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ARTERIAL HOMOGRAFTS

II. Resection of Thoracic Aortic Aneurysm Using a Stored Human Arterial Transplant

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THE PROBLEM of bridging a large gap in a major artery has long been one of importance to both the civilian and the military surgeon. Peirce and his co-workers [1] have recently reintroduced interest in the use of stored arterial homografts for this purpose. In their preliminary studies on dogs these workers demonstrated that such homografts, if taken aseptically within the first few hours after death of the donor animal, could be stored in a standard refrigerator when placed in buffered salt solution containing 10 per cent dog serum. When transplanted into a recipient animal after storage up to fifty days, these homografts would function successfully as a conduit of blood for periods longer than a year. A high percentage of successful "takes" could be obtained by careful anastomotic technics. In addition, it was shown by tissue culture methods that "viable" cells persisted in the stored vessels up to forty days. Gross [2] has subsequently used the stored human arterial homograft in the repair of coarctation of the aorta.

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1. Peirce, E. C., II; Gross, R. E.; Bill, A. H., Jr., and Merrill, K., Jr.: Tissue-Culture Evaluation of the Viability of Blood Vessels Stored by Refrigeration, Ann. Surg. **129**:333 (March) 1949. Gross, R. E.; Bill, A. H., Jr., and Peirce, E. C., II: Methods for Preservation and Transplantation of Arterial Grafts: Observations on Arterial Grafts in Dogs; Report of Transplantation of Preserved Arterial Grafts in 9 Human Cases, Surg., Gynec. & Obst. **88**:689 (June) 1949.

2. Gross, R. E.: Blood Vessel Grafts, read before a meeting of the Surgery Study Section, National Institutes of Health, United States Public Health Service (Jan. 21) 1950.

In a previous communication,[3] we reported experimental data suggesting that the storage solution can be extremely simple, consisting solely of Ringer's solution to which has been added 10 per cent by volume of homogenous plasma. Vessels stored in this solution in a common refrigerator for as long as six months have been transplanted into recipient animals with consistent success and have remained functional for periods exceeding one year. Careful pathologic study indicated that in the case of short storage grafts, i. e., grafts stored less than forty days, there was often some survival of smooth muscle. In both short storage and long storage grafts the elastic tissue of the media survived relatively intact for many months. All other tissue layers disappeared and were replaced by layers which grew in from the host. It was our feeling that the longer the storage the earlier and more prominent was the appearance of mild degenerative changes in the new vessel. These changes consist of fibrillary destruction of elastic tissue and diffuse calcification of the media and the new intima. In general, therefore, it would appear that grafts stored for less than forty days are preferable, although the evidence on this point is not entirely clearcut, and vessels stored for much longer periods give satisfactory short term results.

Before the use of the homogenous arterial graft may become widespread, it will be necessary to solve the many practical problems related to the establishment of an artery bank. Obtaining suitable vessels is often difficult. The donor should be young and should have been in previous good health before succumbing to a rapid, noninfectious fatal episode. The graft must be taken aseptically within six hours of death. This combination of requirements is exceedingly difficult to fulfil, even in a large city. With current storage methods, the vessel is probably best used within a period of forty days, thus requiring a rather rapid turnover of vessels. Ways and means must be sought to develop an effective method of preservation for long periods. Rapid freezing technics and fixation with formaldehyde or alcohol are currently being investigated in several laboratories in this country.

The limitations on the use of homogenous arterial grafts have not yet been clearly delineated, particularly in regard to the size and length of the transplant. What is the smallest artery into which a graft may be successfully transplanted? Miller and his co-workers [4] have reported good function in the femoral artery of dogs. One of us (H. S.) has had gratifying results with the femoral artery in human patients. It would

3. Swan, H.; Robertson, H. T., and Johnson, M. E.: Arterial Homografts: The Fate of Preserved Aortic Grafts in the Dog, Surg., Gynec. & Obst. **90**:568 (May) 1950.

4. Miller, H. H.; Callow, A. D., and Welch, C. S.: The Fate of the Arterial Graft in Small Arteries, Bull. Am. Coll. Surgeons **35**:55 (Jan.) 1950.

seem probable that even smaller vessels, such as internal carotid, popliteal, or superior mesenteric arteries, could be successfully bridged. What is the maximum length of graft which can safely be used? This question has not been thoroughly studied experimentally. Gross [5] has used human aortic grafts from 2 to 6 cm. in length. In one of our patients with a femoral transplant, the segment was 7 cm. long. In the case reported in this communication, the aortic segment was 8 cm. long. Perhaps even longer segments might be successful. On the other hand, it is possible that there is a relation between the size of the vessel and the greatest usable length of graft.

CASE REPORT

W. M., a 16 year old school boy, was first admitted to the surgical service of the Colorado General Hospital on May 15, 1949, with a complaint of exertional dyspnea and easy fatigability of five years' duration. At the age of 11, on a routine physical examination, it was discovered that he had congenital heart disease, probably coarctation of the aorta. Three weeks later he became seriously ill and was hospitalized and treated for subacute bacterial endocarditis with sulfonamide drugs and with malarial fever therapy. After a two month stay, he was sufficiently improved to continue treatment on an outpatient basis, but a relapse occurred several months later, requiring rehospitalization. At this time he was treated with penicillin, which was continued for a period of several months. Since that time the patient had noticed dyspnea with mild exertion and occasional palpitation. In addition, dizzy spells with occasional fainting had occurred about twice a month for the past year. There had never been cyanosis or peripheral edema. Physical examination revealed a well developed but thin, intense white boy in no distress. The pulse rate was 130 and the blood pressure 175 systolic and 105 diastolic in both arms. No blood pressure or arterial pulsations could be obtained in the legs. The heart was not enlarged to percussion. A grade II blowing systolic murmur could be heard in the second interspace on each side of the sternum. In addition, there was a lower-pitched grade I systolic murmur over the apex. The aortic second sound was greater than the pulmonic second sound, although both were snapping in character. No cyanosis or edema of the extremities was evident. The day after admission, simultaneous direct arterial pressure recordings were made in the brachial and femoral arteries on the left. The brachial pressure was 175 systolic and 100 diastolic and the femoral pressure 93 systolic and 82 diastolic. Attempted intravenous angiocardiographic examination was unsatisfactory. The patient was discharged, to be readmitted during the school vacation for repair of his coarctation. Operation was performed on June 28, 1949. An adult type of coarctation, 2 cm. below the origin of the left subclavian artery, was found. Below the coarctation was an aneurysm of the aorta about 2 inches (5 cm.) in length and 2 inches in diameter, irregular in shape with areas of calcification within its walls. After mobilization of the various structures it did not appear to be safe to attempt resection of the coarcted area only with anastomosis between the aneurysm and the descending aorta above. Accordingly, a decision was made to resect the coarctation and the aneurysm a distance of about 2½ inches (6 cm.) and to bridge the gap with an arterial homograft. We had available an aorta which had been obtained aseptically three hours after the death

5. Gross, R. E.: Personal communication to the authors.

of a 14 year old boy who had been killed in an automobile accident fifty-two days previously. This had been stored in Ringer's plasma in the blood bank refrigerator. The length of the segment selected was 8 cm. The coarctation and aneurysm were now resected, and the gap was bridged by means of the graft. The proximal anastomosis was difficult because of the friable nature of the aorta at this point and had to be repeated. During the procedure there was one moment of brisk hemorrhage, but this was soon controlled, and the child left the operating table after the nine and one-half hour procedure in apparently good condition. The postoperative course was essentially uneventful with the exception of the behavior of the blood pressure. On the first postoperative day the pressure rose to the neighborhood of 200 systolic and 130 diastolic, where it remained with some fluctuations for a period of eight days. During this period, there were full bounding pulses palpable throughout both lower extremities. The urinary output was normal. Because of our concern with the possible fate of the graft in the face of this hyper-

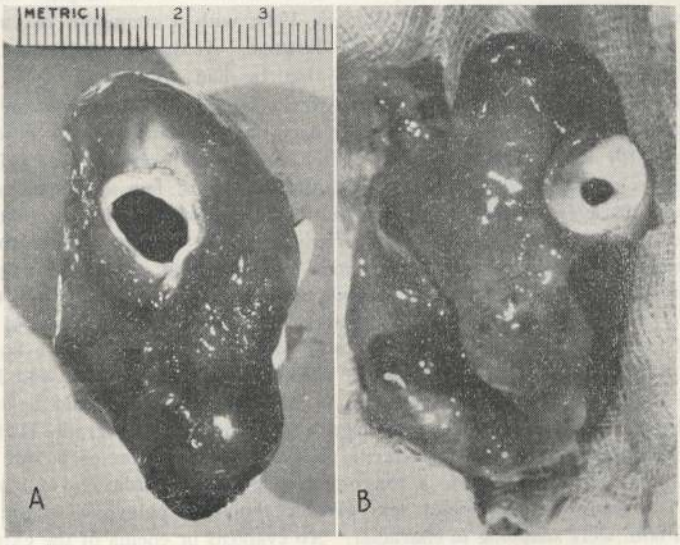

Fig. 1.—*A*, photograph of resected aortic aneurysm as seen from below. *B*, specimen as seen from above. The area of coarctation is just superior to the irregular aneurysm.

tension, the patient was given repeated large doses of tetraethyl ammonium chloride (etamon chloride®), but without noticeable effect on the blood pressure. During the next two weeks the blood pressure showed a slow trend toward normal levels, until at the time of discharge, four weeks after operation, the blood pressure in both arms and in the left leg was 135 systolic and 90 diastolic. In the six months that have elapsed since this operation, the patient has been feeling well, no longer observes exertional dyspnea and has had no further attacks of vertigo or fainting. Good femoral pulsations are still palpable, but the blood pressure in the arms has risen to about 160 systolic and 90 diastolic.

COMMENT

This human arterial homograft which had been in storage for fifty-two days at the time of transplantation has apparently remained

functional for a period of six months. At the present time the heart is normal in size on roentgen ray examination and there is no evidence of calcification appearing in the area of the transplanted vessel. The long term result, of course, cannot be predicted with accuracy.

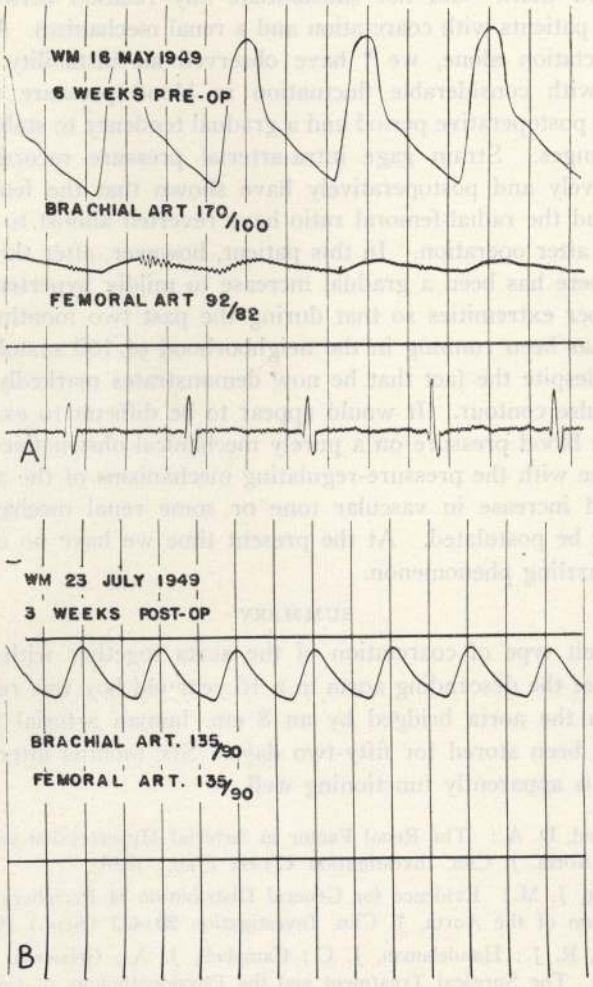

Fig. 2.—In (*A*) simultaneous strain gage intra-arterial pressure tracings of the left brachial and femoral arteries taken six weeks before operation are shown. The low femoral pulse and abnormal contour can be contrasted with the femoral artery tracing (*B*) taken three weeks after operation.

Of particular interest is the behavior of the patient's blood pressure since operation. The whole problem of the etiology of the hypertension

associated with coarctation is currently an unsettled one. Rytand [6] and Steele [7] have suggested that the diastolic hypertension in the lower extremities of many of these patients could not be explained on a mechanical basis and postulated interference with renal blood flow. Studies of renal blood flow, however, by Bing and others [8] and by Barker and Clark [9] did not substantiate any relation between hypertension in patients with coarctation and a renal mechanism. After repair of a coarctation alone, we [10] have observed an instability in several patients, with considerable fluctuation in blood pressure during the immediate postoperative period and a gradual tendency to stabilize within normal ranges. Strain gage intra-arterial pressure recordings taken preoperatively and postoperatively have shown that the femoral pulse contour and the radial-femoral ratio have reverted almost to normal by six weeks after operation. In this patient, however, after this return to normal, there has been a gradual increase to mildly hypertensive levels in the upper extremities so that during the past two months his blood pressure has been running in the neighborhood of 160 systolic and 190 diastolic, despite the fact that he now demonstrates markedly improved femoral pulse contour. It would appear to be difficult to explain these changes in blood pressure on a purely mechanical obstructive basis, and interference with the pressure-regulating mechanisms of the aortic arch, generalized increase in vascular tone or some renal mechanism must apparently be postulated. At the present time we have no explanation for this puzzling phenomenon.

SUMMARY

An adult type of coarctation of the aorta together with a mycotic aneurysm of the descending aorta in a 16 year old boy was resected and the gap in the aorta bridged by an 8 cm. human arterial homograft, which had been stored for fifty-two days. Six months after operation the vessel is apparently functioning well.

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6. Rytand, D. A.: The Renal Factor in Arterial Hypertension with Coarctation of the Aorta, J. Clin. Investigation **17**:391 (Jan.) 1938.

7. Steele, J. M.: Evidence for General Distribution of Peripheral Resistance in Coarctation of the Aorta, J. Clin. Investigation **20**:473 (Sept.) 1941.

8. Bing, R. J.; Handelsman, J. C.; Campbell, J. A.; Griswold, H. E., and Blalock, A.: The Surgical Treatment and the Physiopathology of Coarctation of the Aorta, Ann. Surg. **128**:803 (Oct.) 1948.

9. Barker, H. G., and Clark, J. K.: Renal Function in Coarctation of the Aorta, Bull. Am. Coll. Surgeons **35**:53 (Jan.) 1950.

10. Grover, R. F.; Swan, H., and Maaske, C. A.: Intra-Arterial Pressures Before and After Aortic Resection for Coarctation in Man, Federation Proc. **9**:53 (March) 1950.

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