Vascular access for chronic haemodialysis

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Introduction

The availability of suitable vascular access for chronic haemodialysis is essential for the preservation of life in patients with end stage renal failure. The exposed Silastic arteriovenous shunt developed by Quinton and associates' in 1960 permitted intermittent dialysis. In the early days, shunt insertion was a complicated open theatre-based procedure, which was the case in Sri Lanka until about 7 years ago. Currently, all shunts are inserted percutaneously into either the femoral or subclavian vein. External shunts are associated with many problems, which limit their use to about two weeks. These drawbacks were overcome with the advent of the subcutaneous arteriovenous fistula (AVF) created at the wrist by Brescia and associates[2] in 1966. This allowed repeated cannulation of the arterialised subcutaneous veins of the forearm without the problems associated with external shunts, such as infection and thrombosis, which required multiple revisions, as well as loss of freedom of activity. Nevertheless, long-term preservation of fistulae, access in children and HIV patients, and the need to use prosthetic grafts in the absence of suitable veins, continues to pose new challenges in the care of these patients. Current views and strategies that have evolved with the objective of overcoming these problems are reviewed.

AV fistula versus graft and catheter

Complications of haemodialysis vascular access contribute to as much as 25% of total end-stage disease costs in the USA. According to Schwab[3], the panel of the National Kidney Foundation Dialysis Outcomes Quality Initiative (DOQI)[4] concluded that tunnel cuffed percutaneous catheters, though the ideal intermediate access method, must be discouraged as a means of permanent access to the circulation. This is because the complication rate dramatically exceeds that of AV access for haemodialysis. Such complications include thrombotic malfunction, infection, and central vein stenoses.

Infection: This is the primary cause of both morbidity and mortality associated with catheter use. The risks are now well established. In a large prospective observational study, Marr et al[5] detailed the incidence of catheter-related infections. They reported that bacteraemia occurred at a rate of 3.9 episodes per 1000 catheter days. Similarly, Kovalik et al[6] have documented that osteomyelitis occurs at a much greater rate in patients with catheter access when compared with patients with AV access. Similar conclusions were drawn regarding an increased risk of endocarditis[7]. Hence, chronic catheter use should be minimized.

Thrombosis: The cause(s) of AV access thrombosis (neo-intimal and fibromuscular hyperplasia) and its prevention remain under investigation. However, we must continue to treat thromboses with thrombolysis, thrombectomy, angioplasty and surgical revision. AV fistulae last longer and show a lower tendency to clot than with AV grafts[3].

New techniques: microsurgery and clips for AV access creation

In a comparative, randomized trial, Schild et al[8] created anastomoses using a new vascular clipping system (VCS) or with polytetrafluoroethylene (PTFE) suturing. In a two year follow up, primary and secondary potencies were similar for both the VCS and suture groups, with the exception that a statistically significant improvement was found in secondary patency for autologous fistulae when performed with the VCS. The author emphasizes the case and relative speed of the VCS.

Bourquelot[9] reported results from the use of microsurgery for distal AV fistula creation in children and adults. Importantly, long-term patency (up to 25 years) was observed in distal AV fistulae. Microsurgery has greatly improved and simplified the creation of distal AV fistulae in adults and children, and has virtually eliminated the use of long-term venous catheters and AV grafts in children.

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Strategies to improve the long-term preservation of vascular access

Duplex ultrasonography

Pre-operative evaluation. Silva et al[10] studied the efficacy of preoperative, non-invasive assessment of the upper extremity to identify arteries and veins suitable for haemodialysis access in order to increase the use of autogenous fistulae. From 1994 to 1997, 172 patients requiring chronic haemodialysis underwent segmental upper extremity doppler pressure measurement and duplex ultrasound with mapping of arteries and veins. The criteria for satisfactory arterial inflow were:

1. absence of a pressure gradient between arms
2. a patent palmar arch,
3. arterial luminal diameter of at least 2.0 mm.

The criteria for venous outflow were:

1. venous lumenal diameter greater than or equal to 2.5 mm for autogenous fistulae
2. venous lumenal diameter greater than or equal to 4.0 mm for synthetic bridging grafts
3. continuity with superficial veins in the arm.

Contemporary experience (1994-1997) was compared with the two previous years (1992-1994), before the protocol was implemented. During the period 1994-1997:

1. the percentage of autogenous fistulae versus grafts and permanent catheters improved from 14% to 63%
2. early failure of autogenous fistulae decreased from 36% to 8%
3. the autogenous fistula primary cumulative patency rates at one year increased from 48% to 83%.

Routine, non-invasive assessment is recommended to document adequacy of arterial inflow and delineate venous outflow to maximize opportunities for AV fistulae.

Prognostic value

Sands has evaluated 253 patients (177 with PTFE grafts and 76 with AV fistulae) with duplex ultrasonography and followed them for six months[11]. Access flow was the best predictor of future thrombosis. In-patients with Polytetrafluoroethylene (PTFE) grafts with flow rates less than 800 cm/min, the incidence of thrombosis over 6 months was 92% compared with incidences of 25-28% among those with higher flows. Patients with low-flow grafts and who had an elective revision of an area of more than 50% stenosis had a thrombosis rate of 6% (1 of 18 patients) over 6 months compared with 42% (29/69) in those who were not revised.

Colour-flow Doppler ultmound examination has been conducted in 2792 haemodialysis patients to evaluate its predictive value for haemodialysis access failure[13]. Decreased access blood flow had the strongest predictive value ($p<0.0001$). Quantifying blood flow in a prosthetic graft can identify those at risk of failing; the relative risk increased by 40% when the blood flow in the graft declined to less than 500 ml/min. The relative risk doubled when the blood flow was less than 300 ml/min. In contrast, colour Doppler volume flow in native AV fistulae could not predict fistula survival.

Native fistulae and grafts

The distribution of access flow rates in native fistulae and grafts has been determined, based on more than 6000 curves ftom the Transonic archives[13] The average flow rates were close: 938 ml/min in grafts, 928 ml/min in fistulae. Upper-arm native fistulae (and, sometimes, artificial grafts) may have extremely high access flows, in the order of 3-4 litres/min, which may create cardiac overload. If the high-flow condition is diagnosed accurately in a timely manner, intervention to reduce it may he performed, and symptoms may disappear. The distribution of access flow rates in grafts and fistulae is different. Of the fistulae observed, 31% had a flow rate lower than 600 ml/min; only 21% of observed grafts had access flows lower than this threshold.

These grafts are prone to clot and need immediate attention; the threshold for interventions in fistulae is greater as they remain patent longer at lower flows.

Prediction of thrombosis

Sands et al[14] randomized 103 patients (68 with AV fistulae, 35 with PTFE grafts; followed for a mean of 197 days) to monthly ultrasound measurement of access flow, monthly measurement of static venous pressure, or no monthly monitoring (control patients). Of those patients monitored monthly, 9.7% developed access thrombosis compared with 22% of control patients ($p<0.05$). Measurement of access flow was associated with lower thrombosis rates than static venous pressure measurements.

Magnetic Resonance Angiography (MRA)

MRA and duplex ultrasound examination have been compared for the evaluation of central and peripheral veins prior to dialysis surgery[15]. Subclavian and central venous stenoses were accurately diag-

nosed by MRA. This study did not make a comparison with the theoretical gold standard, angiography. Further research is needed to identify appropriate patients who would benefit from pre-operative MRA.

Patency of grafts

Bourquelot has reported on a new bioprosthetic vascular graft (ProCol®, Vascular Bioprosthesis, Hancock Jaffe Laboratories, Irvine,California) treated with a combination of glutaraldehyde cross-linking and gamma-irradiation[16]. Forty-nine patients with multiple failed accesses and compromised haemodynamics received 50 ProCol as straight grafts (31 at the forearm, 19 at the upper arm). From a comparison of primary patencies (derived from life-table analyses) from this and a previous study involving PTFE grafts, Pro Col appears to be superior to PTFE grafts. With regard to PTFE grafts, it remains to be seen whether the new gelatin sealed graft (SEALPTFE™, Sulzer Vascutek Ltd., Inchinnan, UK), which is bonded antibiotic, has a beneficial effect on early graft infection.

Interventional radiology for stenosis and thrombosis

Interventional radiology is now a validated alternative to surgery for the treatment of stenosis and thrombosis in haemodialysis access. It offers advantages over surgery in that it is, of course, less invasive and allows better preservation of the patient's veins. Turmel-Rodrigues et al use manual thromboaspiration as a main means of declotting dialysis access, followed by dilation of unmasked stenoses[17]. In a series of 43 PTFE grafts, they report an initial success rate of 100%, with a primary non-assisted patency rate of 85% at one month, and a secondary patency rate of 86% at one year. The success rate was 81% for native fistulae, with a primary patency rate of 81% at one month and a secondary patency rate, which includes primary assisted patency, of 81% at one year.

Multidisciplinary approach to haemodialysis access

This approach developed by Allon et al[18] involves nephrologists, access surgeons and radiologists, with a full-time dialysis access coordinator and a computerized database developed for prospective documentation of procedures and complications. The integrated multidisciplinary approach has been shown to reduce markedly the rates of surgical complications of access surgery and access failure. These improvements occurred despite a marked decrease in hospitalization for access procedures, with a substantial cost saving. The major findings were that

1. The approach to clotted grafts evolved from an in-patient, surgical procedure to an outpatient, radiological procedure.
2. The immediate technical success rate of graft declotting increased from 48% to 69%.
3. Elective placement of arteriovenous (AV) grafts evolved from a procedure requiring 3-day hospitalization to a largely out-patient procedure.
4. The proportion of AV grafts placed as same-day or out-patient surgery increased from 16% to 81%.
5. Surgical complications of new AV graft surgery decreased from 25% to 11%.
6. Aggressive detection and correction of graft stenosis decreased the incidence of graft thrombosis by 60%.
7. The proportion of native AV fistula construction in new dialysis patients increased from 33% to 69%.

HIV-positive patients

Curi et al[19] have reviewed 112 vascular access procedures (48% autologous fitulae, 52% grafts) in 104 patients (42 HIV-positive; 62 HIV-negative). Prosthetic graft infection rates at 2 years were increased and patency rates were decreased in HIV-positive patients compared with HIV-negative patients and those who were HIV-positive and had autologous AV fistula. There were no differences in patency rates or infection rates of autologous access procedures between HIV-positive and HIV-negative patients. Long-term graft patency rates were not affected by HIV status, and CD4+ lymphocyte counts were not predictive of infection. Because the prosthetic graft infection rates exceeded those of the autologous access procedures, the authors strongly recommend the use of autologous AV fistulae in all HIV-positive patients, regardless of CD4+ count.

The future: Dialock device

Canaud et al[20] have reported their preliminary experience with a subcutaneously implantable chamber connected to catheters placed in the right atrium via the right internal jugular vein (Dialock, Biolink Corporation, Massachusetts) in 10 haemodialysed patients. The valve is accessed percutaneously with needle cannulae for each dialysis session. The average duration of use was 5.7 patient-months (1.3-9.6 months). Only three episodes of bacteraemia occurred in the early phase of the study and appropriate antibiotics cured these. No device was removed because of infection. Skin condition at the puncture sites has remained satisfactory in all patients. Effective blood flow was 307 ± 3.3 ml/min. The Dialock device could offer

an alternative to catheters, which are associated with a significant risk of infection, but further long-term clinical studies are needed to determine its place in vascular access.

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