SHUNT GRAFTS*

A METHOD OF REPLACING SEGMENTS OF THE AORTA AND LARGE VESSELS
WITHOUT INTERRUPTING THE CIRCULATION

HOWARD MAHORNER, M.D., AND ROWENA SPENCER, M.D.

NEW ORLEANS, LOUISIANA

The modern treatment of aneurysms is closely associated with the problem of replacing segments of large arteries. A trend toward this method of attack is definite, and this procedure, with variations, promises to be more successful than previous attempts in the surgical management of this condition.

The technical problem of replacing a portion of the aorta with a graft is a difficult one. Blalock and Park,5 Schafer and Hardin,16 and Clatworthy and Varco8 have reported a high incidence of paraplegia in dogs when the thoracic aorta was cross clamped. Schafer and Hardin, and Clatworthy and Varco, instituted the use of temporary polythene tubes as a conveyor for the arterial flow during the period the aorta was occluded and the graft sutured in place. Schafer and Hardin found that in 13 dogs in which they attempted to replace segments of the thoracic aorta by direct clamping, death supervened in six and paralysis of the hindquarter in an additional six, a paraplegia presumably due to insufficient supply of blood to the spinal cord. On the other hand, using temporary polythene tube shunts, they were able to accomplish the operation without paraplegia. Whether these observations in animals indicate a danger of a similar complication in a human still awaits definite proof.

No conclusive evidence has been reported to show whether the aorta can be cross clamped at the arch or upper thoracic region sufficiently long to replace an excised segment with a graft, though presumably the closer to the heart occlusion of the aorta is contemplated the greater the possibility of back pressure on the heart with danger of failure, and the greater the probability of neurologic complications.

Other pertinent data are the following: It is true that the aorta usually may be completely occluded to excise a coartation, but here the collaterals are so well developed that spinal cord damage usually does not occur. However, at least two cases of paraplegia have been reported following cross clamping of the aorta for excision of a coartation.3, 4 Gross13 and Swan17 and Brock6 have successfully employed homologous grafts to bridge defects after excising aneurysms associated with coarctation.

Dubost,11, 12 DeBakey and Cooley,9, 10 Brock,7 and Julian14 have successfully removed a segment of the lower abdominal aorta and replaced it by a homologous graft. The aorta was cross-clamped during the operations. No neurologic complications were encountered by them. After performing an operation for aneurysm of the lower abdominal aorta, occlusion of the aorta below the renal vessels for one hour and 45 minutes, while a segment was excised and a graft replaced, we observed paraplegia in
a poor risk, badly debilitated patient. The patient died the day following operation. DeBakey and Cooley have successfully removed a large aneurysm of the lower thoracic and upper abdominal aorta. The aorta was crossed clamped for one hour and 45 minutes and a graft was placed. No neurologic nor renal complications followed. This is the highest segment of the aorta so far to be replaced except in coarctations.

Lam and Aram,15 using a lucite tube as a temporary conduit during placement of a graft for an aneurysm of the mid-thoracic aorta, clamped the aorta for two separate periods of 24 and 15 minutes; this patient had a resultant paraplegia which disappeared after some weeks. When the aorta is clamped at a high level, in addition to the possibility of neurologic sequelae, there is a tremendous back pressure on the heart. Bahnson reported clamping the aortic arch for lateral excision of an aneurysm, and reconstruction of the lumen of the distal aortic arch. After seven minutes, because of hypotension and irregularity of the heart, the clamp had to be removed. In another case for lateral excision of an aneurysm sac just distal to the left subclavian, he cross clamped the aorta for 20 minutes. The patient did not have complications. The lumen of the aorta was restored. A segment of the aorta was not excised, and no graft was employed. Schaefer attempted to replace the aortic arch in a patient for aneurysm. He used temporary polythene shunts. The patient died one hour after operation.

At these higher levels in the aorta it would seem preferable to maintain circulation through to the distal aorta at all times during excision of a segment, provided this can be accomplished without technical disadvantages.

Herein is reported a method of accomplishing this. It consists in applying homologous shunt grafts around a segment of the aorta to be removed. Two end to side anastomoses are made, using partially occluding clamps (Potts or Beck). The circulation is partially maintained through the original vessel at all times while the graft is being applied. Then the intervening segment is removed.
EXPERIMENTAL WORK

Experimental work on 30 dogs is reported here. In the first eight dogs the polythene tube was used as a shunt during the time the segment of the aorta was replaced. Five died within 24 hours after the operation, from hemorrhage and shock. The graft could be sutured in place with ease, but difficulty was encountered when the polythene tube was removed. Closing the small incision in the aorta was much more difficult than making the anastomoses; in many instances exsanguinating hemorrhage resulted before the opening could be sutured. The closure of the longitudinal incision in the aorta constricted the lumen, and the expanding force of the blood pressure had a tendency to tear the wall of the vessel. The anastomoses to the graft, however, held without difficulty. Of the three dogs that survived the procedure, one died at 42 days with a thrombosed graft, having developed paraplegia two days before death; one was sacrificed at 18 months with a very good graft, and one is still living at 18 months.

A new technical method was used in replacing segments of the thoracic aorta in the remaining 22 dogs.

Instead of clamping entirely across the aorta while a segment was excised and replaced with a graft, the thoracic aorta was partially occluded with Potts or Beck clamps while two anastomoses were made, suturing each end of the graft to the side of the aorta. There was then no need for a polythene shunt, since the blood continued to flow through part of the aorta. After the anastomoses were completed, first the distal clamp was removed, then the proximal one. After integrity of the suture lines was determined, the intervening segment was removed.

In some dogs after the arterial shunt was placed, the intervening segment was simply ligated in order to determine the feasibility
Fig. 5. Case 1. This demonstrates the position of the clamps at the first operation. The aneurysm can be seen to involve the innominate and subclavian and carotid arteries.

of placing a shunt around an aneurysm and ligating it to isolate it from the circulation. In other animals, ligatures were placed around either the proximal or the distal end of the segment of aorta between the two anastomoses. In another group the intervening segment was ligated and excised; then retraction of the cut ends of the aorta straightened out the shunt. When the by-passed segment was ligated and left in
Fig. 6. Case 1. At the second operation the ends of the aneurysm were ligated and divided and the sac was removed, leaving the circulation through the intact graft.

place, in some cases the ligature cut into the vessel; the lumen fenestrated and became re-established.

None of these animals developed neurologic complications even though it was estimated the Beck and Potts clamp occluded over 50 per cent of the lumen of the aorta at the time the anastomoses were being made. Of the 22 dogs in which double end-to-side anastomoses were made, seven died within 24 hours, again of hemorrhage and shock. An additional six died
within seven days, and three more within three weeks of operation; one of the last three had a good graft, whereas all the others had bled either from the suture line, or from rupture of the graft or of the ligated aorta. Three were sacrificed at three, six, and 13 months, one with a thrombosed graft and two with large calcified plaques in the grafts. Three dogs are still living at nine, ten, and 12 months after operation.

CLINICAL USE

We would like to be able to report the use of this method for the replacement of a segment of the upper thoracic aorta involved by aneurysm, but we have not encountered such a case during the period of these studies. We have used the principle in one human, admittedly where, though it worked successfully, it may not have been absolutely necessary to keep the blood flowing through the involved segment while the graft was being placed.

CASE REPORT

Case 1. A. R., a 50-year-old white man (Charity Hospital No. L52-71916), was admitted to the medical service on August 8, 1952, because of pain and numbness of the tips of the right 4th and 5th fingers and the ulnar aspect of the right forearm and progressive loss of strength in the right hand for 9 months. He had been treated for neuritis by his physician without relief of symptoms. He had gonorrhea treated at 25 years of age, but was not aware of having contracted syphilis.

Physical examination on admission revealed a well developed and well nourished white male in apparent good health. Blood pressure in the right arm was 140/88; in the left arm, 134/90. There was fullness and exaggerated pulsation in the right supraclavicular fossa. Neurologic examination revealed weakness of grip in the right hand with hypesthesia of the ulnar surface of the right forearm. The remainder of the examination revealed no other abnormalities. Laboratory investigation showed normal routine blood count, urine and electrocardiogram; Kolmer and Kahn tests were positive in the blood and spinal fluid, with a paretic colloidal gold curve in the spinal fluid. Venous pressure was 932 mm. saline in the left arm, 124 in the right arm, and 130 in the left leg. Routine chest roentgenograms showed a homogeneous density in the right apex consistent with an aneurysm of the innominate artery.

Angiocardiogram with diodrast injected into the left antecubital vein showed obstruction to the left innominate vein at the level of the superior vena cava. Repeat angiocardio gram through the right antecubital vein visualized the heart and great vessels. The aorta and innominate artery were thought to be greatly dilated. The patient was discharged to the surgery clinic on September 17, 1952, after having received 23 million units of penicillin.

He was admitted to the surgery service on October 8, 1952, at which time examination revealed weakness of grip of the right hand, with hypesthesia of the ulnar surface of the right forearm and atrophy of the thenar and hypothenar eminences and interossei. The circumference of the right forearm measured 2 cm. less than that of the left.

The patient was operated upon on October 10, 1952. A semi-circular incision was made beginning above and parallel to the outer end of the clavicle, extending along the margin of the sternum, and curving laterally over the third rib toward the axilla. The pectoral muscles were divided, the inner half of the clavicle, the right half of the manubrium, and portions of the first and second ribs were resected, and two intercostal bundles.
SHUNT GRAFTS

were ligated and divided. The right pleural space was opened. A large fusiform aneurysm was found to involve the innominate artery, the first portion of the subclavian, and the origin of the common carotid. The superior vena cava lay directly anterior to the aneurysm, and the left innominate vein stretched across the surface of the aneurysm, producing partial obstruction of the vein.

Because of dense adhesions to surrounding structures, particularly the trachea, it seemed dangerous to persist in the attempt to free the posterior surface of the aneurysm. A four-day old quick-frozen arterial graft was sutured to the base of the innominate artery and to the common carotid above the aneurysm with two end-to-side anastomoses, using a Potts and a Beck aorta clamp to partially occlude the flow of blood while the anastomoses were being made. The innominate and carotid ends of the aneurysm were ligated, leaving the graft to conduct blood from the innominate to the carotid. Pulsations in the graft and in the carotid and temporal arteries were good. The subclavian artery distal to the aneurysm was ligated. The wound was closed in layers with 0.2 black silk after infusing the lung and aspirating the pleural cavity.

The postoperative course was afebrile and was complicated only by a pleural fluid which responded to thoracentesis. There was absence of the right radial pulse, and the right hand and forearm were cool for a few days, but there was never evidence of alarming circulatory deficiency.

The patient was discharged on the 25th postoperative day and followed in the out-patient clinic. The pain in the arm and hand disappeared and muscular function improved with the aid of physical therapy.

Angiogram on December 15, 1952, with diodrast injected into the right antecubital vein, showed excellent visualization of the cardiac chambers and great vessels. The dilated segment of the innominate artery and a small segment of the subclavian artery were visualized, but the aneurysm was not definitely delineated.

Pulsation, however, became increasingly more evident in the segregated aneurysmal sac. On December 30, 1952, an attempt was made to wire the aneurysm percutaneously. Very little wire could be thread into it although bright red blood under low pressure pulsed from the aneurysm needle.

On April 15, 1953, penicillin therapy was re-instituted because of evidence of continued activity of the luetic infection.

The patient was again admitted to the hospital on May 16, 1953, for excision of the aneurysm. Physical examination showed continued atrophy of the intrinsic muscles of the right hand. The carotid graft could not be palpated with certainty, but the aneurysm pulsed vigorously.

At surgery on May 21, 1953, the old incision was re-opened and the aneurysm exposed. The graft was found to have rotated over the aneurysm so as to lie anterior to it. The graft was soft and pliable, with strong pulsations. By sharp and blunt dissection the aneurysm was carefully freed. The phrenic nerve was isolated and preserved, but the recurrent nerve was not identified. The subclavian end of the aneurysm was divided between Bainbridge clamps and the distal end of the subclavian closed with a continuous mattress suture of 4-0 black silk. The carotid end was divided proximal to the entrance of the graft and similarly closed. The innominate end of the aneurysm was divided obliquely, distal to the graft, and closed with two layers of 4-0 black silk. It was noted that the graft was now too long, since it did not have to course across the surface of the aneurysm. Circulation to the carotid was adequate, as evidenced by a strong temporal pulse. The wound was closed in layers with 2-0 black silk after aspirating the right pleural cavity and infating the lung.

The postoperative course was complicated by the appearance, 24 hours postoperatively, of a partial left hemiplegia. There were two possible causes for this complication: first, cerebral ischemia during surgery, and second, kinking of the graft. During the operation, strips of Penrose drainage tubing were placed around the vessels to control possible hemorrhage; traction on these strips aided in the dissection of the aneurysm, but temporarily occluded the circulation, as evidenced by disappearance of carotid and temporal pulses. The weakness was noted after the patient was elevated in bed with a pillow behind his head, which caused a rather acute flexion of the neck. The paresis began to disappear within a few hours after the patient was placed flat in bed with his head turned to the side opposite the graft. He was discharged from the hospital on June 3, 1953, the wound having healed without incident and the paresis barely noticeable.

The patient was followed in the clinic since his discharge from the hospital. His only complaint is hoarseness, present since operation. Indirect laryngoscopy showed abductor paralysis of the right vocal cord. The postoperative hemiparesis completely disappeared. He has returned to work as a building engineer, and continues to do well.

SUMMARY

A method is described for replacing segments of large arteries by shunt grafts while the circulation is partially maintained
through the main vessel. The intervening segment may be excised and the graft then permanently carries the circulation. This was done experimentally in dogs and the principle has been employed in one human. A shunt graft carried the circulation to the common carotid, and a huge aneurysm involving the innominate and its bifurcation was excised. The method will probably have its greatest field of usefulness in replacing segments of the upper thoracic aorta and aortic arch.

BIBLIOGRAPHY


8 Clatworthy, H. W., and R. L. Varco: A Small Bore Polythene Shunt to Prevent Mechan-