Replacement of Large Veins with Free Inverted Segments of Small Bowel:

Autografts of Submucosal Membrane in Dogs and Clinical Use

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REPLACEMENT of major veins, specifically the superior vena cava and inferior vena cava, is an infrequent surgical problem, but has not yet been satisfactorily solved.[1, 6] Homografts have been unsuccessful.[3] Teflon and Dacron prostheses function for short periods; thrombosis occurs after 3 to 6 months.[2, 4, 5] No attempt, to our knowledge, has been made to replace a segment of vein with small bowel; yet, autografts of small bowel are readily available in almost any length. This paper reports experience with experimental replacement of segments of the superior and inferior vena cava with small bowel autografts in dogs, and the use of a small bowel autograft to replace the inferior vena cava in man.

Materials and Methods

Fifty-nine mongrel dogs of both sexes ranging from 15 to 20 ks. were used. All were fed a normal laboratory diet and given water ad lib. Recommendations of the Institute of Laboratory Animal Resources (NAS-NRC) were followed. All vascular operations were carried out under intravenous pentobarbital anesthesia under sterile conditions and with 7-0 vascular silk sutures. Patency of graft was determined by weekly cavograms and by autopsy in dogs dying or sacrificed.

Group I. In ten dogs, segments of inferior or superior vena cava up to 10 cm. in length were replaced by free grafts of jejunum used as a simple tube, not inverted.

Group II. In nine dogs, the bowel was inverted, and mucosal villi were scraped off with scissors. The tube was then restored to its original position with the villous surface inside and the graft was sutured in place.

Group III. In 40 dogs the bowel was inverted, as one might turn a coat sleeve inside out, prior to use as a free graft. In eight the tube of bowel was used after simple inversion. In 18 the mucosa was removed from the inverted segment by abrasion with cotton gauze. In 14, a graft composed only of submucosa was prepared by vigorous abrasion of the serosal and mucosal surface with gauze. This procedure removed the serosa, muscularis and mucosa (Fig. 1). All dogs were given heparin postoperatively for 14 days.

To investigate possible infection by intestinal organisms three normal segments of jejunum were cultured. All grew E. coli, Alpha Streptococcus, and Staphylococcus species, etc. These organisms were sensitive to neomycin, chloramphenicol and

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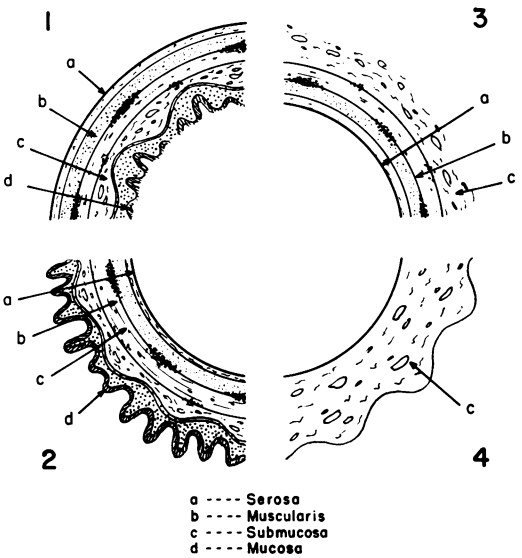

FIG. 1. Schematic drawing of the various grafts employed. 1) Unsuccessful graft, villi abraded. 2) Successful graft, simple inversion. 3) Successful graft, inversion, mucosa abraded. 4) Successful graft, submucosa only.

streptomycin. In all dogs, the bowel segments removed were irrigated with 2% neomycin in saline for at least 5 minutes prior to grafting. A culture was taken of the washed segment just before grafting. Blood cultures were taken on each of the first three postoperative days in all animals. In ten dogs of Group III, reoperation was performed to obtain cultures 7 days after the first operation.

Results

Groups I and II were all failures. The lumen of the bowel was occluded by thrombus within 72 hours and at autopsy acute and chronic inflammation was found in the vein and in the graft.

In Group III all grafts remained patent. Four of these dogs have been followed for 14 months with weekly cavograms, and no narrowing of the lumen has been seen in any of the inverted autografts.

Histologic studies of sacrificed animals showed preservation of all layers present initially in the graft. In those cases where mucosa or serosa was not removed, focal coagulation necrosis of that layer occurred. There was *complete endothelialization* of all inverted grafts in Group III. Except for foreign body reactions about sutures, no reaction was found in inverted segments except for a few isolated inflammatory cells (Fig. 2, 3).

Positive cultures were obtained on 18 of 59 grafts after neomycin irrigation and prior to insertion of the graft. E. coli was the organism in each case. In the ten dogs of Group III operated upon one week after grafting, there was *no evidence of infection* and cultures taken from the outward facing mucosa were negative. Serial blood cultures taken on the first three postoperative days were negative in all 59 dogs.

Discussion

Initially, it was assumed that a vascular pedicle would be necessary for survival of grated segments. This pedicle was preserved in some preliminary inferior vena cava grafts (not reported in this paper) but technical difficulties were created when the superior vena cava was replaced. In the initial replacement of the superior vena cava, anastomosis was attempted between the internal mammary vessels and those of the vascular pedicle of the bowel. Though the anastomosis failed, this did not lead to failure of the autograft. Therefore, free autografts were used.

It was found, not unexpectedly, that when the mucosa faced the blood stream, all grafts failed (Groups I, II). Grafts were therefore inverted to present the smooth surface of the serosa to the blood stream. *Mucosa* was removed for several reasons: to reduce bacterial contamination, to avoid the theoretical possibility (later proved) of mucocele production, and to reduce the total amount of tissue to be nourished as a living free graft. Further reduction in the thickness of the graft, down to submucosa only, represented the logical end point of this consideration. In addition, this maneuver facilitates handling and suturing of the

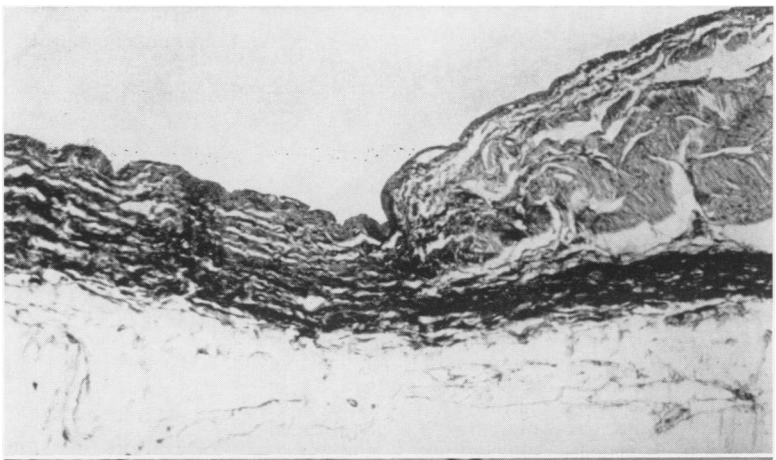

FIG. 2. Junction between the vein and the graft of submucosa 12 months after operation. The darker material is collagen, and the lighter muscle. Masson's Trichrome stain with red filter.

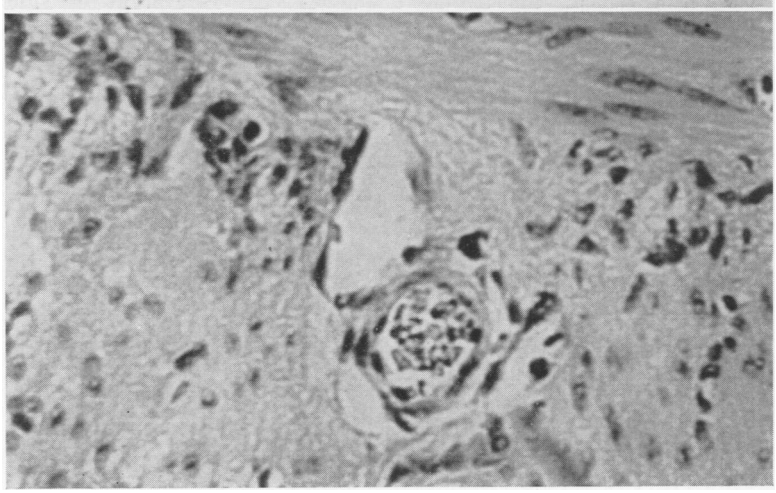

FIG. 3. Viable muscularis of jejunum which has been used as a venous graft for 10 months.

graft, which then corresponds in thickness and diameter to the canine vena cava. There has been no difference in results using inverted segments with or without mucosa, muscularis and serosa, all variations being successful. Submucosa of the jejunum is a thin but strong membrane, easily capable of holding sutures and containing the venous blood pressure. The surprising survival of these free segments of intestinal elements is probably due to diffusion of oxygen from venous blood. Further studies on this phenomenon are in progress.

Despite the presence of coliform organisms in 18 of 59 grafts after neomycin irrigation, negative blood cultures and absence of clinical infection indicate that, in the dog at least, infection is not a problem.

Diameter of Graft

In man the jejunum is appreciably larger than the vena cava, and this may be expected to complicate the anastomosis. Some preliminary observations have been made on this problem in dogs. In eight dogs the inferior vena cava was replaced by a 5-cm. segment of jejunum which was twice the diameter of the cava. Fibrin was deposited along the internal surface of these grafts, leading to narrowing in some and thrombosis in others. In ten additional dogs, a longitudinal segment was removed from jejunum of large initial diameter. The segment was then reconstructed with everting sutures to create a smaller diameter. This attempt was also unsatisfactory, as thrombosis occurred at the suture line in 3 to 7

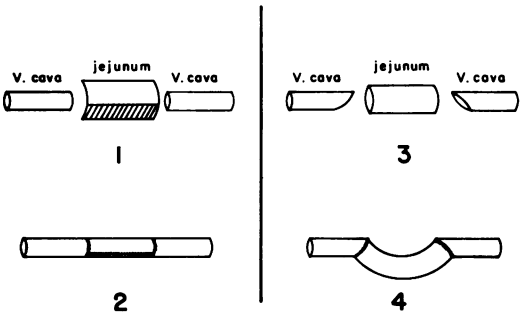

FIG. 4. Surgical technic for equalizing diameter of the vena cava and jejunum. 1) Jejunum longitudinally incised. Shadowed area excised. 2) Jejunum reconstructed and anastomosed to vena cava. 3) Vena cava obliquely sectioned to increase diameter. 4) Completed end to end anastomosis.

days in six of the dogs. Another method was more successful; an *oblique section* was made across the vein to increase the circumference of its free end, a circumference equivalent to that of the bowel segment which was sectioned perpendicularly. In 15 dogs in which this procedure was carried out, serial cavograms and autopsies show no stenosis or occlusion for periods up to 8 months. It is, therefore, believed that the ostia of the conjoined tubes must be approximately of the same diameter (Fig. 4).

Clinical Experience

Recently, with the co-operation of Dr. T. Wada, Professor of Surgery at Yokohama Medical College, the inferior vena cava of a human patient was replaced.

A 46-year-old Japanese man had carcinoma of the right renal pelvis with metastasis to the inferior vena cava. Following excision of the primary lesion by Dr. Wada, the senior author replaced a 15-cm. segment of the inferior vena cava from below the left renal vein to the confluence of the iliac veins, with inverted jejunum taken at a distance of one meter from the ligament of Treitz. The mucosa was partially removed by gauze abrasion. After the operation the patient did well for 10 days and was ambulating well without leg or ankle edema. Unfortunately the primary lesion had induced severe pyelonephritis, and he died of uremia 13 days after operation.

At autopsy, the graft showed no infection or occlusion. The muscularis appeared viable throughout the segment. Some areas of mucosa which had not been abraded showed coagulation necrosis with minimum edema of the underlying muscularis. Death was attributed to widespread metastatic tumor and exacerbation of the chronic pyelonephritis.

Summary

Experiments indicate that inverted free segments of small bowel can be used as autografts in the replacement of segments of major veins in dogs. Grafts in which mucosa, muscularis and serosa were removed by abrasion were successful. The resultant tube is then comprised essentially of submucosa which provides a trellis for complete endothelialization.

When the ostium of the graft is large, the vein can be sectioned obliquely to match the diameters of the apposed ends. Infection has not been a problem with any inverted segment.

A small bowel vein graft has been used successfully for the first time clinically.

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