The Modified Bovine Heterograft in Vascular Access for Chronic Hemodialysis

JOHN M. JOHNSON, M.D., M. RAY KENOYER, M.D., KENNETH E. JOHNSON, M.D., DANIEL J. POTTER, M.D., GEORGE M. NICKAS, M.D., TROY WILLIAMS, M.D.

The results of 100 modified bovine heterografts constructed in 93 patients for subcutaneous arteriovenous fistulas for chronic hemodialysis have been reviewed. Fifty-seven patients had the bovine heterograft inserted as the primary method of vascular access. Twenty-eight patients had complications consisting of graft thrombosis and stenosis, graft infection, and hemorrhage that required additional surgical procedures. Three patients with diabetes mellitus developed ischemia of the hand. Fourteen patients have died but none of the deaths could be attributable to the use of the bovine heterograft. In our experience the modified bovine heterograft has enjoyed a higher patient acceptance as compared to other methods of vascular access for hemodialysis. The chief advantage of the bovine graft has been the ability to use the graft in any patient as a means of immediate dialysis.

From the Department of Surgery and Department of Medicine, Good Samaritan Hospital and Maricopa County General Hospital, Phoenix, Arizona

THE CAPABILITY of repeated access to the peripheral circulation is a critical factor in the successful management of patients with end-stage renal disease who undergo chronic hemodialysis. The silastic arteriovenous cannula was a major breakthrough in this regard.[6] Frequency of thrombosis and infection, however, have prompted the use of subcutaneous arteriovenous fistulas.[1] We have reported our experience with 25 patients in whom the modified bovine heterograft was used in the construction of subcutaneous arteriovenous fistulas.[3] Through the continued use of the modified heterograft, certain peculiarities of this prosthesis have become aparent, and it is now possible to make specific recommendations for its use in the patient with end-stage renal disease.

Materials and Methods

From May 1973 through March 1975, 93 patients at Good Samaritan Hospital Kidney Center and Maricopa County General Hospital Dialysis Unit, Phoenix, Arizona, have been dialyzed using the modified bovine heterograft (Table 1). Fifty of these patients were male; 43 female. The age range for this group was 16 years to 74 years, with a mean age of 44 years. One-hundred arteriovenous fistulas have been created, using the modified bovine heterograft, according to techniques of graft preparation and insertion described in an earlier report.[3] Fifty-four fistulas were straight forearm grafts, and 24 were loop forearm grafts. Straight thigh fistulas were placed in 18 patients, 3 patients had a loop thigh graft, and one patient had an axillo-axillary graft. The period of observation has ranged from four to 102 weeks. This excludes 3 patients who refused dialysis, 3, 5 and 9 weeks postoperatively. Fifty-seven patients had bovine arteriovenous fistulas constructed as the first method of vascular access. The remaining patients had had arteriovenous cannulas, radiocephalic arteriovenous fistulas, or saphenous vein reroutings prior to the construction of the modified bovine heterograft arteriovenous fistula. General anesthesia was administered in 72 cases, local anesthesia and sedation in 24 cases, and 4 patients had regional block.

Results

Satisfactory results have been obtained using the modified bovine heterograft for the construction of arteriovenous fistulas. In 45 cases there were no complications, 28 patients had complications requiring surgical intervention with the remaining patients experiencing complications not requiring additional surgery.

Submitted for publication July 16, 1975.

Reprint requests: J. M. Johnson, M.D., 550 W. Thomas Road, Suite 211-B, Phoenix, Arizona 85013.

Non-operative complications. Most patients developed some degree of postoperative localized edema in operated extremities, and 10 patients had persistent swelling from 2 to 4 months following surgery. Nine of these patients had received straight thigh fistulas, and one had a loop forearm fistula. The swelling has not been incapacitating in any case, but it has resulted in minimal separation of incisional lines, with subsequent delay in wound healing and difficulty in graft palpation. Since electromagnetic flow rates of forearm and thigh fistulas have averaged 440 cc per minute and 880 cc per minute, repsectively, it seems valid to assume that the edema seen commonly in thigh fistulas is the result of a higher venous pressure. In most instances, limited ambulation, elevation of the affected extremity, and precise elastic support has helped to control swelling.

Localized skin necrosis of the incision over the radial artery occurred in one patient with a straight forearm graft and was the direct result of extensive tissue undermining. Local wound care resulted in healing without infection of the graft.

Three patients with straight thigh fistulas developed bleeding in the subcutaneous tunnel but did not require reoperation. This bleeding may have resulted from inaccurately applied compression after removal of the dialysis needles. Application of pressure over the site of skin perforation may not cause tamponade at the graft site because the point of graft puncture is often different from the skin puncture site. When this is the case, bleeding may continue into the tract alongside the graft. Since skin and subcutaneous tissue are thicker in the thigh, more bleeding complications may be expected with thigh fistulas.

One patient in our series developed an aneurysm in the midportion of the graft secondary to multiple needle punctures in one area of the graft. The aneurysm slowly enlarged over a period of 6 weeks but has remained stable during the past 8 months. There has been no sign of further enlargement, skin erosion, infection, or embolization. To avoid aneurysm formation from repeated needle punctures in one location, it is necessary to use numerous puncture sites along the full length of the graft, sparing 2 cm nearest each anastomosis. Also single-needle dialysis may decrease the number of true or false aneurysms associated with repeated cannulations.

Fourteen of the patients in the series have diabetes mellitus. Straight forearm arteriovenous fistulas were constructed in 4 cases, and the other 10 diabetic patients had loop forearm fistulas. Patients with diabetes mellitus have significant small-artery atherosclerosis, and the creation of an arteriovenous fistula by graft interposition appears to hasten the progression of atherosclerotic occlusion.[4] Gradual occlusion of the proximal radial artery over a 10-month period occurred in one diabetic patient following placement of a straight forearm fistula. Because of retrograde flow through the distal radial artery, via the palmar arch and ulnar artery, the graft remained patent (Fig. 1). However, progressive decrease in flow through the graft necessitated construction of a loop forearm fistula in the contralateral arm. With our experience with this one case, it appeared that ischemia may be avoided by constructing loop forearm fistulas in all diabetic patients. However, this was not the case and three patients with diabetes mellitus developed pain, paresthesia, and coolness of the ipsilateral hand following placement of loop forearm fistulas. Progression of these ischemic symptoms has not occurred. All 3 patients had adequate preoperative radial and ulnar artery perfusion of the hand.

TABLE 1. *Operative Experience with Bovine Arterial Grafts*

Number of Patients	93
Male	50
Female	43
Number of Grafts	100
Forearm, straight	54
Forearm, loop	24
Thigh, straight	18
Thigh, loop	3
Axillo-axillary	1
Age Distribution	
10–19	8
20–29	14
30–39	12
40–49	16
50–59	30
60–69	9
70–79	4

Operative complications (Table 2). In our series, reoperation was necessary to reverse such complications as graft thrombosis, graft infection with false aneurysm formation, hemorrhage and bovine graft stenosis. For purposes of discussion, we have arbitrarily classified thrombosis according to the time of its occurrence, i.e., within one week of operation (early), or after one week (late).

Four patients had early thrombosis of the graft, and in two of these cases, exploration at the time of reoperation did not reveal a specific cause for thrombosis. Following thrombectomy, both bovine heterografts have remained patent for 9 and 14 months, respectively. In a third patient, a loop forearm fistula thrombosed within 12 hours following surgery, and at reoperation kinking of the mid-portion of the graft was found (Fig. 2). After resection and anastomosis, the graft has remained patent. Thrombosis of a straight forearm fistula in another patient occurred during dialysis 3 days following graft placement. Thrombosis appeared to be secondary to embolization from arterial line clotting within the dialysis machine.

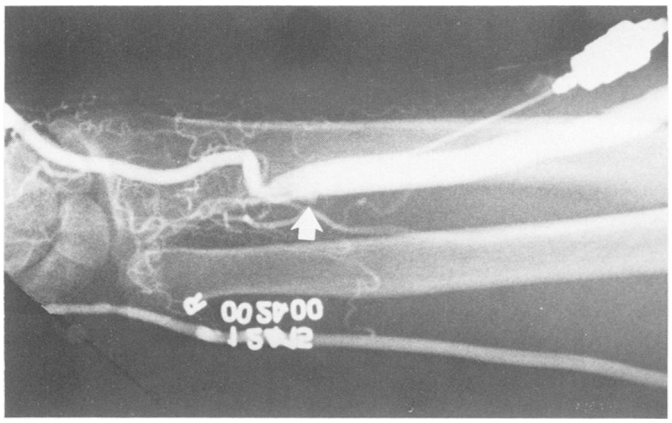

FIG. 1. Graft patency maintained by distal radial artery with occlusion of the proximal radial artery (arrow).

At reoperation, no mechanical basis for the thrombus was found, and four months following thrombectomy, the graft remains patent.

Temporary low flow states were documented prior to late thrombosis in two patients. In a third case, no explanation for thrombosis was found. Following thrombectomy all 3 grafts have remained patent at 5, 7, and 11 months, respectively. Proliferation of pseudo-intimal fibrous tissue resulted in the occlusion of 6 grafts 4 to 15 months after insertion. All cases have involved the venous anastomosis, which leads us to the conclusion that the increased turbulence from retrograde flow in the veins must play a role in the genesis of obstructions of this type. Because of occlusion at the saphenofemoral junction in one thigh fistula, the common femoral vein is now used as a venous outflow track. In one case, however, stenosis of the bovine graft developed in spite of the fact that the venous anastomosis was made at the common femoral vein (Fig. 3). One variation in technique which may improve flow characteristics is a longer venotomy, which may reduce turbulence. Histologic studies of resected specimens have consistently shown proliferation of fibrous tissue and hyalinization throughout the length of the graft and particularly prevalent near the venous anastomosis. Pseudo-intimal fibrous proliferation with resultant graft stenosis can be anticipated when there is a consistent rise in venous resistance during dialysis. This phenomenon has been noted in 6 patients in whom contrast studies of the bovine graft disclosed significant venous stenosis. In all 6 cases, revision of the venous anastomosis was performed before the thrombosis occurred. In such cases, our procedure has been to remove the pseudo-intimal fibrous tissue by endarterectomy, followed, when necessary, by bovine, vein or Dacron patch-graft angioplasty (Fig. 4).

Infection of the modified bovine heterograft has developed in three patients, one of whom was clawed by a pet cat. This injury resulted in graft puncture and subsequent infection, false aneurysm formation, and hemorrhage. Partial removal of this graft has been necessary. In the other two cases, infection occurred at 6 and 51 weeks, respectively. The grafts were surgically removed, and modified bovine heterografts were placed in new locations in both of these patients. This low incidence of infection may be attributable to our technique of preparing the extremity prior to cannulation for dialysis with routine surgical scrub and mask and glove precautions.

Postoperative bleeding of sufficient magnitude to require reoperation occurred in two patients early in the series. Both had straight thigh fistulas, and suture ligation of a posterior wall puncture was necessary to control the bleeding in both instances. Since then this complication has not occurred, partly because of increased experience with cannulation, but more im-

TABLE 2. *Operative Complications*

	No. of Patients	Bleeding	Thromboses		Infection	Bovine Graft Stenosis
			Early	Late		
Straight forearm graft	54	—	3	9	1	4
Loop forearm graft	24	—	1	1	2	—
Straight thigh graft	18	2	—	2	—	2
Loop thigh graft	3	—	—	—	—	—
Axillo-axillary graft	1	—	—	—	—	—

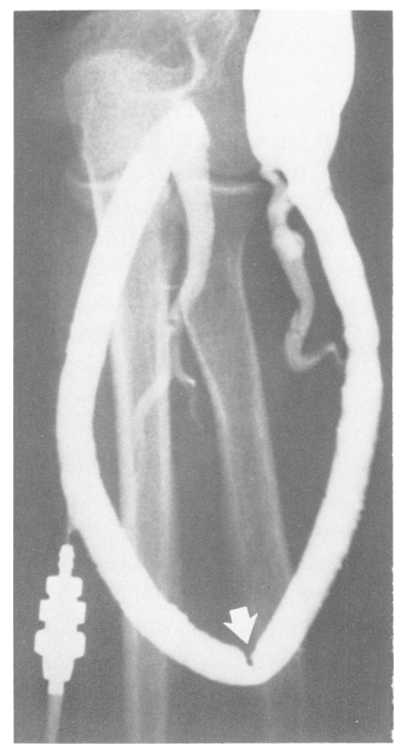

FIG. 2. Kinking of bovine heterograft placed in the forearm as a loop fistula.

FIG. 3. Stenosis of the bovine heterograft adjacent to the common femoral vein anastomosis.

portantly because of accurate and precise construction of a subcutaneous tunnel. Several patients have had continued bleeding following removal of dialysis needles, but nonoperative treatment with elevation, accurate compression, and additional Protamine administration has served to stop the bleeding in most instances. Continued external bleeding, limb enlargement, distal ischemia, or poor fistula flow would be obvious indications for reoperation.

Mortality. Fourteen patients in this series have died. None of the deaths have been directly attributable to the use of the modified bovine heterograft. Three patients refused dialysis at 3, 5, and 9 weeks after insertion of heterografts and died of complications of renal failure. Two patients could not be resuscitated after cardiac arrest was precipitated by hyperkalemia. One patient with severe uremia developed an acute cardiac tamponade and died. An air embolus was inadvertently introduced during initiation of hemodialysis in another patient, and this caused cardiac standstill and death. Another patient developed upper gastrointestinal hemorrhage and died later of operative complications. An elderly male suffered an acute myocardial infarction during the insertion of the graft and died of cardiac failure 16 days later. Two middle-aged diabetic females died of sepsis following prolonged hospitalization. One died from complications from a perforated colonic diverticulum, and another died from complications associated with the amputation of a gangrenous lower extremity. Two elderly patients with functioning fistulas could not tolerate the hemodynamic changes associated with dialysis and died of multiple system failure. Acute myocardial infarction was the cause of death in another patient 4 months after insertion of the graft.

Discussion

Frequent complications and high failure rate encountered with other types of vascular access for chronic hemodialysis have prompted the search for better methods. Payne, et al.[5] reported 32 patients in whom bovine grafts were used for construction of arteriovenous fistulas. All of their patients had had multiple failures of other types of shunts and fistulas. Haimov and Jacobson[2] reported on 40 grafts in 33 patients who had multiple vascular access procedures performed previously.

In our experience, the modified bovine heterograft has enjoyed improved patient acceptance, high success rate, and relatively low rate of associated complications. The main advantage of the bovine graft has been the effective use in any patient as a means for im-

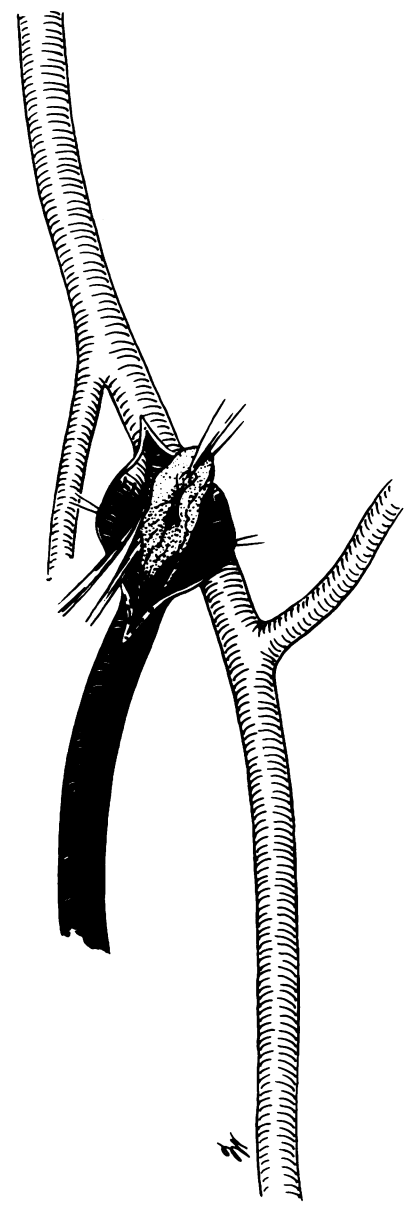

FIG. 4. Method of removal of pseudo-intimal fibrous tissue.

mediate dialysis. We initially preferred to wait several weeks after placement of the graft to allow for wound healing before it was used for hemodialysis. Circumstances arose, however, in which the graft had to be used within several days after surgery, and we now have dialyzed patients several hours after construction of the bovine arteriovenous fistulas. No complications have been seen from this early use of the graft, provided that meticulous hemostasis was obtained at the time of surgery and careful regulation of anticoagulants was performed during dialysis.

The phenomenon of fibrous pseudo-intimal proliferation within the graft may continue to be a significant factor in causing late thrombosis. It has developed in all cases in which grafts have been removed because of infection and in which grafts have been explored for thrombosis or stenosis. The degree to which this fibrous growth produces clinical signs, however, is variable. Further refinement in surgical procedure by lengthening the venotomy may alter flow characteristics and reduce turbulence so that this obstructing lesion is minimized.

Our own observations and the complications reported by Payne[5] and by Haimov and Jacobson,[2] emphasize the extreme importance for precise preoperative surgical judgment in selecting the location for placement of the bovine heterograft. We have had 3 patients with ischemia of the hand but all have improved without resorting to removal or ligation of the fistula. In selecting the graft location, the possibility of precipitating vascular insufficiency should be considered. Important factors related to graft site locations are: the presence or absence of adequate collateral circulation; previous arterial or venous surgery; factors predisposing to progressive atherosclerotic disease, such as diabetes mellitus; type of activity or employment; and the dominance or nondominance of the extremity. Unless previous cannulas, radiocephalic fistulas, saphenous vein or bovine graft arteriovenous fistulas have used available vessels, the fistula should not be located in the dominant extremity. Careful evaluation of the vascular system is an absolute prerequisite to arteriovenous fistula construction.

Our procedure of choice has been and remains the straight forearm fistula. However, we do not agree with Haimov and Jacobson[2] that the loop forearm fistula is "hemodynamically wrong," because our patency rate with this type of fistula has been excellent. It was our procedure of choice with patients having diabetes mellitus because of progressive atherosclerosis so commonly seen in these patients but with three patients developing ischemia of the hand following construction of this type of fistula, we have returned to doing the straight forearm fistula in diabetic patients provided the radial artery is satisfactory for anastomosis.

The bovine heterograft has had a longer and more effective patency rate than when a saphenous vein has been used. It has a distinct advantage over saphenous vein rerouting in that it decreased operative time, there is less surgical trauma, and the heterograft fistula can be easily cannulated soon after placement. The modified bovine heterograft has proved to be an acceptable fistula for hemodialysis.

References

1. Buscia, N. J., Cimino, J. E., Appel, K., Hurwich, B. J.: Chronic Hemodialysis Using Venipuncture and a Surgically Created Arteriovenous Fistula. N. Engl. J. Med., 275:1089, 1966.
2. Haimov, M. and Jacobson II, J. H.: Experience with the Modified Bovine Arterial Heterograft in Peripheral Vascular Reconstruction and Vascular Access for Hemodialysis. Ann. Surg., 180:291, 1974.
3. Johnson, J. M. and Kenoyer, M. R.: Bovine Graft Arteriovenous Fistula for Hemodialysis. Am. J. Surg., 128:728, 1974.
4. Lindern, A., Charra, B, Sherrard, D. J. and Scribner, B. H.: Accelerated Atherosclerosis in Prolonged Maintenance Hemodialysis. N. Engl. J. Med., 290:697, 1974.
5. Payne, J. E., Chatterjee, S. N., Barbour, B. H., and Berne, T. V.: Vascular Access for Chronic Hemodialysis Using Modified Bovine Arterial Graft Arteriovenous Fistula. Am. J. Surg., 128:54, 1974.
6. Quinton, W., Dillard, D. and Scribner, B. H.: Cannulation of Blood Vessels for Prolonged Hemodialysis. Trans. Am. Soc. Artif. Intern. Organ., 6:104, 1960.