Vascular access failure causes substantial morbidity in patients with end-stage renal disease who require long-term hemodialysis. As standard vascular access, an arteriovenous (AV) fistula created with a superficial vein or a prosthetic AV access with a suitable deep vein are used. Still, in some patients, veins can be exhausted owing to multiple long-term indwelling central vein catheters (CVC), transvenous pacemakers, or previously failed AV vascular access attempts.

Stenosis or occlusion of central veins can be treated surgically or by angioplasty to establish sufficient outflow required for AV access. Central subclavian vein obstruction can be reconstructed by different surgical techniques with good results. However, these procedures need a suitable jugular vein or undisturbed contralateral venous outflow.

Endovascular interventions for the treatment of central venous obstruction show excellent initial success, but primary patency rates for 1 year are ≤50%, restenosis rates are high, and long-term results are uncertain. Several uncommon procedures for maintenance of AV grafts at central venous obstruction have been published. However, some of these approaches appear inadequate for the creation of vascular access.

Symptomatic ischemia distal to an AV fistula occurs in around 4% of patients. In a very few patients, the arterial status does not allow the construction of an AV graft, even if the graft is fed by a central artery.

These patients represent a group with complex vascular access problems that preclude the creation of a conventional vascular access. Tunneled central venous catheters do not represent an acceptable long-term alternative.

We developed a procedure to establish an arterioarterial prosthetic loop (AAPL) for such patients. The AAPL is a polytetrafluoroethylene (PTFE) graft loop interposed in the continuity of the axillary or femoral artery that can be used as the vascular access for hemodialysis.

METHODS

Patients. From April 1996 to September 2004, 36 AAPL procedures for vascular access were performed in 34 patients with end-stage renal disease. All patients who received an AAPL agreed to the procedure by signing a consent form.

Indication. An AAPL for vascular access is indicated only for patients who have no suitable superficial vein (defined as the cephalic and basilic veins) for an AV fistula and who belong to one of the following indication groups:

1. The unsuitability of large deep veins (defined as the subclavian, internal jugular, and external iliac and femoral veins), the unsuitability of all six veins, or the unsuitability of five of six veins in younger patients with good prognosis. The last suitable vein should be reserved as an access for a CVC in an emergency. A vein is considered unsuitable if an occlusion or high-grade long stenosis (<70% in diameter, >4 cm long) of the vein or the venous outflow is detected and can not be treated promisingly by any interventions.
2. Critical ischemia of the extremity at the arterial inflow site of an intended AV access or severe access-related ischemia of an existing AV access without other options of reconstruction.

3. Cardiac insufficiency that is intolerable to the additional cardiac load of a high-flow AV graft and the risk of exacerbation of congestive heart failure.

**Operative technique.** The central axillary artery for axillary chest AAPL, or common femoral artery for femoral inguinal AAPL, were used as vessels for this procedure (Figs 1, 2 and 3). The operative procedure includes the exposure of the central axillary artery or the common femoral artery, the subcutaneous placement of an expanded PTFE prosthesis (Bard Peripheral Vascular, Tempe, Ariz) with a 6- or 7-mm diameter (adapted to the diameter of the artery) as the loop; the occlusion and oblique discission of the artery; and the creation of an end-to-end anastomoses between the ends of prosthesis and the artery using a 6-0 polypropylene suture. The length of the implanted graft was 27 to 38 cm.

**Management.** Duplex mapping of veins and supplementary contrast venography are essential for defining adequacy or inadequacy of deep veins and were performed in all patients. Color duplex ultrasound scanning of arteries was regarded as mandatory for all patients. An arteriography was performed in all cases of suspected arterial inflow or outflow lesions (n = 9).

After the perioperative administration of heparin, patients received oral anticoagulation (Cumarine), with an international normalized ratio of 2.5 to 3.0. Six patients with a contraindication for oral anticoagulation received aspirin only (300 mg/day). Patients were hospitalized ≥7 days. The first needle puncture of the graft was done not before 2 weeks after the procedure.

The patients’ nephrologists were informed about the specifics of this access. They were advised to compress the puncture site for 20 minutes after the removal of the needle, to adjust the temperature of the reinfused blood, to continue the supply of heparin until 30 minutes before finishing hemodialysis, and to refrain from any infusion of medications (intra-arterial injection).

Every 6 months, patients were followed up in our institution, where a clinical examination and duplex ultrasound scanning of the AAPL were performed, including measurement of access flow by the Doppler method. Most patients had one hemodialysis treatment that was used to determine the Kt/V (clearance multiplied by time/volume of fluid cleared) and the urea reduction ratio. The Kt/V was determined by using a Hospal urea monitor (DQM 200, Gambro Hospal GmbH, Martinsried, Germany).

**Statistical analysis.** The Kaplan-Meier method was used to compute survival and graft patency. The Cox-Mantel log-rank test was used to compare the differences between the Kaplan-Meier method curves. Significance was assumed at $P < .05$. Values are expressed as mean ± SE or observed range.
RESULTS

In the past 8 years, 36 AAPL have been created in 34 patients. This represents 1.2% of all created vascular accesses for hemodialysis in our institution during this period. The mean patient age was 62 ± 13 years; 59% were women. Comorbid conditions included diabetes mellitus (56%), peripheral arterial disease (Fontaine stage III and IV) (50%), coronary artery disease (58%), adipositas (39%), hyperlipidemia (53%), and documented hypercoagulability (19%). The patients had been receiving hemodialysis for 5.4 ± 6.2 years (range, 1 to 30). They had undergone 15/8 (range, 2 to >30) previous procedures for 5 ± 2 (range, 1 to 9) different permanent hemodialysis accesses.

The patients were dialyzed through a temporary CVC placed in the jugular vein (36%), femoral vein (56%), left atrium (5%), or through an insufficient AV graft (3%).

AAPL was reserved only for selected cases in which the possibility for the construction of a conventional access was precluded. None of the patients had suitable superficial veins for the creation of a native AV fistula. AAPL placement was indicated in 23 patients (64%) who had unsuitable large deep veins. Phlebography demonstrated an occlusion of all six large deep veins in eight patients and a stenosis of the last patent deep vein in three patients. In 12 patients, one suitable vein (jugular or femoral vein) was found, where a CVC was placed. A previous endovascular intervention of stenoses of the subclavian or the innominate vein had been performed in 10 patients.

In four patients (11%), deep veins were suitable, but all patients had a severe steal syndrome, with finger necrosis at a low-flow central AV graft (axillary-axillary chest loop and femoral-femoral looped inguinal access, respectively). The necrosis healed after the construction of the AAPL and the ligation of the AV access. One patient with gangrene required a finger amputation.

Eight patients (22%) had a mixed indication, with unsuitable upper body veins and suitable femoral veins, but coexistent peripheral arterial disease at Fontaine stage IV (previous major amputation in 5 patients). Severe congestive heart failure (NYHA class IV, ejection fraction 20%, valvular defects, massive obesity) was regarded as indication for an AAPL placement in one patient (3%).

In seven patients, the construction of AAPL was performed under local anesthesia and under general anesthesia in 29 patients. The axillary chest position was preferred in 31 patients (86%), and the femoral artery was used in only five patients.

No complications were observed in the early postoperative course. All AAPL were cannulated 18 ± 4 days postoperatively.

During the late postoperative period, thrombosis of the AAPL occurred in 15 patients (42%) at a mean of 15 ± 14 months (range, 1 to 48) after placement. In nine patients, repeated thrombectomies were required. Thrombectomy was combined with the reconstruction of an anastomotic stenosis in seven patients. A distal embolism of the brachial artery due to partial thrombus occurred in one patient after thrombectomy of an axillary AAPL and was treated by embolectomy. Thrombosis of the femoral AAPL required immediate thrombectomy, whereas occlusion of the axillary AAPL caused only mild ischemia and was tolerated much better.

Four AAPL were abandoned. One axillary AAPL thrombosed repeatedly due to the long stenosis of the distal axillary artery, and a new femoral AAPL was constructed 19 months after placement. The femoral AAPL in another patient was destroyed by puncture when it demonstrated anastomotic stenosis and a new AAPL was placed at the same site after 48 months. Repeated thrombosis of AAPL occurred in two patients. In these cases, femoral AV grafts with only the suitable femoral vein were created 12 and 25 months after AAPL placement, despite a high risk of infection due to a rectovaginal fistula in one patient. Artery reconstruction was not necessary in the patients whose axillary AAPL were abandoned.

The achieved primary and secondary patency was 73% and 96% at 1 year and 54% and 87% at 3 years, respectively (Fig 4).

Our analyses revealed only documented hypercoagulability as a risk factor for graft thrombosis (primary patency rate 80% vs 57% at 1 year and 57% vs 14% at 3 years; P < .05). A significant difference in patency rates could not be demonstrated for the site of the AAPL, postoperative anti-coagulation, diabetes mellitus, peripheral arterial disease, or gender.

The cumulative survival rate for all patients was 93% at 1 year and 67% at 3 years. No deaths were related to the AAPL.

Despite instructions provided to the nephrologists, the needle puncture was performed in only two small areas in
some patients. Consecutive destruction of the graft led to aneurysms in six patients. Ten reconstructions by replacement of the destroyed graft part were performed in six patients at a mean of 18 months after placement. In one patient, an infection at the puncture site was reconstructed in the same manner after 23 months. The rate of all interventions for maintenance of AAPL function was 0.47 procedures per patient year.

Postoperative flow of 272 ± 61 mL/min for axillary AAPL and 416 ± 40 mL/min for femoral AAPL was measured by a duplex scan. The flow changed only marginally over time.

More than 11,000 hemodialysis treatments were performed in patients through the AAPL. A two-needle puncture was the standard technique. All but two AAPLs allowed an efficient hemodialysis in the regular time of a 4-hour treatment at a dialysate flow rate of 284 ± 53 mL/min, arterial pressure of -65 ± 28 mm Hg, and outflow pressure of 173 ± 39 mm Hg. In 90 measurements, the urea reduction ratio was 71% ± 9%. The Kt/V exceeded 1.2 (range, 1.2 to 1.8) in 4 hours of therapy at a dialyzer blood flow rate of 200 mL/min for 72 measurements in 22 patients. For two patients with a dry weight >100 kg, the Kt/V was between 0.9 and 1.1. The treatment time for these patients was extended to 5 hours.

A compression time of 10 minutes was sufficient to stop the bleeding at the puncture site in most of the patients. Hemodialysis was well tolerated by the patients. A painful reaction by distal arteries to the reinfused blood was observed in a few cases of high-flow dialysis (>400 mL/min).

In no patient with existing angiopathy or congestive heart failure was a deterioration of the symptoms observed.

Finally, we present a special case of AAPL. One very slim patient with a left-sided subclavian AAPL, which had been performed earlier in another hospital, was referred to our center because of insufficient hemodialysis due to a graft flow <140 mL/min. After the exclusion of an arterial stenosis as the reason for the low flow, a second subclavian AAPL was constructed at the right side with a postoperative flow of 160 mL/min. One AAPL was used as an artery, the other as the efferent vessel. A sufficient hemodialysis without any problems over 26 months at a dialysate flow of 250 mL/min was possible because of nonexistent recirculation.

DISCUSSION

The use of an artery as permanent vascular access for hemodialysis is not a new procedure. Brittinger et al25 used the subcutaneously fixed superficial femoral artery for needle puncture. However, in our opinion, this is a very traumatic procedure that can be performed only in younger individuals with an unchanged artery. Also, the recurrent cannulation of the artery can lead to substantial complications (stenosis, thrombosis, arterial aneurysms) that require extensive surgery.

Butt and Kountz26 reported satisfactory results with an arterial femoropopliteal graft that used a bovine carotid artery as vascular access in seven patients. Similar techniques were reported by Zingraff et al27 and Giacchino et al.28 In contrast to these procedures that use a bypass for a patent artery, AAPL represents the subcutaneous placement of an artery that is elongated by graft interposition.

As a result of these promising initial results,29 we performed 36 AAPL in 34 patients over an 8-year period.

The basics of the AAPL compared with an AV graft are:

1. A vein is not essential.
2. The distal perfusion is not decreased.
3. The cardiac load is not increased.

Among the potential problems of AAPL as an angioaccess, we considered the following as most relevant:

1. Occlusion of the graft may lead to distal ischemia and requires immediate salvage. It was observed that thrombosis of axillary AAPL was well tolerated. In the cases of an abandoned axillary AAPL, the arterial reconstruction was not necessary because of good collateralization. The thrombosis of a femoral AAPL required immediate thrombectomy, however.
2. If the whole graft becomes infected, it is mandatory to remove the graft and reconstruct the artery. A severe infection was not seen. However, as a precaution, we recommend that the artery be mobilized over a longer distance than necessary for clamping during the construction of AAPL. A situs will be achieved that renders the potential reconstruction easier.
3. Hemodialysis through an AAPL may cause different potential problems such as embolism, the formation of an aneurysm, and painful reperfusion.30 Embolism was observed in only one patient and does not pose a substantial problem. Because the intraluminal pressure of the AAPL is arterial, it is much higher than the pressure of a well-working AV graft. The risk that the APPL will develop a false aneurysm at puncture sites is therefore increased but is easy to manage. In fact, false aneurysms can be prevented if a careful puncture technique is applied.
A primary patency rate of 87% at 3 years is encouraging. The Dialysis Outcomes and Quality Initiative (DOQI) Guidelines recommend a flow of 600 mL/min, despite a normal arterial inflow, to preclude the possibility of reconstruction of steal syndrome. The distal revascularization interval-ligation procedure was not considered as an option for reconstruction because the femoral or central axillary veins were the only adequate veins for AV access in these patients.

For one patient, severe cardiac insufficiency was seen as an indication for AAPL. This is a very rare indication and may be a difficult decision in the view of life expectancy. This patient died only 2 months after placement of AAPL due to the sudden deterioration of cardiac function after previous stabilization.

The patency and intervention rate of 0.47 procedures per patient year are comparable with results of AV grafts, and meet the demands of the National Kidney Foundation and the DOQI.3 However, this is a general problem of vascular access, especially for patients with transvenous pacemakers.4

Severe steal syndrome at a central AV graft was the indication for AAPL in 4 patients. A flow of 600 mL/min, despite normal arterial inflow, precluded the possibility of reconstruction of steal syndrome. The distal revascularization interval-ligation procedure was not considered as an option for reconstruction because the femoral or central axillary veins were the only adequate veins for AV access in these patients.

For one patient, severe cardiac insufficiency was seen as an indication for AAPL in 4% of the patients. A flow of 600 mL/min, despite normal arterial inflow, precluded the possibility of reconstruction of steal syndrome. The distal revascularization interval-ligation procedure was not considered as an option for reconstruction because the femoral or central axillary veins were the only adequate veins for AV access in these patients.

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The axillary AAPL is reserved only for patients without any other promising possibility for the creation of a more conventional vascular access. For these strictly selected cases, this approach is an unusual but very efficient and attractive alternative as a vascular access for hemodialysis and can sustain the survival of patients.

REFERENCES


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