The Fate of Fresh Autogenous Arterial Grafts Embedded in Submucosal Intestinal Tunnels as Applied to the Bridging of Ureteral Defects*

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RECENT STUDIES IN this laboratory have confirmed and extended the observation that fresh autogenous arterial grafts may be utilized successfully to replace gaps in essential arteries or the aorta.[8] A striking feature of these transplants is the survival, in long-term experiments, of the muscular cells of the media. Stimulated by these results, a systematic investigation has been undertaken of the possibility of replacing portions of other tubular structures, such as the common bile duct, ureter and Fallopian tube, by segments of fresh expendable autogenous arteries.[14, 15] The present report is confined to a study of the morphological and functional behavior of such arterial grafts, buried in submucosal tunnels, as used for the bridging of experimental ureteral defects.

EXPERIMENTAL METHOD

Male mongrel dogs, ranging in weight from 17 to 35 pounds, were utilized. No special preoperative preparation was undertaken. Anesthesia was provided by the intravenous administration of a standard veterinarian solution of nembutal. The peritoneal cavity was entered through a left rectus, muscle-splitting incision. The splenic or carotid artery was utilized as the graft. With the use of the former it was necessary to mobilize the artery from the celiac axis to the hilum, obtaining segments ranging from 6 to 10 cm. in length, and 2 to 3 mm. in width. Its arterial branches were individually ligated. The spleen was left *in situ*. Carotid artery segments varied from 6 to 8 cm. in length and 2.5 to 4.0 mm. in width. In some dogs both common carotid arteries were utilized, with no apparent ill effects. The graft was stripped of loose periadventitial areolar tissue, the edges sharply beveled, and the entire arterial segment kept moist in saline solution until used.

The middle and lower thirds of the left ureter were mobilized, together with the vascular peri-ureteral tissue. A segment of ureter was resected, ranging from 5 to 9 cm. in length. The graft was threaded on a fine polyethylene tube, which was then passed into the proximal ureteral segment and distally toward the uretero-vesical junction. A bulldog clamp was placed to occlude the ureter over the polyethylene tube. Early in the experiment it was noted that the Pott's multi-toothed ductus clamp produced small leaks at the site of its application, and was not suitable.

The anastomosis was done with No. 00000 catgut swedged on curved non-cutting needles at each end.† All layers of the ure-

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TABLE I. *The Fate of Arterial Grafts.*

	Medium	Intima	Media	Conduit	Anastomotic Stricture
Autogenous (Fresh)	Blood	Preserved (?)	Muscle cells preserved	Preserved	No
Homologous (Preserved)	Blood	Replaced from each end of host	Replaced by fibrous tissue	Preserved	No
Autogenous and homologous (Fresh or Preserved)	Urine	?	Replaced by fibrous tissue	No	Yes
Autogenous (Fresh), embedded graft	Urine	Replaced from each end of host	Replaced by fibrous tissue	No	Yes

ter and graft were utilized. These through and through sutures were used as either continuous over and over, or as interrupted sutures at four cardinal points. The polyethylene tube was used as a temporary splint to facilitate accurate suturing, and was removed just before tying the final suture at the distal anastomotic site. Where a leak was noted at the conclusion of the anastomosis, an interrupted suture was taken for reenforcement.

The sigmoid was mobilized adjacent to the graft site. A longitudinal incision was made in the left lateral wall of the sigmoid down to the mucosa, causing it to pout out in a manner analogous to the Fredet-Ramstedt pyloromyotomy. The layers external to the mucosa were undermined. In each instance the sigmoid submucosalmyotomy was made 1 cm. longer at each end than the length of the arterial graft (Fig. IA). The graft, including the proximal and distal ureteric anastomotic sites and 1 cm. on each side, was placed in the trough so created. The graft was buried by oversewing the sigmoid wall, external to the mucosa, with interrupted catgut mattress sutures (Fig. 1B). The anterior taenia was sutured to the lateral peritoneal wall in such a manner as to prevent angulation of the ureter, and to create a drainable pocket apart from the general peritoneal cavity. A Penrose drain, originating in the area of the anastomosis, was brought out through a lateral stab wound (Fig. 1C). Each dog received an infusion of 1,000 ml. 5 per cent glucose in water intravenously during the operation, and 300,000 units of penicillin and 0.5 Gm. of streptomycin daily for one week postoperatively. The drain was removed on the fifth postoperative day.

Eight dogs in Series A were operated upon in this manner. In Series B, comprising five dogs, a polyethylene T tube was used to splint the anastomosis and to divert the urinary stream temporarily. This tube was inserted into a ureterostomy proximal to the proximal anastomosis and threaded toward the uretero-vesical junction distally. The long arm of the tube was brought out through a lateral stab wound. In this series carotid artery was used for the graft in order to have a larger circumference for anastomosis.

Series C comprised six dogs, three with splenic artery grafts and three with carotid artery grafts. The technic is that described for Series A, supplemented by a nephrostomy as the initial step in the operative procedure.

Postoperative intravenous urography, or contrast visualization via a catheter, was obtained at about 14-day intervals.

EXPERIMENTAL RESULTS

A total of 19 dogs was utilized for these observations. The early deaths were due to technical pitfalls, eventuating in anastomotic leakage and generalized peritonitis. There was one anesthesia overdose and one death due to postoperative pneumonia. Eight dogs remained suitable for study of the graft. Four of Series A survived and two each from Series B and C. These dogs were sacrificed between the 20th and the 103rd postoperative days. This report is concerned

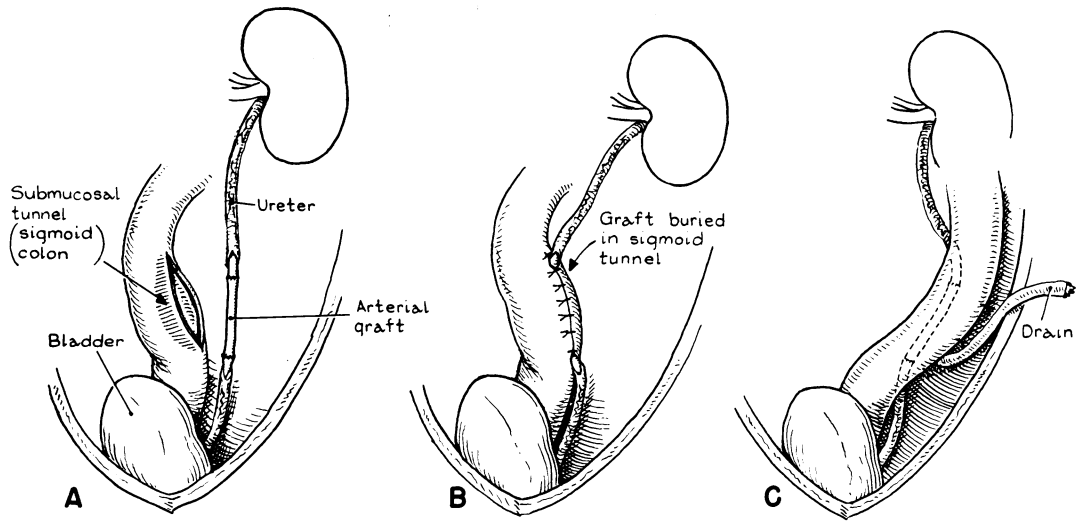

FIG. 1. The operative technic is diagrammatically illustrated.

with the fate of the graft. The detailed urologic observations referable to ureteral and renal changes are the subject of a separate communication.[14] However, obstructive uropathy was noted in all dogs due to anastomotic strictures at the uretero-arterial junction. This was noted as early as the tenth postoperative day; dogs were permitted to survive in order to study the late fate of the graft.

The observations made are considered in two parts. The fate of grafts studied for the first 90 days constitute the early observations, and two dogs studied for longer periods are considered under later results. The earlier results are discussed first.

In the absence of infection, all grafts maintained the gross morphologic character of an artery (Fig. 2B). The tunnel walls were intimately attached to the graft, and the graft had to be dissected out of the wall of the sigmoid (Fig. 2A). The length and diameter of the arterial graft corresponded to the measurements taken at the time of the embedding. There was no shrinkage. The lumen between the anastomotic sites remained open in all cases and preserved its conduit capacity (Fig. 2C). At the anastomotic sites stricturization compromised the lumen 60 to 70 per cent. The intima was smooth and showed no ulceration. The graft appeared somewhat rigid. There was no aneurysmal dilatation. Some dogs survived a small anastomotic leak with the formation of a perianastomotic abscess. Here the graft either could not be identified, or it had shrunk and shriveled to a fibrous cord (Fig. 3.)

The uninfected grafts were studied histologically with hematoxylin and eosin, van Giesson elastic tissue, and Masson trichrome stains. The results were uniform (Fig. 4). The intimal endothelium had been replaced by transitional cell uro-epithelium (Fig. 4B). Van Giesson stains showed preservation of the internal elastic lamina with minimal fibrillation and thinning. The external elastic lamina exhibited some reduplication and fragmentation. No muscle cells could be identified in the media. This layer was completely replaced by fibrous tissue of about the same thickness as the muscular media of the original splenic artery. This layer contained no blood vessels. There was no luminal narrowing. Bony metaplasia and calcification were not observed. There was minimal mononuclear cell infiltration. Giant

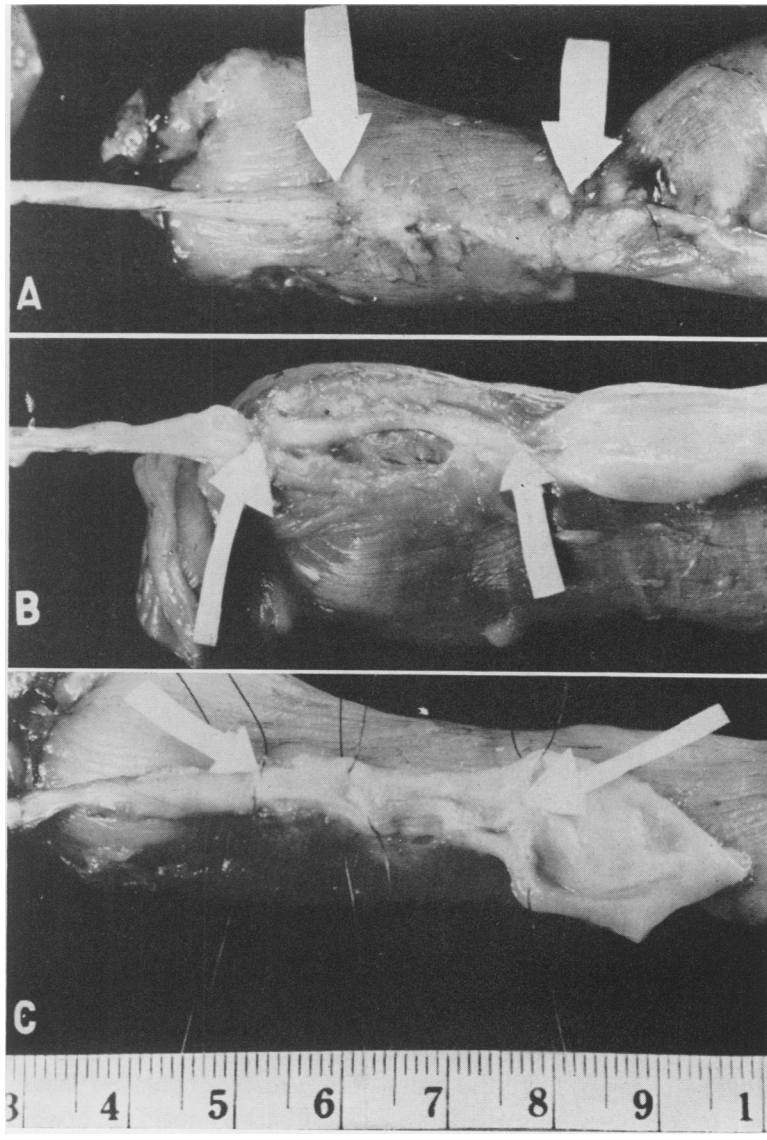

FIG. 2. (A) The bowel wall intimately embraces the graft which lies well buried in the depth of the submucosal-muscular trough. Proximal ureteral dilatation is pronounced. (B) The graft has been dissected away from the wall and floor of the tunnel. (C) Guy sutures hold the graft open. The lumen is preserved and the intima appears smooth and glistening. There is no ulceration or calcification.

cells were seen only about the catgut sutures.

The grafts underwent marked changes after 90 days. Although still firmly embedded in the intestinal trough, the gross morphologic appearance was that of a firm cord no longer distinctly recognizable as an artery (Fig. 5A). Microscopic studies revealed fibrosis of all layers of the graft wall, with progressive obliteration of the lumen. There was increasing fragmentation of the elastic laminae, and complete fibrous tissue replacement of the muscular coat. There was minimum cellular reaction (Fig. 5B).

DISCUSSION

Experimental and clinical studies have established the usefulness and practicability of autogenous and homologous arterial

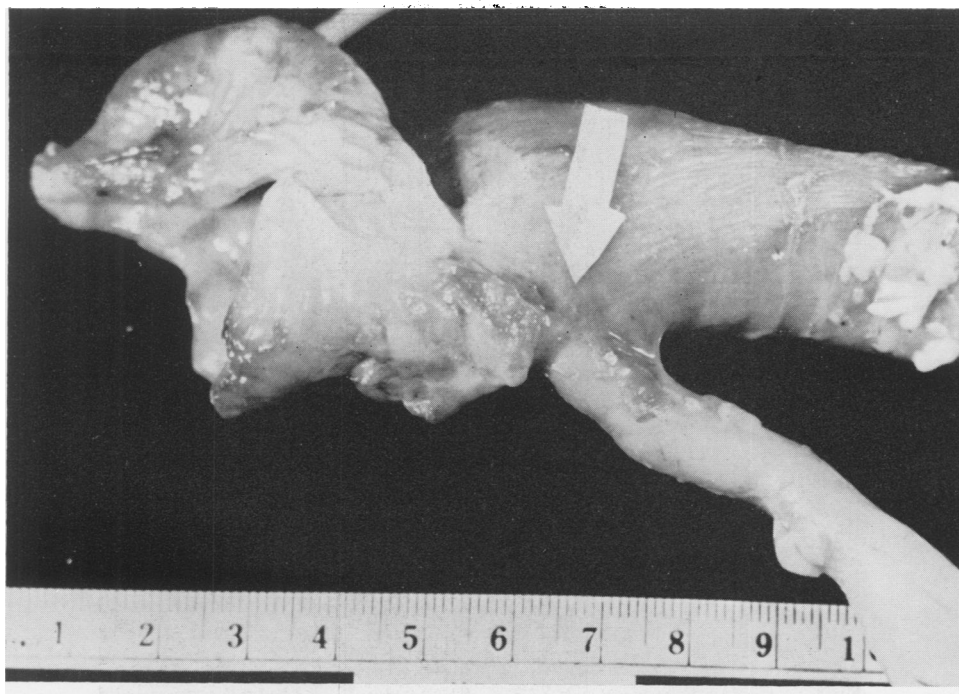

FIG. 3. Infection resulted in a graft which was not recognizable, and the entire area was retracted and fore-shortened. There is marked proximal obstructive uropathy.

grafts for the bridging of arterial defects. This has been accomplished in the abdominal and thoracic aorta, as well as in the muscular vessels of the extremities.[4, 5, 9] Autogenous blood vessel grafts preserve the muscle cells of the media. Homologous grafts, when used to bridge arterial defects, act as satisfactory conduits but exhibit marked histological changes. Here the intima is replaced by cellular ingrowth from the host tissue at each end of the graft, and the media is replaced by fibrous tissue. These grafts derive their principal vascular supply from vessels penetrating the adventitia.[10, 11]

Experiences with the use of vascular grafts to bridge tubular defects, conducting fluids other than blood, have been reported as disappointing, even with modern technics. Numerous authors have reported the failure of the arterial and venous grafts to function as a substitute for the common bile duct. In these substitutions the vascular epithelium had been destroyed and replaced by fibrous granulation tissue, resulting in contraction and narrowing of the graft, going on to complete fibrosis and loss of identifiability of that structure.[7, 12]

Published experiences with the experimental use of blood vessels in the urinary medium have been sparse. Boari's experience in 1900 has no detailed documentation.[1] McClure is quoted as having attempted carotid artery and jugular vein grafts to the ureter in 1907. These results have not been published.[13] In 1938 Calef reported the use of common iliac artery to bridge a ureteral defect in six dogs, followed for two to 56 days. The results were unsatisfactory, and resulted in luminal obliteration and fibrosis of the entire graft wall.[3] Rosenberg and Dahlen in 1953 reported the use of femoral veins to bridge end-to-end ureteral defects in four dogs followed for 21 to 56 days. They reported luminal obliteration with fibrous replacement of the graft wall.[13] Hardin in 1954 replaced ureteral segments with

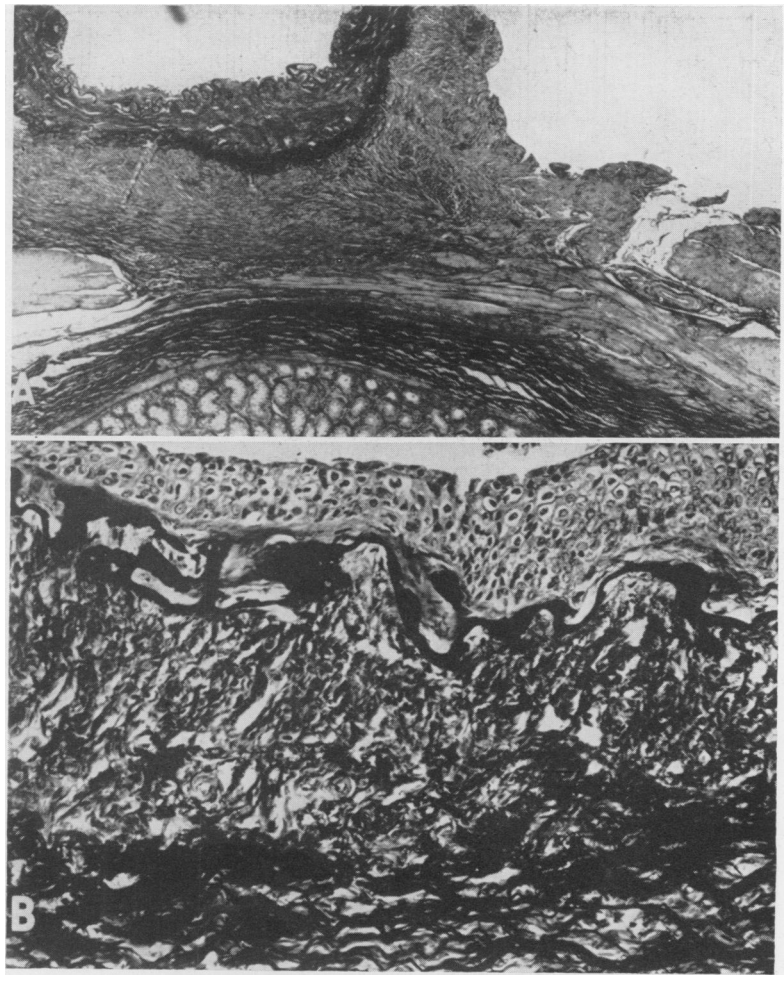

FIG. 4. (A) The bowel wall has been split down to the submucosa and the muscular coat has retracted. The adventitia of the graft is adherent to the bowel wall by dense fibrous tissue. The lumen of the graft is patent (Masson stain, original x40). (B) A high power view of the intima shows that the endothelium above the internal elastic membrane has been completely replaced by transitional cell epithelium of the urinary type. The arterial wall between the elastic layers exhibits replacement of muscle cells by fibrous tissue (Elastica van Giesson stain, original x250).

femoral artery and vein in ten dogs, followed for 21 to 58 days. There was complete degeneration of the graft.[6] In none of these experiences did the lumen of the graft remain open, nor was there any gross or microscopic preservation of the blood vessel wall. Bonanome and Begani used lyophilized arterial grafts splinted over polyethylene tubes to replace segments of ureter. The grafted site was wrapped in omentum. Although this graft acted as a temporary strut, there was marked cellular infiltration into the wall of the artery, with accompanying calcification, ossification and obstructive uropathy. They attribute these results to the failure of the loose, mobile splint to provide adequate urinary diversion.[2]

Embedding the graft in the submucosal muscular tunnel of the colon does not alter the long term fate of the graft. Fibrosis, shrinkage and stricturization occur as in previous experiments in which no attempt has been made to give the graft an exogenous blood supply. Only in the earlier results do

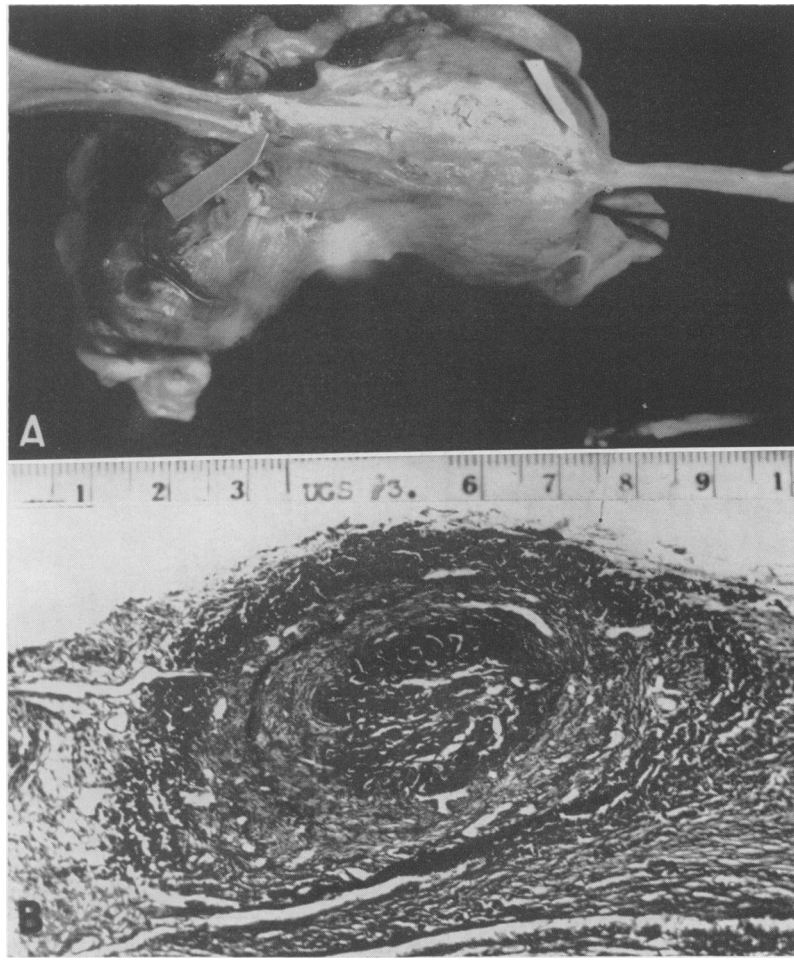

FIG. 5. (A) The graft has narrowed considerably and is no longer recognizable as an artery. (B) Progressive fibrosis of the wall and obliteration of the lumen after 105 days (Elastica van Giesson stain, original x320).

the histologic features and satisfactory luminal preservation of these autogenous grafts parallel the behavior of homologous grafts in the vascular medium. Table I summarizes these facts.

There are specific problems in ureterovascular replacement that are unique, and they may play some rôle in determining the fate of the graft. Unlike vascular anastomoses, minor anastomotic leaks cannot be controlled with Gelfoam or simple pressure. Leaks that do not produce a generalized peritonitis and death result in a marked peri-ureteral and peri-anastomotic inflammatory reaction. This is invariably associated with marked cicatrization and narrowing of the anastomotic site and dissolution of the graft. The lower pressure gradient in the urinary system contrasts markedly with systemic arterial pressure. The rôle of colonic peristalsis in disrupting the anastomosis buried within the intestinal wall remains to be evaluated, as does the valve-like compressive action of the distended colon upon the intramurally buried ureter.[16-18] The purposeful embedding of the graft in such a vascular zone would seem to provide a much more adequate source of external vascularization

of the graft than would chance adhesions or omental wrapping. These grafts must be completely vascularized from without. Whatever the rôle of vascularization from the intraluminal blood may be in the nutrition of arterial grafts, it, of course, plays no rôle as far as the urinary stream is concerned.

The problem of the anastomotic stricture is challenging, and in our hands has not been solved by temporary urinary diversion.

SUMMARY

1. Autogenous arterial grafts were used to bridge ureteral defects in dogs.

2. An exogenous source of blood supply to the graft was sought by embedding the grafted segment in a mucosal intestinal trough.

3. The fate of such fresh autogenous arterial grafts exposed to a urinary medium, for periods up to 90 days, is comparable to that of fresh or preserved arterial homografts in a vascular medium. After 90 days the graft undergoes progressive fibrosis and luminal obliteration.

4. The use of arterial grafts for bridging long ureteral defects is not practical.

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