Internal vascular access for hemodialysis in children weighing less than fifteen kilograms

Hugh B. Robinson, M.D., James E. Wenzl, M.D., and G. Rainey Williams, M.D., Oklahoma City, Okla.

An arterioarterial femoral graft using expanded polytetrafluoroethylene is described which has been used successfully for vascular access in young children having small peripheral vessels. This graft allows high flow and favorable patency for dialysis without the complications of arteriovenous shunting or the risks associated with an external hemodialysis device. This graft has been used successfully for outpatient dialysis in children weighing as little as 9 kg and may be a useful adjunct in long-term dialysis of patients for whom more conventional means of vascular access are not acceptable.

From the Departments of Surgery and Pediatrics, the University of Oklahoma Health Sciences Center, Oklahoma City, Okla.

CHRONIC HEMODIALYSIS in the early pediatric age group has become a technically feasible and clinically acceptable procedure. Increased support from government and private sources is allowing more frequent renal transplantation in children, and therefore an ever younger patient population can be considered for chronic dialysis. Despite some success with peritoneal dialysis in children, hemodialysis remains the method of choice. However, there are several problems which continue to hamper long-term hemodialysis in the small child. By far the greatest limitation is vascular size.

External hemodialysis appliances (Schribner-type shunts) have been used in small children but this device is subject to serious disadvantages, the most notable of which include thrombosis, infection, ischemia, and, occasionally, heart failure. Furthermore, the vigorous and often unpredictable activity of small children has made the external devices subject to accidental (or purposeful) removal. The potentially lethal complications of separation of the arteriovenous connector of a shunt has prompted some groups to insist on permanent hospitalization of a child undergoing dialysis by this method. The expense and obvious psychological consequences of chronic hospitalization makes an internal means of hemodialysis particularly valuable in this group.

Internal vascular access for hemodialysis is even more limited by small vascular size than is external shunting. Although the ability to create a successful arteriovenous fistula by microsurgical techniques certainly exists, a patent fistula between an artery and a vein having very small internal diameters is not immediately usable for dialysis purposes. Weeks or months often are required for dilation of the venous system in small children before the first dialysis can be accomplished. The rapidly progressive uremic patient then requires some temporary form of vascular access, which, although life-saving in some contexts, invariably wastes a site of vascular access which ultimately may be invaluable to the long-term dialysis patient. When anastomoses between large arteries and veins having sizes and flows capable of supporting immediate dialysis are constructed, high-output cardiac failure, distal ischemia, and differential limb growth may occur.

At the Oklahoma Health Sciences Center, small children accepted for chronic hemodialysis are separated into two groups. In those children thought to have a lead time exceeding 8 weeks prior to their first dialysis, an end-vein-to-side-artery arteriovenous fistula is constructed at the wrist level. Warm compresses and venous tourniquets then are used in
The graft is placed in the subcutaneous space and has been used successfully for outpatient hemodialysis in children weighing as little as 9 kg (Figs. 1 and 2).

MATERIALS AND METHODS

Children weighing between 9 and 16 kg (23 months to 8 years of age) and who required semiurgent dialysis (within 1 week of operation) were selected for the arterioarterial graft. A 5 mm polytetrafluoroethylene graft was placed in the subcutaneous space of the medial thigh. The end-to-side anastomosis at each end was performed through a short incision in the femoral triangle and the medial thigh just above the knee. Care was taken to position the graft so that 2 or 3 mm of subcutaneous tissue intervened between the graft and the overlying skin to permit adequate healing and tamponade of the dialysis puncture sites. Placement of the graft more superficially beneath the skin may have led to erosion of the overlying skin or inadequate healing of the repeated puncture sites. Placement of the conduit too deeply makes palpation of the graft by the dialysis technician difficult and subsequent needle insertion may be less than accurate.

RESULTS

Arterioarterial femoral grafts were placed in three children weighing less than 15 kg. More than 200 separate dialyses were accomplished over 18 months with three complications. The first complication occurred early in the series and resulted from the
combined effects of superficial placement of the graft, urgent dialysis within 5 days of operation, and nine consecutive puncture sites within a single 2 cm segment of the graft. This resulted in a false aneurysm which required replacement of the short segment of the destroyed graft (Figs. 3 and 4).

The second complication occurred in a 9 kg infant whose graft became occluded by pseudointimal hyperplasia after 7 months of uncomplicated outpatient dialysis. Endarterectomy of the graft and vein-patch angioplasty at the distal anastomosis were required for correction. Hemodialysis using the same graft was reinstituted the following day and routine outpatient hemodialysis continued without complication. The graft occlusion presented as an inability to achieve dialysis and did not involve any ischemia of the limb.

The third complication arose after 16 months of triweekly dialysis when an aneurysm arose in the segment of graft used most frequently for dialysis. The short length of the overall graft in these infants made concentrated punctures mandatory; however, more uniform use of the entire expanse of the graft should reduce this problem. Segmental replacement was accomplished with dialysis being reinstituted the following day in the undamaged segment.

Dialysis nurses report that needle puncture of the graft is technically managed in the same manner as conventional arteriovenous fistulas in adults. Neither bleeding nor obstructive thromboses have been troublesome and flow rates have been adequate for satisfactory dialysis using a single needle. Routine precautions are adequate to prevent hematomas once tissue fixation of the graft has occurred; however, urgent use of the graft for hemodialysis within 7 days of insertion has produced hematomas if additional measures were not utilized. These measures included prolongation of digital compression and precise reversal of heparin anticoagulation once the dialysis needle was withdrawn. There have been no changes in heart rate, leg size, growth characteristics, or distal blood flow to the extremity. The children
have remained active and as ambulatory as their ages permit and have undergone routine dialysis as outpatients.

**DISCUSSION**

The successful femoral arterioarterial jump graft in adults has been described previously. To our knowledge, this graft has not been used in the pediatric-age group, nor has any previous internal means of hemodialysis which can be used within 1 week of insertion been described in children weighing less than 15 kg. Pérez Alvarez has described the use of a saphenous vein loop for pediatric dialysis in children as young as 7 years, and Hardy, Schneider, and Levitt have described the construction of direct arteriovenous fistulas in children weighing as little as 8 kg. Direct arteriovenous fistula creation also has been performed at this institution in children of this age and size; however, a period as long as 6 months has been required for adequate maturation before these small vessels could be utilized.

The femoropopliteal arterial graft has many features which appear to be particularly applicable to the young child: (1) there are no external projections which extend beyond the skin; (2) blood flow is not shunted away from the distal limb through arteriovenous steal; (3) high blood flow through the graft produces favorable patency rates and allows early use of the graft for dialysis as soon as tissue fixation occurs; (4) there is no stasis dermatitis, peripheral edema, or venous aneurysms as a result of venous hypertension; (5) differential limb growth or high-output cardiac failure as a result of arteriovenous shunting should not be expected; (6) the arms remain free during dialysis so the child may eat or play; (7) this method can be used in very small children whose vessel size obviates conventional techniques for vascular access. Complications using this means of vascular access have been minimized by allowing adequate time for tissue fixation of the graft. This requires at least 1 week prior to the first dialysis in our experience, but in case of an emergency the graft may be used for immediate dialysis. Aggressive medical care, including fluid restriction, protein restriction, administration of ion-exchange resins, and careful monitoring, usually can provide the time required for tissue adhesion prior to the dialysis.

Long-term follow-up of patients with these grafts is not complete yet, but they appear to be satisfactory at 18 months. The effects of a nongrowing graft on a growing native vessel likewise have not been evaluated fully. If adequate growth occurs proximally and distally to the graft, then distortion of the vessel should be minimal. If, however, the graft spans a segment of growing artery and tethers its increasing length, then distortion of this vessel might be expected. It is anticipated that, by the time an objectionable degree of distortion occurs, the child will have obtained adequate weight and size to allow hemodialysis by a more conventional means, and a relatively minor procedure would be required to remove or even lengthen the femoral graft. So far our experience suggests that children on chronic dialysis do not grow at such a rate as to cause one to expect this to be a significant problem.

Fig. 5 A 3,800 gm infant who underwent single-needle hemodialysis using a femoropopliteal graft.
ADDENDUM

Since this paper was accepted for publication, two additional patients have undergone femoropopliteal grafts for hemodialysis. One graft in an 8 kg child is functioning satisfactorily. The second graft, placed in a 3,800 gm infant, functioned acceptably until it thrombosed at the age of 5 months (Fig. 5). The graft has not undergone exploration or thrombectomy since the infant’s kidneys which had not functioned since birth (abruptio placenta) have since begun to produce in excess of 200 cc of urine per day.

REFERENCES

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