

RESECTION OF THE DESCENDING THORACIC AORTA FOR ANEURYSM

A REPORT OF THE USE OF A HOMOGRAFT IN A CASE AND AN EXPERIMENTAL STUDY*

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SEVERAL DIFFERENT SURGICAL procedures have been used in the treatment of aneurysms of the thoracic aorta. Understandably, those resorted to most frequently have been of a rather conservative and non-definitive nature. Such methods include the application of cellophane to the external surface of the aneurysm¹ and the production of intrasaccular thrombosis by electrothermic coagulation.² It is possible to resect a saccular type of aneurysm and to close the neck by suture with maintenance of the continuity of the vessel.³ Coarctation of the aorta is occasionally complicated by aneurysmal dilatation distal to the point of constriction where a forceful jet of blood may be present. There are several reports of resection of this special type of aneurysm. In the case of Alexander and Byron⁴ no attempt was made to restore the continuity of the aorta; the sac in Shumacker's case⁵ was small and end-to-end anastomosis was possible after resection, while Swan⁶ was obliged to insert a homograft. The surgical problem in aneurysms associated with coarctation is unique in several respects. The extensive collateral circulation makes it possible to occlude the aorta for indefinite periods without producing residuals of anoxia in the spinal cord. Because of the low pressure within them, these aneurysms do not erode adjacent structures

and are consequently more susceptible to complete extirpation.

Definitive treatment of a fusiform aneurysm of the thoracic aorta would require that a new vascular channel be provided. This might be a blood vessel graft or a tubular prosthesis. The feasibility of using arterial grafts has been known since the early experimental work of Carrel.⁷ More recently, Gross and his associates⁸⁻¹⁰ have carried out extensive studies of methods of preservation of these grafts, and have applied the procedures in human cases, using homografts in situations encountered in operations for coarctation of the aorta and tetralogy of Fallot.

The possibility of using a plastic prosthesis to replace a segment of the thoracic aorta was investigated by Hufnagel.¹¹ Tubes of methyl methacrylate (lucite) were placed in 15 dogs. Only two survived to be sacrificed in six months. Of six animals which survived the operation more than two days, five died of hemorrhage from cutting through of the ligatures. These results were similar to those we obtained in a survey study of methods of restoration of the continuity of the aorta.¹² We tried Hufnagel's intubation of the aorta in 11 dogs. There were two deaths on the operating table; one was due to anesthetic difficulties and another from hemorrhage during attempts to place the tube. Two animals died from empyema (penicillin had not been used), one died of distemper, and four died of hemorrhage from slipping or

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FIG. 1

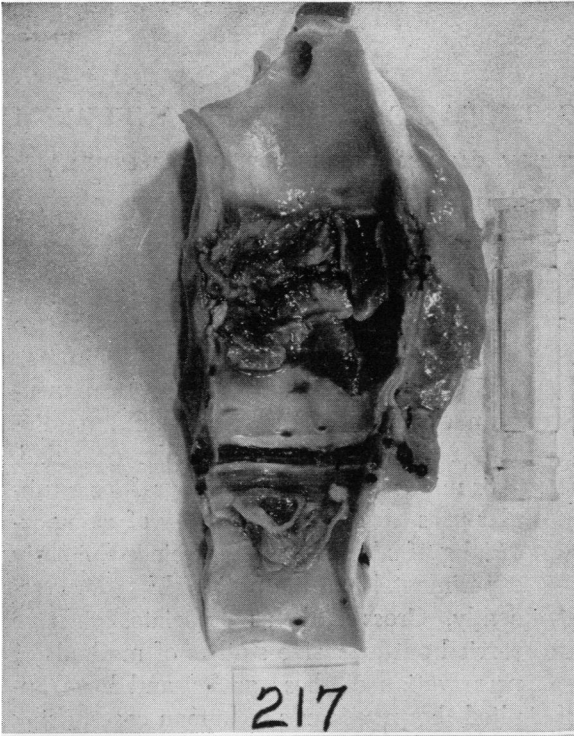
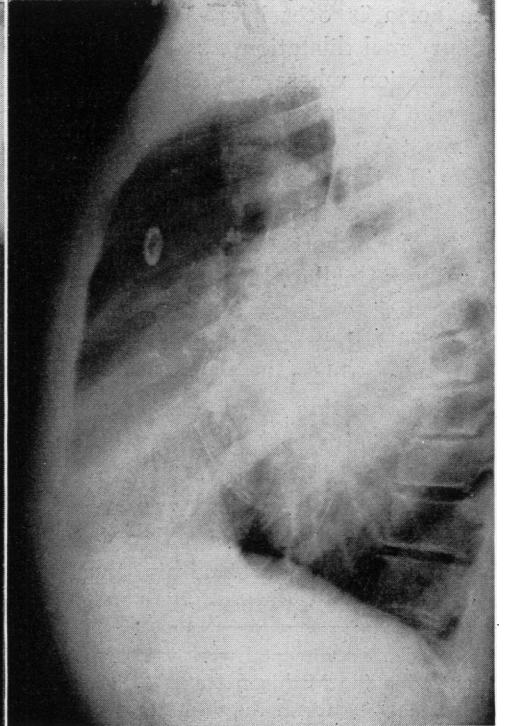
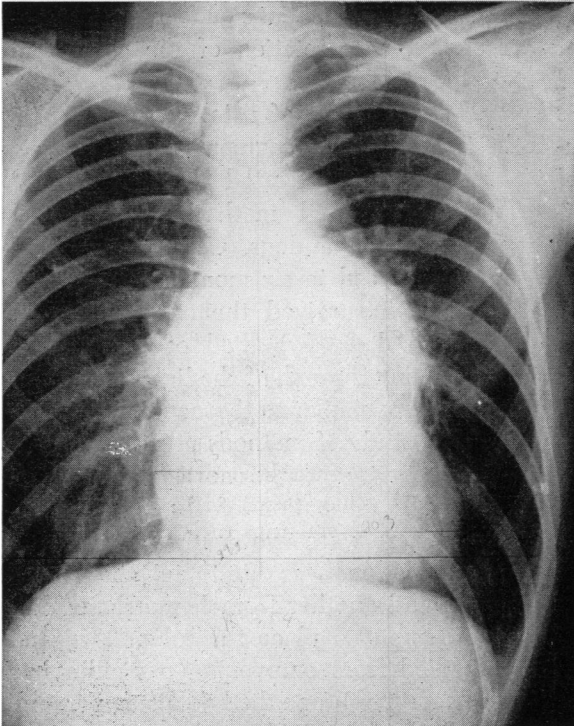
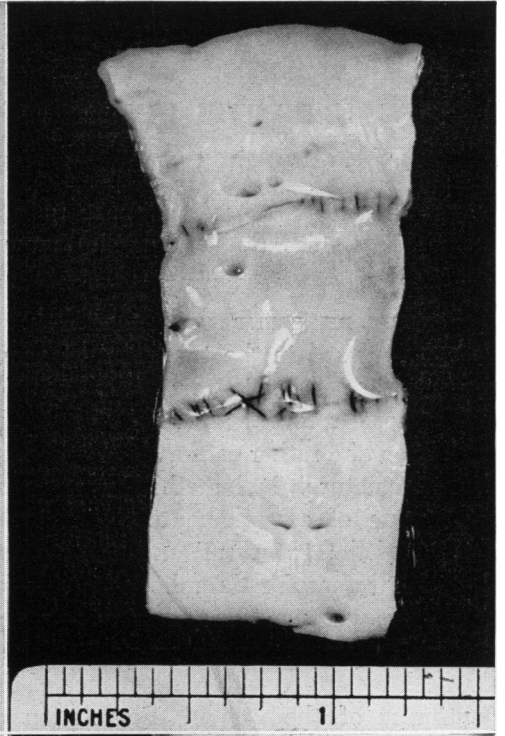


FIG. 2



A

FIG. 3

B

For legend see opposite page.

cutting through of the ligatures (Fig. 1). One animal died on the twenty-ninth day of an undetermined cause and there was no hemorrhage or thrombosis at the site of the tube. On the other hand, homografts were inserted in the thoracic aortas of five animals, with temporary lucite intubation to obviate cord damage as originally suggested by Carrel¹² and more recently demonstrated by Hufnagel.¹³ All three animals which survived the first day lived to be sacrificed at intervals up to 11 months (Fig. 2). One animal died on the first day from hemorrhage from an insecurely ligated intercostal artery, and another died 23 hours after operation from thrombosis in the graft.

As a result of these preliminary trials of the two methods, we did no further work on the problem of permanent intubation, but extended the investigation of the use of different types of homografts and methods of sterilizing and preserving them. And when we were presented with the problem of a human case with a large fusiform aneurysm of the descending thoracic aorta, it was logical that we should elect to attempt to treat it surgically with the use of a homograft.

Case Report.—F. B., a white male of 56 years, came to the Out-Patient Clinic of the Henry Ford Hospital on March 20, 1950. He complained of pain in the right posterior chest. This had begun abruptly in 1943 and had gradually increased in severity. During the previous three weeks he had been obliged to remain in bed because he could not tolerate the discomfort caused by activity. Several injections of opiates were necessary to allow him to get a night's sleep. In nine months,

his weight had decreased from 138 pounds to 112 pounds. The diagnosis of aneurysm of the aorta had been made by roentgen examination a year before. There was a history of luetic infection during World War I. After eight treatments, the Wassermann test had become negative and presumably had remained so.

Physical examination revealed the patient to be emaciated and chronically ill. The chest showed an area of impairment to percussion in the interscapular area. The heart was of normal size and no significant murmurs were heard. The blood pressure was 118/70. The blood serology was as follows: Kline exclusion test, ++++; Kolmer, 10000, Kahn negative; Eagle negative.

The roentgenograms of the chest were of particular interest (Fig. 3). These were described by Dr. H. P. Doub as follows: "In the postero-anterior view, there is evidence of a rather large oval shadow. This would appear to be a portion of the descending aorta. There is some calcification in the wall of this, especially along the left margin. The aortic knob is slightly prominent. The heart shadow is not unusually large. In the lateral view, there is a large rounded shadow of increased density 14.5 cm. in diameter lying just posterior to the heart and apparently attached to the descending aorta. The anterior wall of this is calcified in a fine, linear manner. There is evidence of definite erosion involving the anterior portions of the bodies of the eighth, ninth, and tenth dorsal vertebrae, with rather unusual rounded areas of bone destruction in the eighth and ninth. Impression: This suggests evidence of a large aneurysm involving the descending aorta with marked destruction of the adjacent vertebrae."

The patient was anxious to have surgical relief of the agonizing pain in his back and various methods of treatment were considered. The conservative procedures previously referred to appeared to offer nothing. Accordingly, the patient was admitted to the hospital for "excision of aneurysm of the thoracic aorta and replacement with homograft." Some difficulty was encountered in securing a cadaver graft under aseptic conditions. It was hoped that a specimen could be obtained from a young person who had died in an accident. After several trips to a public morgue, one of us was permitted to take the descending thoracic aorta of a 55-year-old man who had died three weeks after severe burns. It was removed approximately 10 hours after death, the body having been refrigerated during most of this time. After its aseptic removal, it was placed in sterile Tyrode's solution to which had been added penicillin, 100 units per cubic centimeter. It was refrigerated at 5° C. until the next day, when the

FIG. 1.—An example of a common complication of intubation with a lucite prosthesis in the dog: cutting through of the ligatures and death from hemorrhage on the thirty-eighth day.

FIG. 2.—An example of the good functional result from the use of aortic homografts in the dog. Graft was stored for 15 months in Tyrode's solution and penicillin, at 5° C. The animal was sacrificed 11 months after operation. Note the lack of thrombosis about the faultily placed sutures.

FIG. 3.—Postero-anterior and lateral roentgenograms of chest showing large fusiform aneurysm of the descending aorta. The erosion of the dorsal vertebrae is well demonstrated.

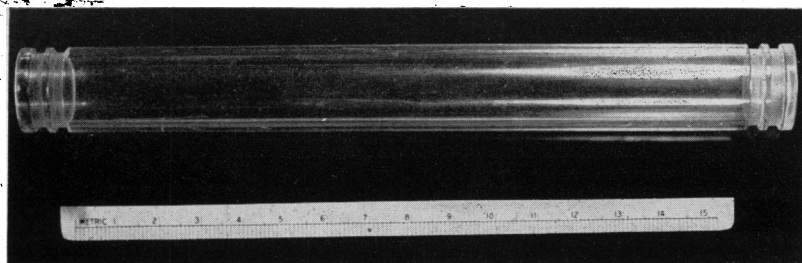


FIG. 4.—Lucite tube used to conduct blood through the graft during the suturing.

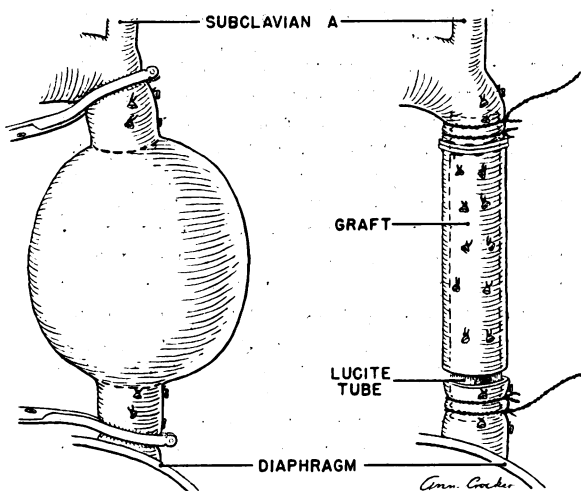


FIG. 5.—Diagram of operative procedure.

specimen was trimmed and 17 intercostal and 3 esophageal vessels were ligated. The specimen was 5 days old when it was used as a graft.

A number of tubes of methyl methacrylate of different bores and lengths were prepared with 2 grooves at each end (Fig. 4). The one which was eventually used measured 18 cm. in length, 1.9 cm. in outside diameter, and 1.5 cm. in inside diameter.

The operation was done on April 2, 1950, under endotracheal cyclopropane anesthesia. A cannula was placed in a saphenous vein for the administration of blood. The chest was entered through the left sixth interspace. Eventually, the fourth through the seventh ribs were transected posterior to their angles. Considerable care was used in cutting the lower ribs because of their proximity to the aneurysm. When adequate exposure was obtained, it was found that the aneurysm was of the fusiform type, about the size of a large grapefruit. There was a short segment of normal-appearing aorta between the subclavian

artery and the aneurysm. Inferiorly, the aneurysm was almost in contact with the diaphragm. There was negligible pulsation of the aneurysm, but it appeared to be filled with liquid blood rather than clot. The lung was very adherent to the aneurysm, and considerable time was spent in dissecting it off. Because of fear of entering the aneurysm at a weak point, a considerable area of visceral pleura was left on it, with the result that there was some troublesome bleeding and leakage of air from the lung parenchyma. Eventually, we were able to pass a tape around the aorta between the subclavian artery and the aneurysm, and with appropriate traction, were able to expose and divide between ligatures approximately six intercostal arteries (Fig. 5). The normal aorta below the aneurysm was similarly mobilized and further intercostal arteries divided.

At this point, non-crushing clamps were applied above and below the aneurysm. Pressure on it resulted in no decrease in size, indicating that few if any functioning intercostal vessels arose from the diseased portion of the artery. The lower clamp was then removed, and the sac emptied of blood. Thereafter, it remained in a collapsed condition; to the palpating hand it suggested a deflated thick tire tube. A second pair of non-crushing clamps were applied to the aorta, one in the region of the subclavian artery and the other near the diaphragm. The aorta was then transected proximally and distally as close to the aneurysm as possible. At this point it was noted that contrary to predictions, the arterial wall immediately adjacent to the dilatation was entirely devoid of gross pathology, and it was obvious that suturing could be carried out with safety. The lucite tube, over which the graft had been placed, was inserted into the upper end of the aorta and made fast with 2 ligatures of hand-braided silk. A similar procedure was carried out below. Both clamps were released, with a resultant brisk flow of blood through the tube. The period of occlusion had been 24 minutes, at least 15 minutes longer than

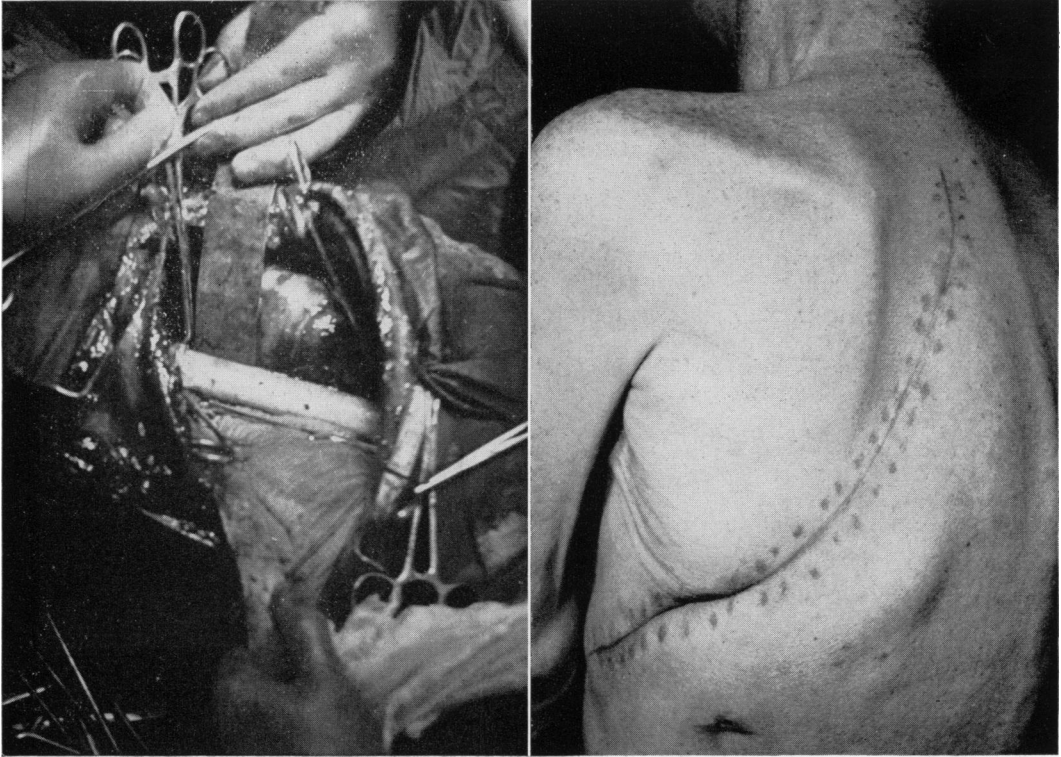


FIG. 6.—Photograph of operation taken during the placement of the upper suture line. The white tubular structure is the graft, and behind this and the retractor is the aneurysm.
FIG. 7.—The healed thoracotomy incision.

had been anticipated from experience in the laboratory. The chief difficulty was that although the tube fit the distal aorta perfectly, the proximal aortic lumen was considerably larger than the tube and it was difficult to place the ligatures properly. The suturing was begun at the proximal end of the graft, but at this point it appeared that the cuff of the aorta available for suturing was dangerously narrow, and it was thought to be advisable to re-apply the upper ligatures. Accordingly, the clamps were placed on the aorta, the 2 proximal ligatures were removed, and with great difficulty the tube was again fixed in place, this time with more margin for suturing. The fixation of the lower end of the tube interfered with its manipulation with the result that there was a second period of occlusion of about 15 minutes. Thereafter, the 2 suture lines were completed without incident (Fig. 6). The suture material was 5-0 Deknatel braided silk on atraumatic needles. A continuous suture of the horizontal mattress type was used; this was interrupted by stay sutures several times. When the lower suture line was two-thirds finished, the clamps were re-

applied, the 4 ligatures removed, and the lucite tube extracted with some difficulty by pressing it downward to displace the diaphragm. The suture line was hurriedly finished and the lower clamp was removed. The only bleeding was from an intercostal vessel on the graft which had not been ligated. The proximal clamp was then slowly released over a period of 5 minutes. The systolic blood pressure which had dropped to 70 mm. Hg. during the suturing in spite of blood replacement had risen to 140 mm. Hg. with the last clamping of the aorta. When this clamp was removed, there was a precipitous fall of pressure to 40 mm. Hg. More blood was introduced rapidly with the result that the blood pressure gradually rose to 80/40.

When it was evident that the graft was functioning satisfactorily, we turned our attention to the aneurysm itself. The question of resection of the sac was considered, but it was deemed advisable to leave it *in situ*. The two clamps which had occluded each end of the aneurysm during the grafting procedure were replaced by running sutures. The aneurysm showed no tendency to fill with blood. Penicillin and streptomycin were

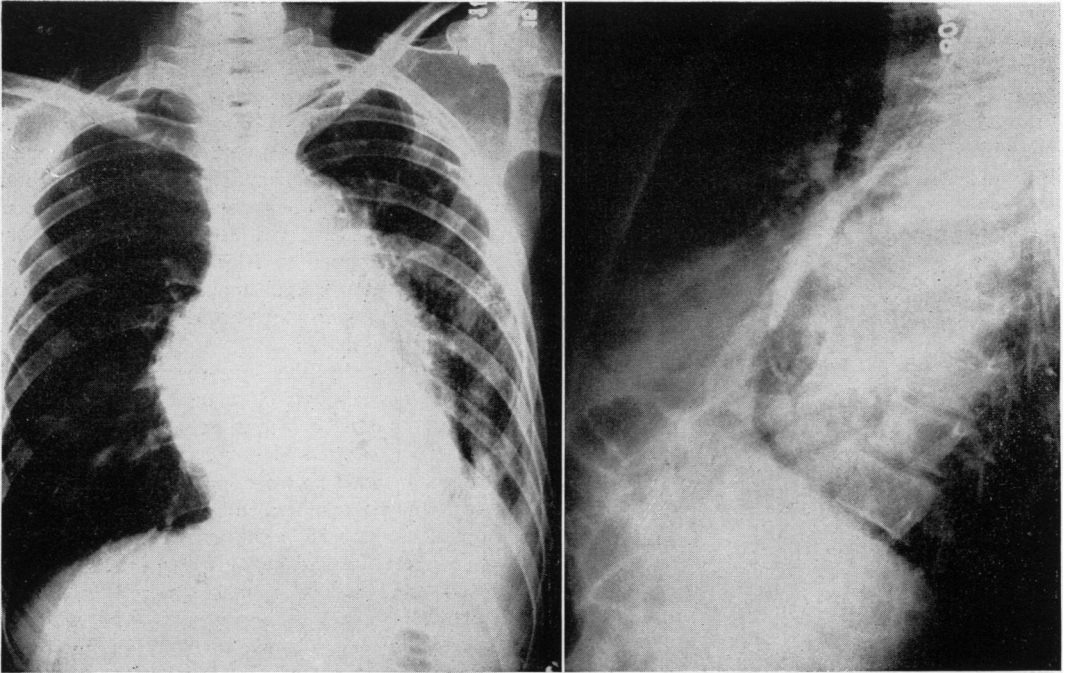


FIG. 8.—Roentgenograms taken six weeks after operation. The outline of the graft may be seen in the postero-anterior view, and the aneurysm is faintly visible in the lateral view.

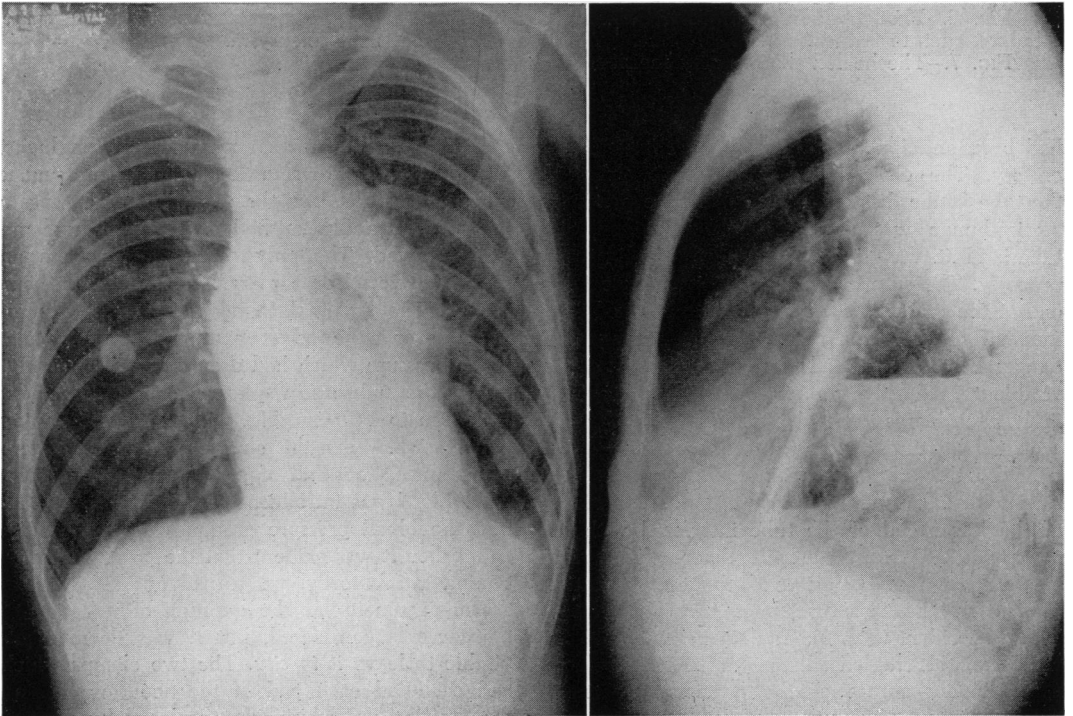


FIG. 9.—Roentgenograms taken 11 weeks after operation, showing a fluid level in the mediastinum. Note the fractures of the fifth and sixth ribs on the left, the result of coughing.

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placed in the pleural cavity, an intercostal drainage catheter was inserted, and the chest was closed. The patient was returned to his room in good condition with a blood pressure of 100/60.

On the first postoperative day, the patient was cheerful and grateful for the relief of the pain in his back. It was obvious that there had been some



FIG. 10.—Autopsy specimen, with a view of the lungs and mediastinal structures from behind. In the center is the remains of the anterior wall of the aneurysm. The arrow points to the intact upper suture line. The lower suture line was disrupted during the removal of the specimen, and a probe has been passed into the abscess cavity, which contained no blood.

cord damage from the operative procedure. There was marked weakness in the lower extremities. He could flex both knees slightly and could dorsiflex the left foot, but not the right. There was hypoaesthesia to pinprick below the L 1 level. He did not urinate spontaneously and an indwelling catheter was placed in the bladder. A cystometrogram on the eighth day was characteristic of a "neurogenic bladder." The highest temperature on the sixth postoperative day was 99.4°. Thereafter, he developed a daily elevation of temperature to 100°-101° which was more or less constant until 36 hours before discharge from the hospital. There was prompt partial recovery from the residuals of cord anemia. The incision was well-healed (Fig. 7). He was able to walk with assistance; the urinary catheter was removed at the end of three weeks. Roentgenograms of the chest showed satis-

factory expansion of the left lung and contraction of the size of the aneurysm, and the aortic graft was visible (Fig. 8). One disturbing factor was the continued presence of an unexplained elevated leukocyte count. On the seventeenth postoperative day, there were 17,900 leukocytes per cu. mm., 83 per cent polymorphonuclears. On the thirtieth day, there were 20,000 leukocytes, 92 per cent polymorphonuclears, and just before discharge, the count had dropped to 16,250, 80 per cent polymorphonuclears. Large amounts of penicillin and streptomycin were administered throughout the postoperative period.

On May 15, the forty-second postoperative day, he was discharged to his home in Canada. For a period of 6 weeks he appeared to make satisfactory progress. He was walking about the yard, had a good appetite and was gaining weight. We were disappointed to re-admit him to the hospital on June 28, 1950, in poor condition. One week before, he had begun to expectorate bloody material and had been unable to rest because of coughing. His legs became weak and he could not get out of bed. Roentgenograms of the chest showed air and a fluid level in the mediastinum, in an area corresponding to the old aneurysm which had been left *in situ* (Fig. 9). It was planned to carry out mediastinotomy for drainage of the abscess the next morning, but he expired quietly during the night, without external evidence of hemorrhage.

The gross postmortem findings were described as follows:

"Upon opening the thoracic cavity the heart lies in the midposition in the anterior mediastinum and appears entirely normal. The right lung is free and the left lung is densely adherent to the thoracic wall over its entire pleural surface. Upon efforts to open the pericardial sac this cavity is seen to be completely obliterated by the presence of fairly well formed fibrinous adhesions between the epicardium and the pericardium. The thoracic and abdominal viscera are removed in block and described from this view.

"A large saccular aneurysm measuring 15 x 10 cm. is found in the midportion of the posterior mediastinum. The posterior wall of this aneurysmal dilatation is completely absent and the boundary of the material found within the aneurysm is that of the thoracic vertebrae numbers 6-10 inclusive and the adjacent posterior pleura. This aneurysmal cavity is estimated to have contained approximately 100-200 cc. of semifluid yellow pus. The inside of the aneurysm anteriorly, which represents the anterior boundary of the abscessed cavity, is covered with plaques of calcific material and probably inspissated pus. The inferior bound-

FIG. 11

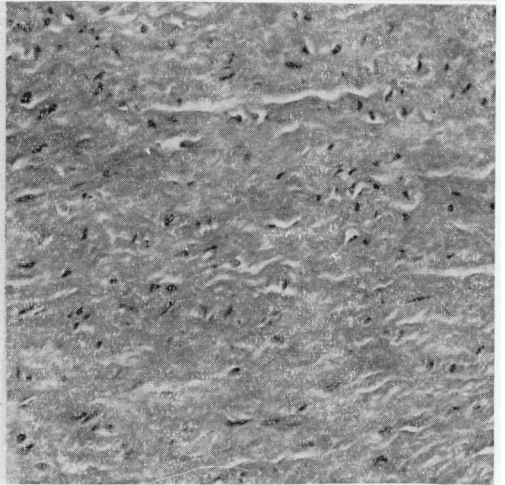
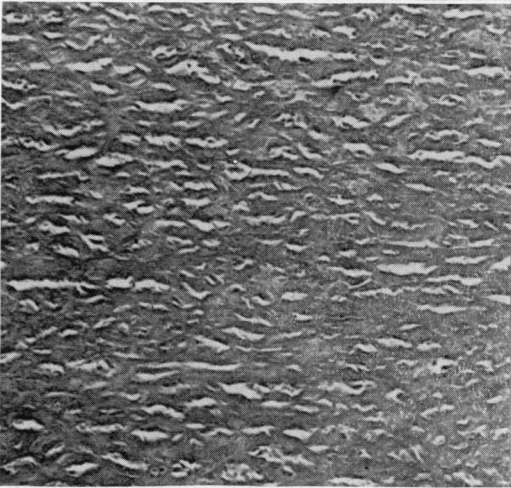
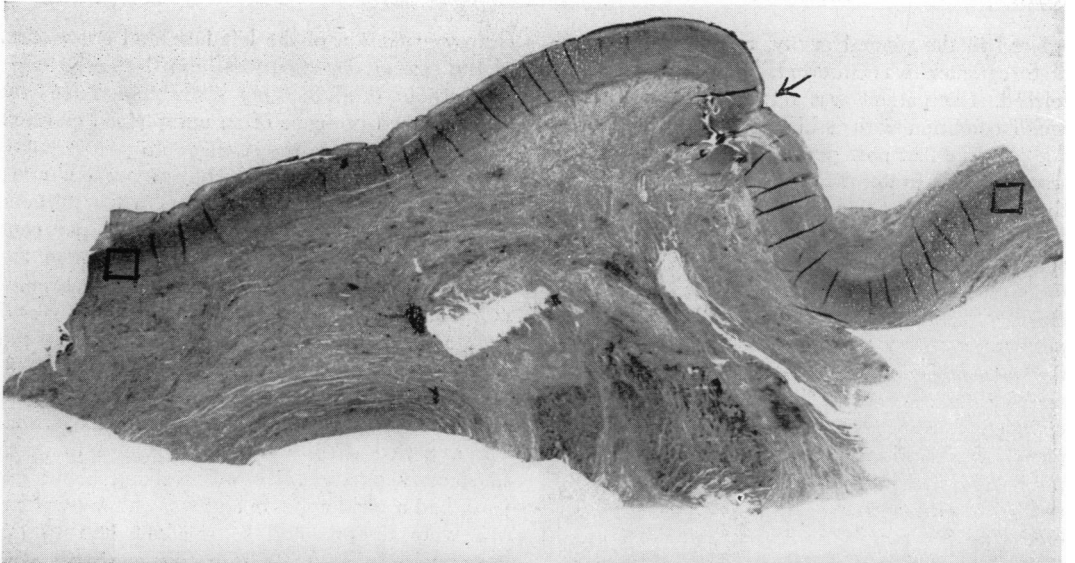


FIG. 12

For legend see opposite page.

ary of the abscessed cavity is identified as the end of the aneurysm and beyond this the abscess has formed a serpiginous tract which extends approximately 6 cm. below the old puckered end of the aneurysm. A lateral branch extends to the left and this comes close to the area of anastomosis of the new segment of aorta. Upon opening the aorta from the arch downward the superior point of anastomosis of the new segment of aorta is found to be approximately 4 cm. beyond the left subclavian vessel and to show good adherence at all points; the black silk sutures identify distinctly the area of anastomosis, no other characteristic scarring being seen in this area, so that almost completely anatomic repair has apparently taken place. This aorta is not remarkable beyond this point except for the presence of four hemorrhagic appearing protuberances which are apparently covered with fine capillaries and are dense to palpation. The segment of inserted aorta measures approximately 14 cm. and at the point of inferior anastomosis the sutures have been broken apart by the trauma of the postmortem procedure. Nevertheless in this area is found a mass of freshly clotted blood, estimated to be not over 5 days old, which has spread medially from a pre-mortem rupture of the anastomotic site and become continuous with the abscessed cavity. This appearance suggests that the medial tract of the abscessed cavity at first approximated itself to the aorta, weakened the area of suturing, and hemorrhage resulted with the clot formation. No blood is seen in any place in a quantity sufficient to account for any cardiac embarrassment or cause of death in this patient" (Fig. 10).

A careful study was made of the microscopic pathology of the aortic tissue of the graft and of the host (Fig. 11 and 12). We are indebted to Dr. Ira Gore for the following description of the photomicrographs:

"There is firm fibrous union of the aortic graft at the proximal anastomosis. The distal one presents partial separation of the edges but there is an abundance of adventitial scarring sufficient to account for the absence of hemorrhage. The endothelial surface of the graft is smooth, unaltered by thrombosis. The media of the graft is

characterized by a loss of the normal cellularity but persistence of elastica. Ghost-like outlines of the degenerated muscle fibers are present save in small foci where cytologic features seem to have been better preserved. The adventitia surrounding the length of the graft has been considerably thickened by reactive fibrosis.

"Segments of the patient's own aorta present stigmata of vascular syphilis; viz., medial destruction with fibrous replacement, conspicuous medial vascularization with perivascular inflammatory cuffs and underlying adventitial scarring."

It is evident that the cause of death was the mediastinal abscess which formed in the old aneurysm. The cause of this may have been necrosis of the wall after it was removed from the circulation, especially that part of the wall presenting in the left side of the chest which was further devascularized by the dissection of the adherent lung from it. We believe that if this part of the wall had been cut away, thus draining the sac into the left pleural cavity, the fatal outcome might have been avoided. It is probable that any vessels connecting with the aneurysm could have been closed by suture from within.

The autopsy confirmed our impression that all of the patient's intercostal arteries had been excluded from the circulation, either by ligature and division or by the by-passing of the aneurysm. It was wondered if all or part of the neurologic damage could have been due to interference with the blood supply of the spinal branches of the posterior rami of the intercostal arteries. To investigate this problem, we operated on ten dogs and ligated and divided every intercostal artery which could be identified.¹⁵ One of these animals showed paralysis of the hind limbs which persisted until sacrifice of the animal two days later, and one showed a very transient paralysis. Eight animals showed no evidence of disturbance of spinal cord function. As a result of this work, it appears that the patient's temporary partial paraplegia was due to the excessively long periods of clamping of the aorta.

FIG. 11.—Microscopic study of the graft (left) and host aorta (right) at the proximal suture line (arrow). Magnification of upper section: 3.5 x. Lower left, section of media of graft, x 110. Note the absence of smooth muscle nuclei. Lower right, section of the media of the host aorta, x 110. H and E stain.

FIG. 12.—Same section of the proximal suture line stained with elastica-trichrome stain. The dark color of the media (elastic tissue) is almost identical in host (right) and graft (left).

SUMMARY

It was found to be feasible to by-pass a large fusiform aneurysm of the thoracic aorta by the use of a homograft. The death of the patient three months later was due to sepsis occurring in the old aneurysm sac which had been left *in situ*. Partial removal of the sac might have obviated this complication.

In experiments on dogs, it was found that ligation of all of the intercostal arteries was rarely the cause of spinal cord ischemia.

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BOOK REVIEW

THE CONTRIBUTION OF SURGERY TO PREVENTIVE MEDICINE. Sir James Learmonth. Oxford University Press. London, New York, Toronto, 1951, 54 pages, \$2.50.

This compact volume comprises the University of London Heath Clark Lectures of 1949 delivered at the London School of Hygiene and Tropical Medicine. It is a philosophic exercise dealing with current mutual problems of preventive medicine and surgery.

Learmonth's aim has not been to detail the discoveries and technics surgery has contributed

but to denote what an ideal surgical outlook might contribute. With characteristic fluency he uses pertinent references to medical history and world literature. After defining the common goal for surgery and preventive medicine "the multiplying of human enjoyments and mitigation of human sufferings," he urges, as a common approach to biological problems, Bacon's eight essential scientific qualities. The interpretation and discussion of these qualities afford the author range for stimulating speculation on surgery as an integral part of the past and future of preventive medicine.

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