3. Strategies for access creation

Guideline 3.1. The access should provide sufficient blood flow to perform adequate haemodialysis (Evidence level II).

Guideline 3.2. Autogenous arteriovenous fistulae should be preferred over AV grafts and AV grafts should be preferred over catheters (Evidence level III).

Guideline 3.3. The upper extremity arteriovenous fistula should be the preferred access and should be placed as distal as possible (Evidence level III).

Guideline 3.4. Fistula maturation should be monitored to allow pre-emptive intervention if needed (Evidence level III).

Rationale

For decades there have been remarkable differences in strategy for access creation between Europe and the USA. In Europe, the majority of new and incident patients receive autogenous arteriovenous fistulae (AVF), in the USA prosthetic graft placement remains the access of choice in most of the dialysis facilities (AVF 80 vs 24%; graft 16 vs 70%). The reason for this marked difference is not clear, although patient comorbidity seems to be more pronounced in USA and this could influence the strategy for access creation. Data from DOPPS (Dialysis Outcome and Practice Pattern Study) showed that rates of diabetes mellitus (46 vs 22%), peripheral arterial obstructive disease (PAOD) (23 vs 19%), coronary artery sclerosis (37 vs 25%) and obesity are significantly higher in the American dialysis population [1,2]. It is estimated that an AVF needs 0.2 interventions per patient/year compared with 1.0 intervention per patient/year for prosthetic graft fistulae for access salvage. In addition, long-term primary access survival (patency rate) differs significantly, ranging from 90% to 85% for AVF and from 60% to 40% for graft at one and 2 year of follow up [3]. With intensive access monitoring and surveillance, the secondary survival of grafts may rise due to a pre-emptive stenosis repair policy. The patency rate for grafts may be comparable with AVFs, ranging from 90% to 70% at 1 and 2 years of follow-up, respectively.

Ifudu et al. [4] stated that grafts do not permit the delivery of better haemodialysis than autogenous arteriovenous fistulae. They analysed 214 patients over a period of 1 month by urea reduction ratio; serum albumin concentration was used as a secondary outcome measure of dialysis adequacy [4].

Primary choice for vascular access

Autogenous AVF creation

Radial-cephalic AVF. The wrist radial-cephalic (RC) AVF is the first option for access creation. When the RCAVF matures adequately, it may function for years with a minimum of complications, revisions and interventions. The high early thrombosis/non-maturation percentage is the major disadvantage of this access and is usually influenced by patient factors like age, diabetes mellitus and the presence of cardio-vascular disease. Early failure rates range from 5% to 30% [5,6] and long-term patency from 65–90 to 60–80% at one and 2 years of follow-up, respectively. The incidence of thrombosis (0.2 events per patient/year) and infection (2%) is low.

Proximal forearm AVF. When a wrist RCVF is impossible due to poor vessels a more proximally located anastomosis from the mid-forearm to the elbow between the radial artery and cephalic vein may be employed.

Brachial-cubital/cephalic/basilic AVF. When peripheral vessels are too tiny and diseased for the creation of an RCAVF, more proximal fistulae are indicated at the elbow and upper-arm region. These AVFs (brachial-cubital ¼ Gracz; brachial-cephalic and brachial-basilic) generate a high blood flow which is favourable for high-efficiency dialysis. The incidence of thrombotic and infectious complications is low and long-term outcome is usually good [7–17]. The major disadvantages of these high-flow AVFs are the risk of distal hypoperfusion, which may lead to symptomatic hand ischaemia, and high-output cardiac failure, particularly in patients with coronary artery disease and/or cardiac failure [18].

Early access failure and interventions

The success rate for AVFs should be enhanced by pre-operative vessel assessment (see Guideline 2), perioperative vasodilatation [19] and post-operative monitoring of maturation. Access blood flow measurement by Doppler ultrasound at day 1 and 7 after operation is indicative of successful maturation. AVFs with initial blood flow rates of <400 ml/min fail to mature in the majority of cases [20,21]. Increased post-operative blood flow through the AVF with high shear stress on the vessel wall initiate the process of vessel adaptation (remodelling) resulting in vessel dilatation and further flow increase. Inability of vessel adaptation is usually due to the presence of significant stenoses or small arterial inflow vessels. Diagnostic angiography or ultrasound evaluation is indicated when there is failure of maturation. Percutaneous intervention (PTA) is indicated for any stenosis, and when not successful surgical revision can be considered [22–24].

The use of non-penetrating vascular clips for arteriovenous anastomosis may cause less endothelial cell damage and reduce the smooth muscle cell proliferation which leads to intimal hyperplasia (IH) [25–27].

Patient variables and outcome of vascular access

Several studies have shown that patient variables may have an important impact on the choice and outcome of vascular access. Age may have an influence on post-operative blood flow in newly created autogenous fistulae, which results in a slightly higher failure rate compared with young patients (18.9 vs 13.6%) [28]. However, the combination of age and diabetes does have an impact on fistula outcome with significantly higher failure rates (28.6%). Large European, Australian and American population-based studies have shown an increased percentage of grafts in elderly patients. In Europe, the use of grafts increased from 5% in patients <45 years to 8.8% in patients >75 years of age [29,30]. In Australia and USA, significant odds ratios were calculated indicating age as a predictive factor for graft use in incident and prevalent patients. In addition, grafts were associated with poor outcome in terms of primary failure and with a higher incidence of revisions compared with fistulae [31–34]. On the other hand, grafts may do well in the higher age group over 70 years. Staramos et al. [35] showed better patency at 2 and 3 year for prosthetic grafts compared with fistulae. This difference can be explained by the high number of dropouts due to early failure of the fistulae (24 vs 11%).

Women usually have smaller arteries and veins and, therefore, may do worse compared with men. And this may be the reason for poorer maturation and survival rates of vascular access. However, the literature remains contradictory. Caplin et al. [36] showed that arterial and venous diameters were not significantly different between men and women and functioning fistulae were created in 72% of the female and 77% of the male patients. In a meta-analysis of RCAVFs, women had similar maturation and 1-year patency rates as men. It is possible that pre-operative vessel selection for AV anastomosis influenced the outcome of access creation, irrespective of gender [5].

Other studies showed that female gender was associated with an increased use of grafts and a higher number of access revisions [30,32,34,37–40]. In the HEMO study, Allon et al. [41] found female gender, PAOD, black race, body mass index (BMI) and older age, significant predictor variables for the chance on fistula use. In addition, they found remarkable differences in the percentage of fistulae used in the different dialysis facilities (ranging from 4% to 77%).

Influence of comorbidity on vascular access creation and outcome

During the past decade there has been a shift in the aetiology of end-stage renal failure. Diabetes mellitus and arteriosclerosis are now the most important causes for dialysis treatment. The presence of diabetes and concomitant arteriosclerosis may have an additional negative impact on the chance of successful access creation [38]. These patients usually have poor, thickened and calcified arteries with proximal and/or distal vessel obstruction [42]. Access creation is more difficult, and the risk of symptomatic ischaemia of the upper and lower extremity due to access-induced steal syndrome is significant (see Guideline 9). Many studies report a correlation between the use of prosthetic graft AVF and the prevalence of diabetes in their population. The probability of graft thrombosis is significantly higher in diabetic patients, which results in decreased graft survival [43]. On the other hand, autogenous fistula creation can certainly be successful in patients with diabetes. Similar percentages of primary fistula creation with the use of comparable vessel diameters in non-diabetic and diabetic patients have been reported but more vessel calcifications were detected in diabetics [44]. Excellent results of primary fistula creation even in diabetics have been described by Konner et al. [17]. Three types of fistulae were created and none of the patients needed grafts. RCAVFs were created in 62 and 23% of patients (non-diabetics vs diabetics), while more proximal forearm and elbow AVFs were needed in diabetics (77%). Primary access survival was similar, however, secondary survival was better in non-diabetics at 2 years of follow-up. Ischaemia occurred significantly more frequently in the diabetic group (7 vs 0.6 events per 100 patient/years).

Homocysteine levels do not have any influence on vascular access failure [45], while elevated lipoprotein among black dialysis patients may be a risk factor for access complications [46]. Chou et al. [47] identified in a retrospective analysis CRP as an independent predictor for AV fistula thrombosis. The association between specific drug use and access failure was investigated in the DOPPS study. Treatment with calcium channel blockers, aspirin and angiotensin-converting enzyme inhibitors resulted in improved graft and fistula patency [48].

Non-patient variables and success of fistula creation

Late referral and starting dialysis treatment with a central venous catheter reduce the chance of successful autogenous fistula creation [49–51]. Experience and dedication of the physician performing vascular access surgery have a considerable influence on outcome. Prischl et al. [52] showed that the experience of the operating surgeon was the major determinant for the patency of RC fistulae. Some nephrologists create vascular access themselves and it has been shown that this approach may result in a higher number of functioning fistulae [53,54].

Vascular access morbidity, hospitalization and mortality

The probability of any access-related hospitalization is greater for patients with grafts than for those with fistulae. Reasons include thrombosis, infection and septicaemia [55–58]. In diabetic patients, the mortality rate is higher for those with grafts or central venous catheters, compared with those with autogenous AVF. In particular, there were more infection-related deaths in both diabetic and non-diabetic patients with central venous catheters compared with those with AVF. AV shunting may increase cardiac risk and death, however, this hypothesis could not been proven in a large patient group [59]. On the other hand, left ventricular hypertrophy does occur in patients with vascular access [60] and may be normalized after access closure in patients with functioning renal transplants [61].

Second choice for vascular access

Upper extremity non-autogenous vascular access

When autogenous AVF creation is impossible or the fistula has failed, one may decide to implant grafts as a vascular access conduit. Greater saphenous vein translocation or homologous saphenous vein implants have been used for some time with moderate results [62]. Nowadays bovine mesenteric vein (Procol®) or ureter (Synergraft®) are popular materials as an alternative access conduit, with acceptable patency and low infection rates [63]. Prosthetic grafts are available as polyurethane (Vectra®) [64], poly-ester (Dacron) and poly-tetrafluoroethylene (Goretex® ; Impra®) material. Short-term functional patency is usually good, but stenosis formation (mostly at the graft-vein anastomoses) will lead to thrombotic occlusion within 12 to 24 months. The primary patency rate of prosthetic graft AVFs vary from 60% to 80% and from 30% to 40% at 1 and 2 years of follow-up. Secondary patency ranges from 70% to 90% and from 50% to 70% at 1 and 2 years, respectively [65–69]. Intimal hyperplasia (IH) with smooth muscle migration and proliferation and matrix deposition is the major cause for stenosis formation and thrombosis. The aetiology of IH is unknown, however, high shear stress will denudate the endothelial layer, resulting in platelet adhesion and initiation of a cascade of proteins that stimulate the smooth muscle cells to proliferate and migrate [70–74].

Grafts may have similar outcomes compared with fistulae, in elderly patients in particular. Staramos et al. [35] showed good results of graft implantation in very old patients. They argued that this patient group has a very limited life expectancy and early cannulation may be considered with the advantage of avoiding central venous catheters. Also the risk on non-maturation is low as compared with autogenous fistulae.

Measures to improve graft patency

Numerous experimental and clinical studies have been employed to outline the influence of type of graft and graft design on graft patency. Modulating the geometry of the arterial inlet and/or venous outlet of the graft could possibly have a beneficial effect on IH. Clinical studies using tapered (at the arterial side of the graft) grafts did not show better patency rates nor did cuff implantation at the venous anastomosis. However, primary patency did improve with the use of a cuff-shaped prosthesis (Venaflo®) [75–79]. Compliant grafts could probably influence IH by the better matching of the stiff prosthesis with the compliant vein at the anastomotic site. However, in clinical studies this feature was not proven [80].

Anticoagulants and graft patency

The use of warfarin or aspirin on graft survival has been studied [81–83]. In a randomized controlled trial, time-to-graft failure was not significantly different in the treatment group receiving warfarin compared with controls. However, major bleeding occurred in 10% of patients in the warfarin group compared with none in the control group [84]. In the DOPPS study, patients that used anticoagulants such as warfarin, showed even worse graft survival [48]. In another study, aspirin and dipyridamole (Persantin ®) administration was compared with a placebo group. Only dipyridamole showed a beneficial effect on thrombosis with a relative risk of 0.35 ($P = 0.02$) [85]. Kaufman et al. [86] showed no effect of aspirin and clopidogrel (Plavix®) on graft thrombosis and in their randomized study the risk of bleeding complications was substantial.

A Cochrane database study showed good results of ticlopidine on AVF and graft patency in a total number of 312 patients [87]. The administration of pentoxifylline does not improve graft patency [88].

Radiation and graft patency

External beam radiation and intravascular brachytherapy have been administered to prosthetic graft AVFs to inhibit smooth muscle cells to proliferate at the venous anastomosis [89]. In animal studies, beneficial effects could be demonstrated, however, in patient groups no improvement in graft patency was shown and the risk of adverse effects such as infection increased [90]. Randomized studies could not show any advantage of external radiation on graft patency rates [91,92].

Lower extremity autogenous and non-autogenous vascular access

Probably the only indication for lower extremity vascular access is bilateral central venous or caval vein obstruction, which endangers the outflow of upper extremity AVF. Saphenous or superficial femoral vein transposition are primary options for thigh AVF with a relatively high risk on ischaemia (see Guideline 9). Clinical follow-up and primary flow reduction by tapering of the anastomosis are indicated to prevent ischaemia [93,94]. Prosthetic graft implantation in the thigh has a high risk of infection and septicaemia [95–97].

Third choice for vascular access

Central venous catheter

There may be a few indications for permanent tunnelled central venous catheters as an (primary) option for vascular access. Patients with severe access-induced upper extremity ischaemia or cardiac failure may be candidates for catheters. Life expectancy for these patients is likely to be poor and the need for vascular access limited to some months. The same holds true for patients with disseminated cancers.

Recommendations for future research

Despite the rationale of creating autogenous fistulae for vascular access, research into the development of new non-thrombotic grafts and the prevention of IH remains of utmost importance.

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