toxic. Nageotte (1920) says that the tendon of the tail of the white rat or of the sewer rat used for suture of pieces of nerve in the dog, or transplanted into the eye of the rabbit, provokes a chronic inflammation which produces its destruction slowly without suppuration.

CONCLUSIONS

1. Grafts of dead fascia, preserved in alcohol, when transplanted among living connective tissues, remain intact and unite with the tissue of the host. After a period of a few months it is impossible to distinguish the living from the "dead."

2. The living and "dead" are likewise indistinguishable microscopically.

3. The suturing together of the internal oblique muscle and Poupart's ligament with strips of dead fascia in the dog results in the firmest type of fibrous union.

4. Large, experimentally produced, ventral hernias in the dog can be successfully repaired by the use of large grafts of dead fascia.

5. Dead fascia grafts may be homogenous or heterogenous.

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