Specialist Vascular Surgeons

Guidelines for Vascular Access
VASSA SAJS

VASCULAR ACCESS GUIDELINES

VASCULAR SOCIETY OF SOUTHERN AFRICA

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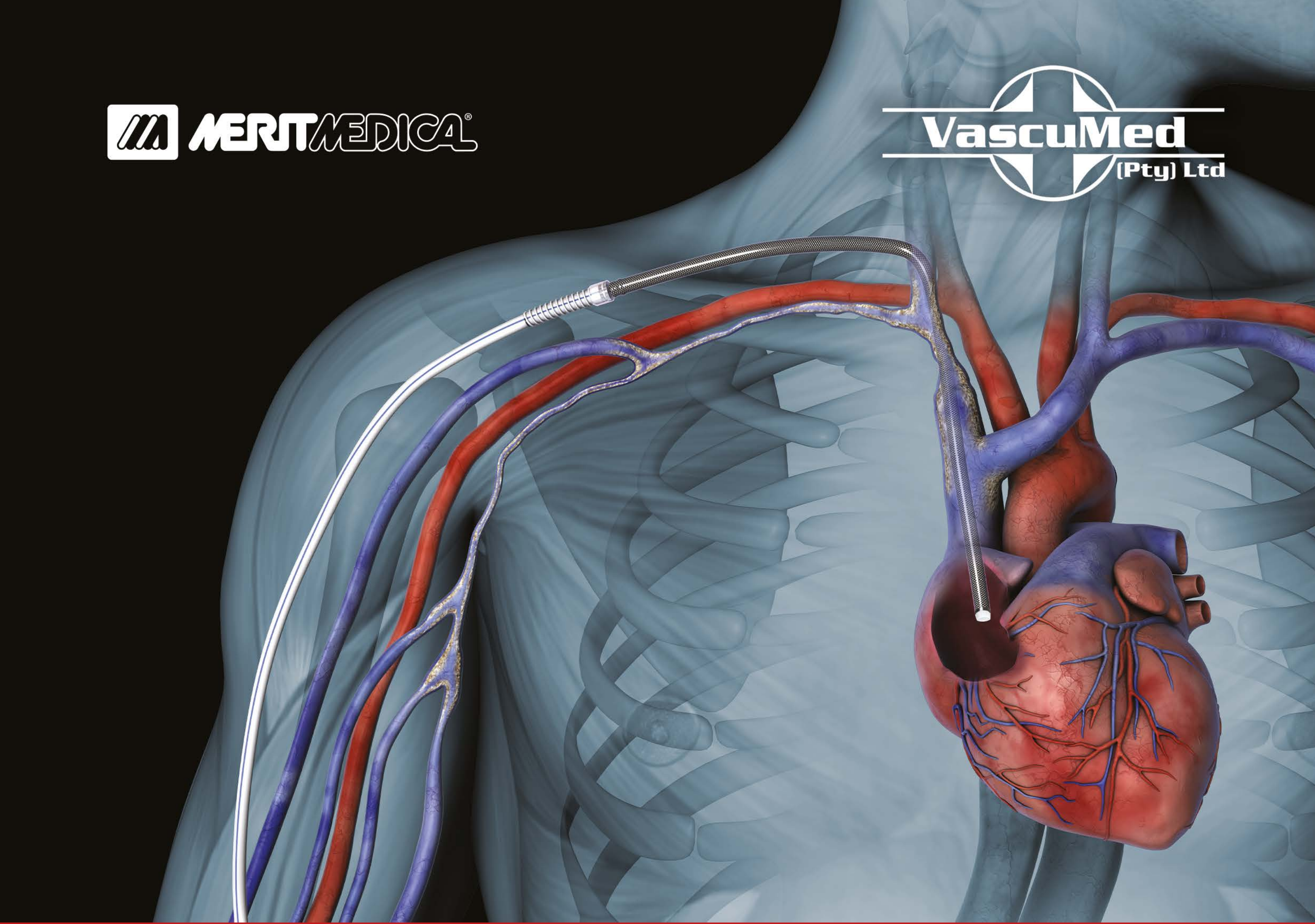
Levels of evidence and class of recommendations

It was agreed by the participants that there are many methods of evaluating the quality of data and making guideline recommendations on the basis of this information. A consistent easy-to-apply system is essential and, as a consequence, the method currently being used in most American cardiovascular guidelines would be adopted by VASSA.[1] This is reflected below.

VASSA would like to acknowledge our corporate members for their continued support of VASSA and Vascular Education Forum (VEF) teaching and training initiatives.



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1. Katzman et al., J Vasc Surg 2009
2. Gage et al., EJVES 2012

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GUIDELINES

VASCULAR ACCESS GUIDELINES

		SIZE OF TREATMENT EFFECT →			
		CLASS I *Benefit >>> Risk* *Procedure/treatment SHOULD be performed/ administered*	**CLASS IIa** *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform multiple procedures/administer treatment	**CLASS IIb** *Benefit ≥ Risk* *Additional studies with broad objectives needed; additional registry data* Procedure/treatment **MAY BE CONSIDERED**	**CLASS III** *no benefit or* **CLASS III** *Harm*
ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	**LEVEL A** Multiple populations evaluated* Data derived from multiple randomised clinical trials or meta-analyses	- Recommendation that procedure or treatment is useful/effective - Sufficient evidence from multiple randomised trials or meta-analyses	- Recommendation in favour of procedure or treatment being useful/ effective - Some conflicting evidence from multiple randomised trials or meta-analyses	- Recommendation's usefulness/efficacy less well established - Greater conflicting evidence from multiple randomised trials or meta-analyses	- Recommendation that procedure or treatment is not useful/effective and may be harmful - Sufficient evidence from multiple randomised trials or meta-analyses
	LEVEL B Limited populations evaluated* Data derived from a single randomised trial or nonrandomised studies	- Recommendation that procedure or treatment is useful/effective - Evidence from single randomised trials or nonrandomised studies	- Recommendation in favour of procedure or treatment being useful/ effective - Some conflicting evidence from single randomised trials or nonrandomised studies	- Recommendation's usefulness/efficacy less well established - Greater conflicting evidence from single randomised trials or nonrandomised studies	- Recommendation that procedure or treatment is not useful/effective and may be harmful - Evidence from single randomised trials or nonrandomised studies
	LEVEL C Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	- Recommendation that procedure or treatment is useful/effective - Only expert opinion, case studies, or standard of care	- Recommendation in favour of procedure or treatment being useful/ effective - Only diverging expert opinion, case studies, or standard of care	- Recommendation's usefulness/efficacy less well established - Only diverging expert opinion, case studies, or standard of care	- Recommendation that procedure or treatment is not useful/effective and may be harmful - Only expert opinion, case studies, or standard of care

Introduction

Pradeep P Mistry

Chronic kidney disease (CKD) is a common public health problem affecting mainly the elderly. In younger adults, the prevalence of CKD is worryingly increasing in hypertensive and diabetic patients. The initiation of timeous renal replacement therapy (RRT) is life-saving to these patients. The management of vascular access (VA) should be multidisciplinary with the approach to planning, creation and salvage of the vascular access. With improved treatment outcomes and consequently improved life expectancy, we are faced with new challenges in "abnormal physiology", while trying to prolong the patency of VA and preserve the vascular bed for future VA procedures.

The Vascular Society of Southern Africa (VASSA) has undertaken to establish good practice guidelines in the various common conditions in the vascular surgical field. As part of this programme, we convened a meeting, in conjunction with nephrology colleagues, to establish the vascular access guidelines. This meeting was held in Pretoria where members of the task force were asked to prepare and present various topics with the aim to create consensus and produce recommendations based on local pathology, the latest evidence, local expertise and resources.

This guideline aims to provide evidence-based best practice for patients who require VA. Many recommendations are based on consensus opinion and hence should not be regarded as "doctrine". This document, while very extensive, is limited by the fact that there is a paucity of local and regional publications in this field. The preparation of this document has highlighted the need for local peer review publications in the management of CKD to better customise these guidelines for local practice.

Planning dialysis access

Early referral to renal services has been shown to lower costs and decrease morbidity and mortality.[2-6] Despite this, 25–50% of patients begin renal replacement therapy one to four months after seeing a nephrologist.

The options for renal replacement therapy include peritoneal dialysis, haemodialysis and kidney transplantation. Patients likely to progress to end-stage renal disease (ESRD) need to be identified. The rate of progression of renal disease is highly variable depending on aetiology and various patient factors. The 2015 Kidney disease outcomes quality initiative (KDOQI) guidelines recommend that patients with an estimated glomerular filtration rate (eGFR) < 30 mL/min/1.73 m^2 should begin education concerning renal replacement therapy.[7]

Successful haemodialysis is dependent on stable access to the bloodstream. The ideal initial placement is in the non-dominant upper limb. All venepuncture should be restricted to the limb not planned for vascular access. All patients should be referred to a vascular surgeon at an eGFR between 20 and 25 mL/min/1.73 m^2.[8]

Recommendation

Early referral of patients with declining renal function [(eGFR) < 30 mL/min/1.73 m^2] to appropriate renal physicians and vascular access teams is recommended. (Good practice statement.)

Peritoneal dialysis – surgical aspects

Peritoneal dialysis (PD) provides short- and long-term clinical outcomes that match or exceed in-centre haemodialysis. PD also provides patients with several lifestyle advantages that are not provided by haemodialysis and is less costly to the healthcare system.[9,10]

Recommendations

A life plan for kidney care

- Timely referral will allow a life plan for kidney care to be discussed with the patient. The life plan acknowledges that a patient may require throughout his/her life more than one renal replacement therapy modality, selected to maximise life span and quality. The life plan must continually adapt to changes in the patient's clinical course. *(Class IIa recommendation/Level C evidence)*
- PD can work well as long-term therapy for almost any patient and should be included in most options discussions.[11] *(Class IIa recommendation/Level B evidence)*

The access team

- Each centre should have a dedicated team involved in the implantation and care of peritoneal catheters. The access team should comprise nurses, nephrologists, and surgeons who have experience in PD.[12] *(Class IIa recommendation/Level C evidence)*

Patient selection

- The most important qualification for the ideal PD candidate is having the desire to perform his or her own care. Ideal candidates should have significant residual renal function; minimally or no abdominal surgery; understand instructions and be able to communicate; have sufficient eyesight, manual strength, and dexterity; suitable environment to store supplies and perform exchanges.[11] *(Class IIa recommendation/Level C evidence)*
- The only absolute contraindication to treatment with PD is lack of a functional peritoneal membrane. Relative contraindications include peritoneal scarring, physical, cognitive, or psychological impairment; lack of appropriate environment, anuria, large patient size, active inflammatory process or cancer, surgical stomas, large abdominal wall hernias and ventriculoperitoneal shunts.[11] *(Class IIa recommendation/Level C evidence)*

Urgent-start peritoneal dialysis

- Indicated for initiation of PD in patients with newly diagnosed ESRD who require dialysis initiation within two weeks after peritoneal dialysis catheter placement. *(Class I recommendation/Level B evidence)*

The implantation technique

- Local expertise at individual centres should govern the choice of method of PD catheter insertion. Each PD unit should have the ability to manipulate, re-implant and when necessary effect urgent removal of PD catheters.[13] *(Class IIa recommendation/Level C evidence)*

- No particular catheter type has been proven to be better than another.[14-17] *(Class I recommendation/Level B evidence)*
- A catheter of a suitable length should be used.[18,19] *(Class I recommendation/Level B evidence)*

Training for PD catheter insertion

- PD catheter insertion training should be available to all trainees with an interest.[20] *(Class IIa recommendation/Level C evidence)*
- PD catheter insertion should not be delegated to inexperienced unsupervised operators.[12] *(Class I recommendation/Level B evidence)*

Audit of PD catheter insertion

- There should be regular audit at not less than 12-month intervals of the outcome of catheter insertion as part of multidisciplinary meetings of the PD team and the access operators. Audit standards for catheter-related complications: > 80% of catheters should be patent at one year, bowel perforation < 1%, significant haemorrhage: < 1%, exit-site infection within two weeks of catheter insertion: < 5%, peritonitis within two weeks of catheter insertion: < 5%, functional catheter problem requiring manipulation or replacement or leading to technique failure: < 20%.[21] *(Class IIa recommendation/Level C evidence)*

Non-infectious complications of peritoneal dialysis catheters

Outflow failure

- An abdominal radiograph can elucidate the cause of outflow failure, particularly in those with severe constipation and/or catheter malposition. Recently implanted catheters have a radiopaque stripe, which permits radiographic visualisation of the catheter tip; the tip should not migrate significantly over time.[22] *(Class IIa recommendation/Level C evidence)*

Encapsulating peritoneal sclerosis (EPS)

- No single strategy to reduce the risk of EPS has been proven in clinical trials. There is no evidence that CT scanning has any value in predicting EPS.[23] PD should usually be discontinued after diagnosis of EPS with transfer to haemodialysis. *(Class IIa recommendation/Level C evidence)*

Radiological diagnosis

- The radiological technique of choice for the diagnosis EPS is CT scanning. *(Class 1 recommendation/Level B evidence)*
- Patients with suspected EPS should be referred or discussed early with units who have expertise in EPS surgery. Surgery should be performed by teams experienced in EPS surgery. *(Class 1 recommendation/Level B evidence)*

Abdominal hernias in continuous peritoneal dialysis

- Based on sensitivity, specificity and cost, we recommend computed tomographic peritoneography (CTP) as the initial diagnostic modality.[24-26] *(Class IIa recommendation/Level C evidence)*
- Patients who develop a hernia after the initiation of PD should undergo elective repair. The use of a polypropylene mesh prosthesis appears to decrease the risk of recurrent hernia and allows for the reinstitution of PD within several days of the hernia repair.[27-30] *(Class IIa recommendation/Level B evidence)*

Acute dialysis access

The indication for acute dialysis is when the patient develops acute kidney injury (AKI) or acute renal failure. This may be due to numerous causes which have been divided into pre-renal, renal and post-renal causes. The Acute Kidney Network has defined this as AKI developing within 48 hours which is manifested by the following:[31-34]

- an absolute increase in serum creatinine of 26.4 umol/l,
- a percentage increase of creatinine of 50% or more (1.5 times from baseline), or
- a reduction in urine output, defined as less than 0.5 ml/kg/hr for more than six hours.

Access site

Ultrasonography is essential[35,36] to insert dialysis catheters as it helps locate the vein and excludes thrombi. It has also been clearly shown to reduce the incidence of puncture-related complications.[1,6]

Central venous catheter complications

Central venous catheter (CVC) complications range from 5–19%.[37] Complications include vascular injury, air embolism, pneumothorax, and malposition and infection. Complications due to accidental arterial puncture can be limited by the use of ultrasound. Infection is responsible for the removal of about 30–60% of CVCs and hospitalisation rates are higher in central venous catheter patients than arteriovenous fistula (AVF) patients,[38] Infections are generally introduced at time of placement or via the entry site infections a few days later. Early removal of acute dialysis catheters and administration of appropriate antibiotics once infection is identified is essential. Early insertion of long-term dialysis catheters will also avoid catheter-related infections. Often patients with chronic catheters return with catheter-related bloodstream infection that requires removal of their catheters. Institution of in-travenous antibiotics and urgent insertion of a new acute dialysis line is required. Only when the infection is completely resolved should a replacement long-term catheter be inserted.

Catheter types, material and duration

Cuffed and non-cuffed catheters are available. Generally, non-cuffed catheters are used in the acute setting. The use is determined by several factors including duration of use, concurrent bacteraemia and the patient's general condition. A non-cuffed non-tunnelled approach is always used for urgent access. The long-term use of acute catheters is not recommended due to the absence of a cuff which has been proven to reduce infection rates. The expected duration with a non-cuffed catheter is usually one to two weeks after which removal or exchange to a new site is required as the rate of infection with acute catheters increases exponentially with time. Most importantly a catheter in the femoral vein should not be used more than five days due to the high risk of thrombosis.

Catheter design over the last few years has improved dramatically. New designs allow high flow rates with less recirculation and improve long term efficiency. Today most catheters are made from silicone or polyurethane, and there has been no overall difference demonstrated in function between the two types. Infection rates are similar with 3.6 infections per 1 000 days with silicone catheters and 3.5 infections per 1 000 days with polyurethane catheters.[39]

New catheters with antimicrobial coating reduce the rate of infections dramatically as evidenced by a reduction of bacterial colonisation by 44% and catheter-related bacteraemia by 79% in a recent report.[40]

Recommendations

- Acute dialysis to be commenced on failure of medical therapy. *(Class I recommendation/Level C evidence)*
- Acute dialysis to be instituted with a non-cuffed catheter rather than a cuffed catheter. *(Class IIa recommendation/Level C evidence)*
- The internal jugular (right before left) vein is the preferred primary site followed by the femoral then the subclavian veins. *(Class I recommendation/Level C evidence)*
- Duration of acute dialysis to be limited to two weeks. *(Class IIa recommendation/Level C evidence)*
- Femoral vein access to be limited to five days maximum due to the risk of thrombotic complications. *(Class IIa recommendation/Level C evidence)*

Catheter placement for exhausted vascular access

- All other dialysis access options must be salvaged or exhausted before considering long term dialysis catheter placement. *(Class I recommendation/Level C evidence)*
- Unconventional access should only be considered when all other alternatives to renal replacement and conventional access sites have been exhausted. *(Class I recommendation/Level C evidence)*

Tunnelled cuffed catheters for haemodialysis access

There remains no well-constructed randomised control trial to demonstrate the superiority of one form of venous access over another. However, evidence from multiple studies suggests that patients who commence haemodialysis should do so with an arteriovenous fistula as first choice, arteriovenous graft (AVG) as second, and a tunnelled venous catheter as third choice.

Dialysis catheter access site: the right internal jugular vein is the preferred placement site. The short and straight course of this vein to the superior vena cava allows a shorter catheter with high flow rates and reduced risk of catheter kink. The subclavian vein should be avoided unless absolutely necessary due to the high rate of venous stenosis.

Choice of tunnelled cuffed catheter: no one catheter has proven superior over its rival despite trials comparing various catheter designs.

Insertion technique: National Kidney Foundation Kidney disease outcomes quality initiative (NKF KDOQI) guidelines recommend the use of ultrasound and fluoroscopic guidance in the placement of these catheters because the risk of complications is significantly greater with the blind insertion.

Infection: remains the Achilles heel of any form of haemodialysis access.[41] Pastan reported a higher mortality rate with catheter dialysis when compared with AVF/AVG. Infection rates are reduced with tunnelled, cuffed catheters when compared with non-tunnelled dialysis catheters. Tunnelled catheters are always to be preferred to non-tunnelled catheters.

Tunnelled catheter exit sites should be cleaned with chlorhexidine 2%. The superiority of chlorhexidine over povidone-iodine has been established.[42] A Cochrane meta-analysis[43] investigated exit site strategy. Mupirocin (Bactroban®) ointment appears effective in reducing the risk of catheter-related bacteraemia. Insufficient reporting on mupirocin resistance was noted and needs to be considered in future studies. A lack of high-quality data on the routine use of povidone-iodine ointment, ointment and topical honey warrant larger randomised control trials. Despite the polysporin reduction in bacteraemia, mortality related to infection was not reduced by polysporin, mupirocin, or povidone-iodine. Insufficient data is available to determine whether a transparent or dry gauze dressing has the lowest risk of catheter-related infections.

Catheter lock solution is used routinely. Catheter lock solutions in clinical trials are gentamicin, heparin, taurolidine and citrate. Meta-analysis suggests antibiotic lock solution is superior in infection prevention, but concern remains regarding bacterial resistance. Taurolidine and citrate solutions are effective as lock solutions but less likely than antibiotic solutions to prevent infection. Further data is required to determine the best solution.[41-44]

Catheter-related bacteraemia incidence is reported at 1–10/1 000 patient days.[45] A number of approaches to reduce bacteraemia have been employed. These include prolonged systemic antibiotic treatment that has the highest risk of bacteraemia recurrence, treatment with systemic antibiotics combined with guidewire exchange of the catheter, treatment with systemic antibiotics and removal of the venous catheter or use of antibiotic lock in combination with systemic antibiotics. Systemic antibiotics are the basis of therapy. Catheter removal is the ideal approach but has to be balanced against immediate alternative dialysis access. Recurrence rates are particularly high with *staphylococcus aureus bacteraemia* when venous catheters are left in situ and this includes catheters exchanged over a guidewire. Catheter-related sepsis is a potentially lethal event and therefore catheter removal should be performed urgently if the patient is seriously ill or if there is evidence of metastatic infection (endocarditis, discitis, osteomyelitis, septic arthritis, spinal/epidural abscess, large atrial thrombi). Ravani et al. in a 2013 meta-analysis of cohort studies including 586 337 patients reported patients dialysing with catheters had a higher risk of all-cause mortality, fatal infections and cardiovascular events when compared with AVF and AVG.[46] In a cost analysis study, Ortega et al. found that patients who were dialysed with a fistula throughout the study compared to those receiving catheter dialysis had the lowest cost per death prevented (Euro 3 318 versus Euro 9 471)[47].

Tunnelled central vein catheter dysfunction is a common event in haemodialysis. There is no evidence that one thrombolytic agent is superior to others in catheter clearance and the success rate is similar with these agents (urokinase, tissue plasminogen activator, alteplase).[48]

Future directions

Clarity on the role of AVF access versus catheter dialysis access in the elderly is necessary and results of a randomised trial are awaited.[49]

Comparative analysis of lock solutions and thrombolytic agents in reducing the risk of catheter thrombosis and for unblocking of catheters is required.

It is also necessary to improve the catheter design to reduce re-circulation, fibrin sheath formation, thrombosis and infection.

The optimal mode of treatment of infections of cuffed haemodialysis catheters must be defined.

Recommendations

Selection of access type

- Tunnelled cuffed haemodialysis catheters should only be placed as a last resort or in emergency situations when more permanent upper limb access is not available for dialysis. *(Class I recommendation/Level B evidence)*
- Tunnelled cuffed haemodialysis catheters for chronic haemodialysis use can be considered when AVF/AVG is impossible or where there is limited life expectancy. *(Class IIa recommendation/Level B evidence)*[50]

Ultrasound-guided access

- Ultrasound-guided insertion technique is mandatory to ensure successful cannulation and avoid complications. *(Class I recommendation/Level A evidence)*

Catheter choice

- No recommendation can be made as to the optimal type or design of tunnelled, cuffed catheters.

Complications of venous access

Prevention of catheter-related infections[51]

- Minimising the use of venous catheters: venous catheters should be employed as a method of last resort for long term haemodialysis access to reduce the overall risk of infection. *(Class I recommendation/Level B evidence)*
- Minimising the risk of catheter-related infection: Aseptic technique should be mandatory at every manipulation of haemodialysis catheters. *(Class IIa recommendation/Level C evidence)*
- Minimising the risk of catheter-related infection: the catheter exit site should be cleaned with chlorhexidine 2%. *(Class I recommendation/Level B evidence)*
- Minimising the risk of catheter-related infection: antimicrobial/antibiotic lock solution should be used to reduce catheter-related bacteraemia. *(Class I recommendation/Level B evidence)*
- Treatment of haemodialysis catheter infection and related bacteraemia: haemodialysis catheters should be removed in all seriously ill haemodialysis patients with catheter-related bacteraemia. *(Class I recommendation/Level B evidence)*
- Prevention and treatment of haemodialysis catheter occlusion: occlusion may be prevented by the use of an antithrombotic lock solution, and catheter occlusion should be managed by using thrombolytic agents before catheter exchange or replacement. *(Class IIb recommendation/Level C evidence)*

Optimal medical therapy for vascular access patients

Neointimal hyperplasia is the major cause of a permanent vascular access failure in haemodialysis patients. Systemic medical adjuvant drugs like intraoperative heparin, recombinant human pancreatic elastase, antiplatelet agents, omega-3 polyunsaturated fatty acids, statins, inhibitors of angiotensin and calcium channel blockers may reduce development of neointimal hyperplasia and thrombosis of the access. From a review of 38 papers, there were no clear guidelines for medical supportive prevention or treatment of vascular access thrombosis. The evidence is often of a poor quality and provides contradictory results of efficacy.

There is no clear benefit of reduction of thrombosis of any routine antiplatelet treatment of vascular access. In view of some positive reports presenting improvement in patency of vascular access, it seems advisable to treat patients with aspirin or clopidogrel. In a large retrospective review involving 24 847 patients, no benefit of clopidogrel in reduction of thrombosis of AVF was observed, but there was a significant decrease in loss of primary patency of AVG. It seems that intraoperative application of vonapanitase and treatment with ticlopidine and dipyridamole provides improvement of patency of AVF and AVG. There is no beneficial influence on access patency of intraoperative use of heparin, fish oil, or treatment with statins. The use of angiotensin converting enzyme (ACE) inhibitors, angiotensin receptor blockers and calcium channel blockers were reported in two retrospective reviews (Taiwan/USA, 1996–2006) of 25 076 patients 22 436 with AVF and 2 640 with AVG. All three agents used for treatment were associated with increased primary patency of the first created AVF or AVG.

Recommendations

- Use of intraoperative heparin during routine arteriovenous access formation does not improve patency of access and is not recommended.[52-56] *(Class IIb recommendation/Level A evidence)*
- Recombinant human type pancreatic elastase (vonapanitase) applied intraoperatively directly to anastomosis improves patency of AVF/AVG. Vonapanitase is hence recommended to improve patency when available.[57-60] *(Class IIa recommendation/Level A evidence)*
- Treatment with omega-3 fatty acids (fish oil) cannot be recommended for the prevention of AVF/AVG thrombosis.[61-63] *(Class III recommendation/Level A evidence)*
- ACE inhibitors, angiotensin receptor blockers and calcium channel blockers should be recommended for improvement of patency of vascular access in haemodialysis.[64-67] *(Class IIa recommendation/Level A evidence)*

- The use of aspirin to improve the primary patency of AVGs is recommended.[68-81] *(Class IIa recommendation/ Level A evidence)*
- Clopidogrel is recommended to increase primary patency of AVFs but not for primary patency of AVG.[82-86] *(Class IIa recommendation/Level A evidence)*
- Statins are not recommended to improve AVF/AVG patency and have shown increased mortality in renal failure patients.[87-89] *(Class III recommendation/Level B evidence)*

Autogenous venous access and sequence of AVF creation

In a recent systematic review and metanalysis on the outcomes of vascular access for haemodialysis, Almasri and colleagues found the overall primary patency rate at two years to be higher for fistulae than for grafts and catheters (55%, 40% and 50% respectively). They also reported that mortality at two years was lowest with fistulae when compared to grafts or catheters (15%, 17% and 26% respectively).[90] In addition, when compared to AVG, fistulae were associated with a significant reduction in the risk of access-related infection (RR 0.18; 95% CI 0.11–0.31) as well as a reduced re-intervention rate to maintain functional patency.[91]

The major drawback of the autogenous fistula has been the high rate of primary failure, which has been reported to be between 15–40%.[91,92] These failures frequently contribute to prolonged catheter use with its associated complications.

When constructing an autogenous access, the most distal site with adequate vessels should be utilised. This is to allow preservation of as much vein as possible, should future access at a more proximal site be required.

Consideration should also be given to creating the access in the non-dominant arm, provided the vessels are of adequate calibre, as this allows the patient to remain as functional as possible during dialysis. The use of bilateral upper extremity arterial and venous ultrasound has been shown to be an invaluable aid in selecting the optimal site for access placement. Silva and colleagues demonstrated that the use of preoperative ultrasound increased the creation of fistulae from 14% to 63% and reduced the rate of primary failure from 36% to 8.3%.[93]

The radiocephalic fistula, whether performed at the anatomic snuffbox or at the wrist, represents the first choice for access creation as, once matured, it may function for years with a minimum of complications, revisions and interventions.

Based on the results of preoperative vessel mapping, it is recommended that for radiocephalic fistulas, the minimum arterial and venous diameter should be at least two mm.[94] The major disadvantage of this fistula is the high rate of early thrombosis and non-maturation, which may be influenced by a variety of patient factors, such as age, diabetes mellitus and the presence of atherosclerotic disease.[95]

Should a radiocephalic fistula not be possible at the wrist, an anastomosis may still be fashioned between the radial artery and the cephalic vein at a more proximal site within the forearm.

Should a forearm fistula not be possible, the brachiocephalic fistula should be considered as the next possible option. A variety of possible configurations are possible including anastomosis to the cephalic vein, the deep perforating vein or the confluence of the basilic and cephalic veins.[96] The brachiocephalic fistula has the advantage of a more rapid maturation time with greater flow rates and a lower incidence of primary failure as compared to the radiocephalic fistula. The drawback of this fistula is the greater incidence of distal hypoperfusion and the cephalic arch stenosis.[97]

In patients in whom the cephalic vein is inadequate for use, the basilic vein presents an additional option for the creation of an autogenous fistula. The brachiobasilic AVF (BBAVF) offers high flows and a higher rate of maturation than the brachiocephalic fistula.[98] It also offers improved patency with lower rates of re-intervention as well as infection when compared to AVG.[99] The major drawback of this fistula is that it is technically challenging to create as it requires transposition of the basilic vein from its medial location in the upper arm, to allow for anastomosis to the brachial or proximal radial artery. These fistulae may be performed as a single or two staged procedure, with no difference in outcome on meta-analysis.[100] The forearm basilic vein may also be transposed for anastomosis to the radial artery at the wrist. An additional factor that has been shown to affect the outcome of an autogenous fistula has been the choice of anaesthesia as well as the experience of the surgeon. In a recent meta-analysis, radiocephalic fistulae created under regional anaesthesia had improved short term patencies as compared to those created under local anaesthesia (OR 0.28; 95% CI 0.14–0.57).[101] With regard to surgical experience, it has been demonstrated that rates of maturation are lower when fistulae are performed by surgeons who perform less than 25 fistulae during their training.[102]

Recommendations

- An autogenous AVF is recommended as the primary option for vascular access. *(Class I recommendation/ Level A evidence)*
- The radiocephalic AVF is recommended as the preferred vascular access in patients with suitable vessels. *(Class I recommendation/Level B evidence)*
- The recommended minimum arterial and venous diameters for a forearm autogenous fistula should be at least two mm. *(Class IIa recommendation/Level B evidence)*
- When the upper arm cephalic vein is unavailable, a basilic vein transposition AVF should be considered in preference to an AVG. *(Class IIa recommendation/ Level A evidence)*
- Regional anaesthesia should be the preferred form of anaesthesia for patients undergoing autogenous access creation. *(Class IIa recommendation/Level B evidence)*

Dialysis access in specific scenarios – elderly, morbid obesity and implantable cardiac devices

Elderly

Elderly patients (over 65 years old) who are on chronic renal dialysis have a shorter life expectancy. In the elderly, the AVF first policy may be a challenge due to their comorbidities and age-related changes to their vasculatures.[103]

Hence, access that is most likely to function well with the fewest reinterventions, rather than longevity is the goal.[104]

Elderly patients have a primary AVF failure rate ranging from 52–70% and twice the risk of fistula non-maturation at six months.[105-107] In contrast AVG has a primary failure rate of around 28%.[105-108]

Elderly patients have increased vascular access-related morbidity and mortality with each intervention.[109] More interventions are needed to assist with maturation and maintenance after AVF than with AVG.[110,111]

Obesity

Obese patients have a reduced catheter life span in PD due to mainly to less successful treatment of infection.[112] Abdominal obesity may make it impossible for a traditional PD catheter insertion and these patients may benefit from extended catheters with exit in upper abdomen. Extended catheter survival at three years is 71%, significantly lower than the 80% of traditional catheters.[113]

Venous access primary failure is more common in obese patients mainly due to difficulty in fistula creation.[114,115] Fistula elevation or transposition, liposuction and lipectomy have been used to improve utilisation.[116]

Cardiac devices

AVF should not be performed ipsilateral to intra-cardiac device (ICD) as primary failure rate is significantly higher compared to contralateral placement, 79% versus 35% (p = 0.02).[117] Stenosis rate after ICD can be as high as 64% but only 2.6% of patients will develop signs of venous hypertension.[118]

Recommendations

- Elderly patients should have an AVG first policy. *(Class IIa recommendation/Level C evidence)*
- In obese patients, AVF should be considered first. *(Class I recommendation/Level C evidence)*
- AVF should be performed in the arm contralateral to implantable cardiac devices. *(Class IIa recommendation/Level C evidence)*

Monitoring and surveillance of established arteriovenous access

A well-functioning vascular access (VA) provides a flow rate of 350–450 ml/minute during 3–4 hours of haemodialysis without recirculation. Access flow and durability are key components.

Thrombosis is the leading cause of loss of VA patency and function. It necessitates immediate hospitalisation and secondary interventions to restore patency. Introduction of a central venous catheter is often necessary and adds to increased costs, morbidity, emotional stress and impacts on the patient's quality of life.[119,120] Overall, 40% of AVF fail within a year of creation and AVG fare worse.[121] Although thrombosis may occur as a complication of extrinsic compression, needling, hypotension and hypercoagulability, stenosis is the main cause (> 75%). Stenosis is initiated by endothelial injury due to shear stress from turbulent flow and mechanical trauma. Ongoing neo-intimal hyperplasia and smooth muscle cell proliferation results in progressive narrowing.[122] The commonest site for stenosis is at the juxta-anastomotic area or in the outflow venous segment (70–80% AVF) and at the venous anastomosis (80–85% AVG).[123] Stenosis severity is the most important endpoint in guiding clinical decision making. The development of a significant stenosis with low flow results in a dysfunctional VA leading to extended treatment times for a dialysis session. Early diagnosis of stenosis can provide a golden opportunity to intervene promptly and prevent thrombosis. Monitoring and surveillance are the "keys" to VA maintenance and survival.

Monitoring

Physical examination and clinical evaluation by skilled staff at each haemodialysis session provides a simple, cost effective, bedside tool and should be the "backbone" of any surveillance program. "Look, listen, feel" provides clues of VA dysfunction.

Abnormalities related to the haemodialysis session, including prolonged bleeding from the needle site, difficulty with needling and aspiration of clots are predictors of an at-risk VA.

Several studies have confirmed the accuracy of monitoring to detect stenosis with 85–95% sensitivity and 75–85% specificity.[124] It can provide equivalent benefit to surveillance but should be complementary.[125]

Surveillance

These involve diagnostic strategies based on evaluation of VA function and anatomy. Developing stenosis reduces flow and alters pressure in VA. Measuring these changes can prove useful as a surrogate for detection of stenosis. Vessel wall size, haemodynamic variability and timing during haemodialysis may affect individual measurements.[126] The combination of both flow and pressure have shown to be better predictors of functional severity of stenosis.[16] The frequency of measurements is dictated by VA type: KDOQI guidelines recommend monthly for AVG and three-monthly for AVF.[127] Recording of serial measurements allows identification of abnormal trends.

Flow

VA flow (Qa) is currently the gold standard and can be measured indirectly using in-line techniques during haemodialysis. It does require specialised equipment and trained technicians. Qa achieves high sensitivity with a fair to good positive predictive value in detecting stenosis at a threshold of 600 ml/minute or > 25% drop.[128,129] Qa has been found to be a better predictor of inflow stenosis, especially with AVF.

Direct flow measurements can be obtained non-invasively by Duplex Doppler ultrasound scan (DDUS), outside of haemodialysis. Its accuracy is operator-dependent but has the advantage of imaging anatomic and flow abnormalities. Significant stenosis of > 50% is defined based on reduction in diameter as compared to an adjacent normal segment, doubling of peak systolic velocity or absolute minimum diameter of 2.7 mm.[130,131] The accuracy of DDU for identifying stenosis was reported as 81% (AVF) and 86–96% (AVG). It has excellent sensitivity but poor specificity (< 60%).[132]

Pressure

Static rather than dynamic venous pressure (VP) measurements are more reliable.[133] The ratio of VP normalised to mean arterial pressure (VAPR) is more useful and a value of > 0.55 is an indication of significant outflow stenosis in AVG. It has failed to show many advantages in AVF.[134]

HD efficiency

VA recirculation refers to the return of dialysed blood to the haemodialysis machine and is a reflection of haemodialysis inefficiency. The total recirculation rate per haemodialysis session is measured by the urea gap clearance with values of > 10% requiring investigation.[135] The haemodialysis delivery dose can be objectively measured via the amount of blood cleared of urea (Kt/V) or percentage of urea cleared (URR). Decreases in delivered haemodialysis dose are frequently associated with venous outflow obstruction.[136]

Intervention

The diagnosis of possible stenosis uncovered by monitoring and surveillance should be confirmed on an imaging study. DDU is the logical choice for the initial study prior to proceeding to angiography.[137,138] DSA is preferred above MRA due to concerns with gadolinium-induced NSF.[139] Computed tomography angiography (CTA) is less invasive and expensive than purely diagnostic DSA and should be considered when there is suspected central venous outflow obstruction.[140] Pre-emptive intervention may be either by percutaneous transluminal balloon angioplasty (PTA) or surgery, depending on availability of endovascular or surgical experience. The evidence for pre-emptive correction of significant stenosis in a functional access is controversial.

Outcomes

Many trials have been performed with the goal of improving VA outcomes. Reporting is heterogeneous with infrequent use of standardised outcome measures.[141,142] They have been small in size, poor in quality and not sufficiently powered to demonstrate a small benefit.

Several systematic reviews and meta-analysis have reported on potential benefit based on the low quality of evidence. Surveillance and pre-emptive correction of a significant stenosis reduce risk of VA thrombosis but may not reduce risk of VA loss in AVF. It does increase the number of angiograms and interventions at the price of higher infection risk and mortality. There was no benefit to patients with AVG.[143,144]

The failure of surveillance to prolong access survival may be explained by false positive referrals with unnecessary interventions that may potentially cause harm as well as poor results from the intervention. Information regarding technical success, restenosis, costs and resource use is scarce.

Conclusion

In terms of WHO screening criteria, the conditions are imperfect with respect to the four components of the current surveillance strategies:

- *Underlying condition* – lack of understanding of the natural history of VA site stenosis.
- *Screening tests* – unreliability of haemodynamic measurements.
- *Intervention* – waiting period that allows time for intervention not always available.
- *Outcomes* – failure to prolong VA survival and potential harm of intervention.[145]

There is little evidence that surveillance as currently practiced provides a significant benefit. Monitoring with PE and clinical evaluation remain the "keys" to VA maintenance and standard of care. Properly designed RCTs together with improvements in endovascular interventions will likely show the anticipated benefits that currently remain unproven.

Recommendations

- Every VA should undergo monitoring by a trained technologist prior to cannulation. *(Class I recommendation/Level B evidence)*
- Surveillance by combined flow and pressure measurements with trend analysis is the preferred method. *(Class IIa recommendation/Level B evidence)*
- Abnormal clinical findings supported by haemodynamic dysfunction and haemodialysis inefficiency should prompt further investigation. *(Class IIa recommendation/Level B evidence)*
- DDU should be performed as the initial diagnostic imaging modality. *(Class I recommendation/Level B evidence)*
- Intervention should be considered in an AVF when risk of thrombosis is high with significant stenosis and dysfunction. *(Class I recommendation/Level B evidence)*

Preoperative assessment and imaging for vascular access

Clinical assessment – history

Of paramount importance in the history of a patient requiring vascular access for haemodialysis is the presence of comorbid conditions, such as coronary artery disease or malignancy. This allows assessment of factors that may limit life expectancy.[146,147] Other comorbid conditions more likely to affect the outcome of VA maturity include DM, severe heart failure, heart valve disease or heart valve prosthesis, or a history of previous arm, neck, or chest trauma or surgery. History of a central venous catheter, pacemaker or peripheral arterial or venous lines may cause central venous stenosis or affect the consideration of target sites for AVF.[147,148] Venous preservation remains an important principle for the renal replacement patient and hence all healthcare workers and patients should be made aware of the significance of careful selection of sites for venous access. It is essential for patient quality of life that the healthcare provider is aware of the choice of the dominant arm. This limb must be avoided if at all possible. Any anticoagulant therapy or coagulation disorder may cause clotting or, more frequently, bleeding and subsequent haematoma formation. The effect of preoperative arm exercises to optimise blood flow and vessel maturation is not as well established as the postoperative effects and is not routinely accepted in practice.[84]

Clinical assessment – examination

A directed and effective examination of the clinical condition of the patient and the patient's vasculature can distinguish features that may predict AVF success or failure. An essential part of the systemic examination is the examination of the potential inflow sources, which are, in the upper limb, the axillary, brachial, radial and ulnar arteries. Pulses should be evaluated for character and quality, and should be classified as normal, diminished or absent, to establish a baseline and for future comparison. The Allen test is useful for establishing the patency of the palmar arch in the hand, and, if not patent, may complicate a radiocephalic fistula.

Bilateral upper arm blood pressures must be taken to determine the appropriateness of upper arm access, in which context a greater than 20 mmHg difference between the two limbs would indicate a possible subclavian artery stenosis limiting AVF inflow in the arm with the lower pressure.[146]

Features of venous hypertension suggestive central venous stenosis need to be assessed. This includes arm oedema, arm size comparison and the presence of collateral veins. The recipient vein should be palpated in a warm room with a tourniquet off and then on. Note should be made of peripheral or central catheters in place or previously placed. Previous DOQI guidelines advocate routine venography for patients with ipsilateral central vein catheterisation, collateral vein development, arm oedema or differential extremity size.[149] As many as 40% of patients with a history central vein catheter may have a moderate or severe subclavian vein stenosis.[95]

Severe comorbid dysfunction, such as cardiac failure, may alter the cardiac output and affect graft maturation, and should be identified on cardiovascular examination.[147]

Assessment by imaging – duplex ultrasound

Duplex ultrasound (DUS) has been proven to enhance the successful creation and outcome of autologous fistulae. Mihmanli et al.[150] demonstrated a significantly higher success rate when an AVF is constructed with the use preoperatively of DUS compared to without DUS (5.6% vs 25%, $p = 0.002$[9]) in a randomised trial, but other trials have failed to substantiate this margin of improvement.[151,152]

DUS allows venous and arterial diameter and flow assessments in a non-invasive, cost effective manner.[153] This modality does, however, depend on the experience of the examiner and does not provide a cross-sectional or reconstructed angiographic map. Through a high-quality and thorough assessment, one can locate and quantify stenosis and occlusions, and can measure flow in an attempt to predict patients who may experience AVF failure.[154] One drawback is that ultrasound is generally not accurate for assessment of central vein stenosis. It may be helpful to look for respiratory phasicity[154] or to assess subclavian vein flow. Some authors advocate a flow speed of less than 400 ml/minute as inadequate.[155]

It is important to consider that the radial artery diameter predicts outcome of a radiocephalic AVF. Wong et al.[156] showed thrombosis or failure of maturation if radial artery diameter was less than 1.6 mm.[152] To date, trials investigating the association between radial peak systolic velocity (PSV) and resistive index (RI) in predicting outcome remain equivocal.[157] Ultrasonographic assessment of the PSV using reactive hyperaemia (opening a fist that has been clenched for two minutes) to simulate the low-resistance biphasic flow seen in the mature AVF has been evaluated to predict patency but is not accepted as routine practice.[154]

Venous diameters of less than 1.6 mm are often associated with AVF failure, while vein diameter ranging between 2 and 2.6 mm is associated with much better patency.[158] Gender-based consideration of diameter has been debated by some authors, but has not been universally agreed upon.[154] The resultant increase of the venous diameter with application of a tourniquet is sometimes a predictor of a vein that will respond well to AVF maturation.[153] A thorough assessment of the vein should include looking for evidence of obstruction, identifying a straight segment within 6 mm of skin surface for cannulation, and ensuring continuity with the proximal vein.[147] Accepted diameters for use for a radiocephalic AVF are a radial diameter more than 2 mm and a cephalic diameter more than 2.5 mm.[156]

The routine use of intraoperative DUS mapping after regional anaesthesia has been suggested as being superior to preoperative mapping by Hui et al.,[159] in response to significant increases in vein diameters of the distal forearm, a two-fold increase in radial artery-based procedures, and a 57% maturation rate at one year follow-up.[160]

A standardised method of reporting on preoperative DUS should be considered in individual units to maintain reproducibility and reduce inter-observer error. Special mention should be made of abnormal flow speeds in the arterial tree which may indicate areas of stenosis.

Other imaging modalities

CT and MRI have a limited role in the standard workup of a patient for an AVF and contrast use remains a concern, although newer methods for MRI without contrast have been reported. The therapeutic advantage of DSA remains for the treatment of inflow and outflow abnormalities but should not be routinely used for diagnostic imaging.

Recommendations

- A thorough history and examination of the arterial inflow source and venous outflow source should be done prior to vascular access. *(Class IIa recommendation/Level B evidence)*
- DUS for assessment of arteries veins of upper limb should be done in all patients prior to vascular access. *(Class IIa recommendation/Level B evidence)*
- Computerised tomographic angiography should not be routinely used, favoured rather for inconclusive imaging results. *(Class IIb recommendation/Level C evidence)*
- Contrast-enhanced magnetic resonance imaging should be avoided in ESRD, but consideration can be given to non-contrast methods utilising time of flight or balanced turbo field echo. *(Class III recommendation/Level C evidence)*
- Digital subtraction angiography should be used for treatment rather than diagnosis of inflow and outflow abnormalities. *(Class IIb recommendation/Level C evidence)*

Stepwise approach to access creation

Choice of vascular access type

There are three principle forms of vascular access available in the treatment of patients of ESRD with haemodialysis. In order of preference, these are AVF, AVG using prosthetic or biological material and finally either tunnelled or non-tunnelled catheters placed in a central vein. Many studies have shown the superiority of AVFs compared to the other forms of haemodialysis access. AVFs have better patency rates, access survival, lower number of interventions during the entire life span of access type, and lower rates of access-related sepsis. The overall morbidity and mortality are lower when compared to AVG and central venous haemodialysis catheters.[148] Furthermore, both hospitalisation frequency and costs are the lowest with AVF access.[84] It is imperative that the goal for the provision of access should be patient-focused and requires a coordinated and multidisciplinary approach in assessing and educating patients in advance of the need for renal replacement therapy in order to provide optimal dialysis access.[149]

Recommendation

- Patients with ESRD who are on long-term haemodialysis or commence haemodialysis should dialyse with an autogenous AVF as first choice, AVG as second choice and central vein catheter as third choice. *(Class I recommendation/Level A evidence)*

Timing of AV access and vein preservation

AVF placement should be arranged at least 3–6 months and AVG at least six weeks before the need for dialysis. A more recent use of self-sealing grafts has been used more frequently and requires only 24–72 hours before cannulation. The challenge for nephrologists is predicting accurately when dialysis will be required. However, it is generally agreed that AV access planning should commence shortly after an individual reaches CKD stage 4.

In 27 longitudinal cohort studies, it was found that being referred earlier to a nephrologist resulted in a reduction in mortality and hospitalisation, a decreased likelihood of requiring temporary vascular access at the start of dialysis and increased likelihood of having an AVF.

Early referrals yield more functioning AVFs and late referrals increase the need for CVCs and non-maturation of AVFs.[84,95,153,154] It has also been shown that timely referral slows down the decline in eGFR.[155] For the surgeons the challenge is to construct access that will be adequate for cannulation during dialysis and have sufficient longevity. The knowledge and experience of a surgeon performing access surgery is vitally important in the outcome of AV access success and most importantly on the outcome of AVF functioning.[156,157]

Recommendation

- Patients who may require haemodialysis should have education of upper limb vein preservation. *(Class IIa recommendation/Level C evidence)*

Vascular access grafts

There are a number of grafts available to create an AVF for chronic long-term haemodialysis. There are synthetic and biological grafts. Synthetic grafts are preferred because they are less costly and the long-term problem of degeneration in biological grafts prevents usage. Biological grafts are more resistant to infection and may be considered in contaminated fields.[161]

Expanded polytetrafluoroethylene (ePTFE) grafts are commonly used and there is some evidence that primary and secondary patency is better with a cuff or expansion at the venous end.[162,163]

Heparin bonded grafts have failed to show a significant patency advantage up to 1 year in a randomised study despite a reduced thrombosis rate.[164] Another randomised trial[165] showed significant improvement in primary patency rates at one year with heparin-coated grafts. Carbon coating and external and internal support have not shown any benefit. Six-millimetre diameter grafts are often used but there is no evidence to support this over other diameters. Stepped or tapered have also no proven advantage.[166] Most prosthetic grafts can be used two weeks post implantation.

Newer multilayer ePTFE grafts can be needled within 1–2 days which can avoid the need for central venous catheter access. There are five types of grafts that can be used for early cannulation. These are the Rapidax II, Vectra, Acuseal, Flixene and AVFLO.

The haemodialysis reliable outflow device (HERO)[167] graft has a standard ePTFE graft anastomosed at the arterial end with a central venous catheter distally. This graft may be useful in situations when no arm veins are available. The pooled primary and secondary patency in a systematic review was 29% and 59.4% respectively.[167]

Recommendations

The ESVS guidelines[166] have not given a recommendation with regard to the routine use of grafts as there are no comprehensive randomised studies comparing several grafts, but they do state that a self-sealing graft be utilised for patients who have difficult central venous access and who require early haemodialysis.

- In the presence of infection, a biosynthetic graft is preferred to a synthetic graft when no vein is available. *(Class IIa recommendation/Level C evidence)*
- The use of self-sealing grafts is recommended in patients with difficult central venous access and who require immediate cannulation. *(Class I recommendation/Level C evidence)*
- The use of ePTFE grafts for vascular access whether tapered or straight is acceptable in routine use for the creation of dialysis access. *(Class IIb recommendation/Level C evidence)*

Non-maturing AV-fistula

Non-maturation of an AVF is defined clinically as insufficient vessel development one month after creation, difficulties in cannulation or inability to achieve a dialysis rate > 300 ml/minute.[168] The non-maturation rate is variable between 10–33% for brachiocephalic arteriovenous fistulae and higher for radiocephalic arteriovenous fistulae (RCAVF). Risk factors for non-maturation include women, older patients, comorbid profiles, uraemic states, distal placements and small diameter arteries and vein.[170,174] The two common causes for non-maturation are stenosis (arterial, juxta-anastomotic and venous) and competing collaterals (or accessory veins).[173] Stenosis occurs as a result of operative trauma during mobilisation for vessel transposition that leads to loss of vaso vasorum or resultant neointimal hyperplasia from microtrauma incited by accelerated blood flow from artery to vein.[163,174] Venous outflow stenosis is characterised by reduced outflow, prolonged bleeding time, and raised venous pressure.[166] Competing collateral or accessory veins induce competing parallel flow owing to decreased luminal pressure and resistance in the main outflow vessel. The altered flow dynamics are dictated by the variable flow patterns, lengths, calibre and tortuosity of the competing collateral network.[174]

The diagnosis of non-maturation fistulae is based on the behaviour of the haemodialysis access site and examination: critical stenosis water-hammer pulse, competing veins and disappearance of sustained thrill/pulsatile flow.[166,175,176] The first line investigative tool is a DUS and then if indicated a fistulogram that should be used to determine the site of stenosis, competing collaterals/accessory veins and the location of the arteriovenous anastomosis.[177] The collateralisation venous network may complicate location of the original arteriovenous anastomotic channel. For this purpose a retrograde brachial and antegrade venous access with a micropuncture set may be required.[177]

Treatment entails surgery or endovascular intervention with no significant difference in the success rate for these two modalities.[178-183] Stenotic lesions have traditionally been rectified with surgical re-siting of the proximal stenosis or insertion of a short prosthetic graft for a forearm AVF.[166] Endovascular intervention includes pre-emptive balloon dilation or primary PTA for arterial and juxta-anastomotic lesions.

Venous stenotic lesions < 2 cm should undergo PTA, while lesions > 2 cm can be subjected to either PTA, transposition, or bypass surgery. High pressure and cutting balloons should be reserved for challenging lesions. If PTA fails, a stent graft (barring cost implications) may be considered as it reduces restenosis, neointimal hyperplasia and prevents recoil.[182] Collateral veins may be treated with surgical ligation or coil embolisation.[175]

Recommendations

- Diagnosis[174,176-181] – Non-maturation of fistula within six weeks, DUS should be considered. *(Class IIa recommendation/Level C evidence)*
- Treatment[175,178-183] – PTA is recommended as primary therapy for arterial access stenosis. *(Class I recommendation/Level C evidence)*
- Forearm juxta-anastomotic stenosis should be surgically rectified with a proximal relocation. *(Class IIa recommendation/Level C evidence)*
- PTA is recommended for venous outflow obstructions. *(Class Ia recommendation/Level C evidence)*
- For elastic recoil, recurrent stenosis and residual stenosis > 30% stent grafts are recommended. *(Class IIb recommendation/Level C evidence)*
- Ligation or embolisation is employed for collateral or accessory veins. *(Class IIa recommendation/Level C evidence)*

Transposition procedures in vascular access surgery

Autogenous access is preferred to prosthetic grafts. The order of preference for autogenous access is to perform distal access first (snuffbox, wrist and forearm fistulae) followed by more proximal access (brachiocephalic, median cubital or deep perforating veins). Once these superficial vein options are exhausted, then a brachial basilic transposition should be considered.[184] In practice the principle of constructing fistulae as distal as possible from an adequate arterial inflow source to an adequate calibre and length of superficially located vein creates multiple other transposition options for the vascular/access surgeon. In the forearm this includes radiocephalic transposition (often used in patients where the cephalic vein is deeply located such as in obese individuals) and radio(ulnar)-basilic transposition (placing the vein on the anterior aspect of the forearm where it is accessible to puncture).[185-188] Both the forearm cephalic and basilic veins can also be transposed to arteries in the antecubital fossa in a looped configuration if the distal arterial inflow is inadequate.[189] In the upper arm, the basilic vein transposition is most commonly performed,[190] but the cephalic vein can also be transposed if not located superficially,[191] Brachial vein transposition is also performed occasionally before resorting to lower extremity access.[192,193]

When the veins of both forearms are exhausted, brachial-basilic AVF (BBAVF), first described by Dagher,[195] is usually preferred to forearm looped graft or a brachioaxillary graft because of better patency and lower infection rate.[166] The basilic vein is often well preserved and is relatively larger and thicker than the cephalic vein.[190] Controversy exists regarding the number of stages (i.e. one-stage vs two-stages), the means of vein harvest (open vs minimally invasive) and the means of elevation to make the vein accessible (transposition vs superficialisation).[190]

BBAVF without transposition or superficialisation with a side-side anastomosis has also been described.[195] Preoperative venous and arterial imaging in the vascular laboratory is mandatory. In the one-stage procedure the basilic vein can be superficialised by tunnelling the transected vein through a subcutaneous tunnel lateral to the incision – basilic tunnel transposition (BTT). This has the disadvantage that stenosis frequently develops at the swing point. The vein can simply be elevated closer to the skin which has the disadvantage that the fistula has to be cannulated through the incision scar and a more medial less accessible location. Alternatively, the vein can be elevated and placed in a subcutaneous pocket anterior to the incision – basilic elevation transposition (BET).[196] Wang et al. reported improved primary patency for the BET technique with fewer interventions required.[196] Hossny reported more complications with the elevation technique and less satisfaction from dialysis staff.[197] Some authors advise a 2-stage procedure with initial fistula creation and later tunnelling or elevation 4–6 weeks later when the fistula is mature. This avoids the more complex procedure if the fistula fails to mature and improves maturation in children and, if the basilic vein is between 2.5–4 mm,[198] in adults.[199] Endoscopic vein,[200] two small skin incisions[201] and a keyhole technique using a wire and vein inverting catheter are all described harvesting techiniques.[202]

A randomised controlled trial comparing BBAVF with prosthetic brachial-antecubital forearm loop grafts confirmed significant better 1-year primary (46% vs 22%) and primary assisted patencies (87% vs 71%) for BBAVF with fewer interventions. However, despite similar secondary patencies (89% vs 85%), they recommended that BBAVF should be preferential to forearm loop grafts,[203] a recommendation in keeping with a meta-analysis comprising 1 509 patients that reported pooled secondary patencies of 67% vs 88% for AVGs and BBAVFs respectively with higher re-intervention rates in AVGs.

Controversy remains whether a BBAVF should be performed in one or two stages. A recent meta-analysis by Wee showed significantly higher 2-year primary patency rates for the two-stage procedure with no significant differences in complications.[204] However, multiple other meta-analysis did not show benefit from a two-staged approach.[205-207]

Recommendations

- When other autogenous forearm and antecubital options are exhausted, BBAVF is preferred over grafts. *(Class IIb recommendation/Level B evidence)*
- For BBAVF tunnel transposition or elevation transposition is preferred to simple elevation. *(Class IIB recommendation/Level B evidence)*
- It is unclear if BBAVF should be performed in one or two stages, but 2-stage transposition should at least be considered for veins 2.5–4 mm in diameter. *(Class IIb recommendation/Level B evidence)*
- Brachial artery–brachial vein AVF can be utilised (probably in two stages) before abandoning the upper extremity for access, the sequencing in relation to grafts is unclear. *(Class IIb recommendation/Level B evidence)*
- AVF deeper than 6 mm needs superficialisation through either elevation or transposition. *(Class IIa recommendation/Level B evidence)*
- Lipectomy or liposuction can be used for vein superficialisation in obese individuals. *(Class IIa recommendation/Level C evidence)*

Lower limb vascular access

Autogenous access

Available data is limited to single-centre observational studies with small patient numbers and limited follow-up.

Transposed femoral vein AVF

It is associated with a low thrombosis rate with primary patency rates of 78% and 73% at six and 12 months respectively and secondary patency rates of 91% and 86% at six and 12 months respectively. A major concern is infection at the femoral vein harvest site, especially in patients with low ankle-brachial index, distal limb ischaemia and compartment syndrome.[208-211]

Great saphenous vein AVF

This is rarely created because of high incidence of maturation failure.[212]

Prosthetic access

Infection and thrombosis rates are higher with AVG compared with AVF, however, access salvage after a thrombotic event is superior with AVG.[213,214]

The primary and secondary patency rates for AVG have been reported as 34–62% and 41–83% respectively, and infection rates up to 46%.[213,214]

Loop mid-thigh AVG

The loop mid-thigh AVG is a variation to the thigh AVG. It avoids the groin and provides easy access for cannulation with lower risk for infection. Results indicate superior patency and it should be considered before placement of a thigh loop AV access.[214]

Recommendations

- Patient with exhausted upper limb access must first be considered for PD before lower limb haemodialysis. *(Class I recommendation/Level B evidence)*
- Patient selection is critical before creating lower limb vascular access (exclude lower limb arterial occlusive disease and iliac vein occlusive disease). *(Class I recommendation/Level C evidence)*
- Lower limb AVF or AVG is superior to femoral vein central venous catheter. *(Class I recommendation/Level C evidence)*
- Lower limb AVF is the first choice followed by AVG. *(Class IIa recommendation/Level C evidence)*

Unconventional/exotic dialysis access strategies

Broadly the options can be categorised into three groups: arterial access procedures (arterial-based loop access, superficial femoral artery transformation), unconventional cuffed haemodialysis access (transthoracic, translumbar, transhepatic catheter access), and exotic AV access (axillary atrial shunts). The durability and long-term morbidity remain unclear from the available data. It is unlikely that the level of evidence for these treatment modalities will improve, as they will remain reserved for isolated scenarios.[215-221]

Recommendations

- Consideration of these access options should be a last resort as they remain unproven with scant evidence to support any recommendation. *(Class IIb recommendation/Level C evidence)*

Treatment of septic AVF and prosthetic grafts

Graft infections are the second leading cause of graft failure after thrombosis and the second leading cause of mortality in chronic renal failure patients after cardiovascular disease. Although the transcutaneous catheters are the most frequent source of these infections, the incidence graft infections range from 0.56–5% per year for venous fistula[222,223] and 4–20% per year for prosthetic graft fistulas.[223-225]

Diagnosis is usually based on local findings of tenderness, erythema, induration, masses, drainage and exposed graft. Systemic manifestations are more associated with catheter infections and are associated with higher morbidity and mortality. Ultrasound is used to confirm the diagnosis and the extent of the infection.

Fistula infection can occur during surgery or during the multiple graft punctures for dialysis, therefore are mainly caused by the skin flora: *staphylococcus spp* constitute 32–53%, enterococcus and coagulase negative staphylococcus 20–32%, and polymicrobial infections account for 10–18% of cases.

Treatment options depend on the extent of infection (localised or whole graft and arterial anastomosis involvement), type of graft (venous or prosthetic), functional status of the graft (patent or occluded), bacterial aetiology (virulent or nonvirulent) and presentation (fever, bleeding, pus discharge and aneurysm).

Autogenous localised infections may respond to 4–6 weeks of broad-spectrum antibiotics.[226-229] But if the autogenous graft sepsis is associated with bleeding, pseudoaneurysm, pus drainage and anastomosis involvement, it requires graft ligation.[224,225,230]

Prosthetic grafts with localised infection can be treated with segmental excision and jump graft replacement through a sterile field.[231] Subtotal excision leaving only the arterial anastomosis graft stump is done for more extensive sepsis that does not involve the arterial anastomosis; this avoids the extensive dissection at the anastomosis site that can cause injury to the nerve and artery.[226,232] Total graft excision is only indicated when the arterial anastomosis is involved and if necessary, brachial ligation can be done and is usually well tolerated.[224,233-235]

Recommendations

- Autogenous graft infection in absence of bleeding, discharge or pseudoaneurysm, antibiotic therapy is recommended. *(Class I recommendation/Level C evidence)*
- Autogenous graft sepsis with bleeding, aneurysm and discharge is treated with ligation. *(Class I recommendation/Level C evidence)*
- Prosthetic graft with localised infection is treated with segmental excision and replacement with a jump bypass through a sterile field. *(Class IIa recommendation/Level C evidence)*
- Prosthetic graft with extensive infection sparing the arterial anastomosis is treated with subtotal excision, leaving a small arterial anastomosis graft stump. *(Class IIa recommendation/Level C evidence)*
- Extensive prosthetic graft infection involving the arterial anastomosis is treated with total graft excision, with or without arterial ligation. *(Class IIa recommendation/Level C evidence)*

Failing arteriovenous graft

AVG dysfunction and failure is common. Immediate failure in the postoperative period is usually due to technical issues. Delayed graft failure is predominantly related to stenotic vascular lesions. AVG failure can also be related to complications such as infection, pseudoaneurysm, or other conditions that lead to the sacrifice of the graft.

For patients with an abnormal clinical examination or abnormalities on monitoring and surveillance, the cause of the problem may be obvious on physical examination of the AVG. Most cases of AVG thrombosis are preceded by progressive stenosis at the vein-graft anastomosis that can be documented by access surveillance or clinical monitoring. However, up to 25% of AVG clot fairly abruptly without prior indication of critical stenosis.

Although most AVG requiring treatment have only one stenotic site, up to 30% can have two or more stenotic sites. A clinically significant stenosis in an AVG is defined as a greater than 50% narrowing of the diameter with abnormal findings, such as decreasing intragraft blood flow (less than 600 ml/minute) or elevated static pressure within the graft. Affected sites are venous anastomotic stenosis, intragraft stenosis, peripheral draining vein stenosis, central vein stenosis and arterial stenosis.

Stenotic vascular lesions should be treated with PTA, with lesions unsuitable for PTA referred for surgical revision. Even with excellent technical success rates, approaching 100 per cent, the low rates of subsequent AVG patency are discouraging.

Once thrombosis of an AVG has occurred, treatment options include percutaneous or surgical thrombectomy, in conjunction with angioplasty (balloon, patch) of the underlying stenotic lesions. Primary patency of stenotic lesion is much worse following thrombectomy compared with pre-emptive PTA.

Recommendations

- Pre-emptive PTA rather than surgery as the initial procedure.[233-236] *(Class I recommendation/Level B evidence)*
- In vascular access dysfunction, digital subtraction angiography should be performed only when subsequent intervention is anticipated.[237] *(Class I recommendation/Level C evidence)*
- Routine physical examination is recommended for vascular access surveillance and monitoring.[238,239] *(Class II recommendation/Level B evidence)*
- PTA is recommended for the treatment of venous outflow stenosis.[240] *(Class II recommendation/Level C evidence)*
- Endovascular treatment with stent grafts should be considered for the treatment of cephalic arch stenosis.[241] *(Class IIa recommendation/Level B evidence)*

The occluded arterio-venous fistula/graft

As the use of AVF has expanded to include older patients and patients with comorbidities, so have AVF complications increased significantly.[89] AVF occlusions may occur early or late. Early AVF occlusion is defined as fistulae that have not developed to the point to which they may be used or fistulae that occlude within the first three months.[244,245] Generally, strategies to reverse fistulae occlusion are challenging and are associated with high rates of re-occlusion.[245,246] Long standing fistulae with extensive thrombus, degeneration and aneurysms are associated with the worst outcomes. Associated studies involve small patient numbers, do not compare the different treatment modalities and do not evaluate the important outcome of "an adequately functioning fistula".

Immature fistulae and early occlusion

Fistulae may fail to mature due to unrecognised stenoses or large tributary veins that limit blood flow through the main draining vein.[245-248] Assessment and monitoring in the first few weeks after fistulae creation is essential. Assessment may include DUS: palpation and auscultation.[89,252] Although DUS provides important information with regards to changes (especially increments) in fistula blood flow, the most appropriate monitoring strategy has not been identified.[250,251,253]

Fistulae maturation is usually evaluated by subjective clinical examinations by an experienced dialysis nurse or nephrologist.[89] Beathard et al. reported their experience in

71 patients with immature fistulae.[244] Sixty-three of these patients underwent PTA, tributary ligation or both; 82% of the fistulae matured adequately for subsequent dialysis. Turmel-Rodrigues et al. evaluated 109 patients with immature fistulae: 78% had venous stenoses (43% juxta anastomotic) and 29% accessory veins (92% salvage).[246]

Late AVF thrombosis

Thrombotic mechanisms include outflow stenosis; traumatic degeneration; same site needling; turbulent flow; aneurysmal formation and intimal hyperplasia.[89] Hypertension, cardiac failure and hypercoagulability may be contributing factors. Clot burden may vary from an anastomotic plug to complete outflow vein thrombosis. Clot characteristics and wall adherence are also variable. Salvage techniques variably include surgical thrombectomy, thrombolysis, angioplasty/stent, mechanical thrombectomy and open surgical correction. The studies that evaluate salvage outcomes are hampered by small numbers and do not specifically address a single technique.[249-251] Experience and interventional bias generally dictates the salvage modality used.[89,252] Salvage techniques are generally less successful beyond 48 hours.[89,245,246,252]

Forearm fistulae seem to have better outcomes compared to arm fistulae. Turmel-Rodrigues et al. and Haage et al. reported good success rates in declotting AVF using endovascular techniques. In both studies the immediate technical success rate was 90% and patency rate was 50% at six months.[89,247,248]

Recommendations

- Occluded AVF should be assessed for declotting by an experienced surgeon/interventionalist. *(Class II recommendation/Level C evidence)*
- Salvage techniques (open surgery and/or endovascular strategies) should preferably be attempted within 48 hours of fistula occlusion. *(Class II recommendation/Level C evidence)*
- In patients who present beyond 24 hours with extensive thrombosis of a degenerated AVF, attempts at salvage are likely to be futile and alternative dialysis access should be considered. *(Class I recommendation/Level C evidence)*
- In patients who present with localised thrombosis of a forearm fistula, salvage strategies must be attempted. Surgical reconstruction is recommended if the thrombosis is localised to the anastomotic site. DUS should be used to access the status of the draining vein. *(Class I recommendation/Level C evidence)*
- We recommend balloon angioplasty to treat non-anastomotic high-grade stenoses that become apparent after thrombus dissolution. Stent insertion may be considered for residual stenosis provided fistula needling is not compromised. *(Class I recommendation/Level C evidence)*
- We recommend clinical monitoring of newly created AVF at 1–2 week intervals. *(Class II recommendation/Level C evidence)*

Aneurysmal fistula and peri-graft aneurysms

The formation of aneurysmal dilatations and pseudo-aneurysms is a potentially serious complication that can develop in any AVF. A working and practical clinical solution may be to define an aneurysm in an AVF as an abnormal localised dilatation of the vessel and classify it on the basis of true aneurysm or false (pseudo) aneurysm, anatomical location and site (anastomotic/puncture site/native vessel and whole outflow vein).[253-257]

Venous aneurysms

Following the creation of an AVF, dilatation of the draining vein is a physiological response and necessary for the proper functioning of the AVF. Certain circumstances may contribute to excessive dilatation of the vein (venous aneurysms). These may be secondary to vessel wall weakness, increased endoluminal pressure, and outflow stenosis. Repetitive cannulation of the same segment of the vein can also cause a weakness in the wall that predisposes to ectasia, a phenomenon known as 1-site-itis, which is commonly seen in practice.[258] The use of the buttonhole technique (to cannulate a fistula with a blunt needle instead of a sharp needle at exactly the same spot on the fistula to create a tunnelled track) also seems to prevent the formation of aneurysms.[259]

The diagnosis is clinical. DDUS examination is used to determine the diameter and the presence of endoluminal thrombus and detect distal stenoses. The natural history of venous aneurysms is most commonly a benign process where patients remain stable and asymptomatic without jeopardising the functioning of the access or the haemodialysis.[257]

Indications for intervention are skin changes that predict an increased risk of bleeding. These include skin atrophy, erosions, and areas of inflammation or the presence of an eschar. Other indications for treatment include thrombosis of the aneurysm, venous hypertension, hyperdynamic flow, limited puncture sites or aesthetic reasons.[260,261]

Haemorrhage due to venous aneurysm rupture is a life-threatening emergency and is an indication for urgent surgery. The priority is to control the bleeding, and if possible, to preserve the AVF.[257] Treatment techniques include exclusion of the aneurysm (with or without its excision) with interposition of autologous or prosthetic graft,[254,259] excision with direct end-end anastomosis,[260] partial resection of the aneurysm,[259,261,262] as well as different types of aneurysmorrhaphy.[260,263-269]

Percutaneous treatment of venous aneurysm consists of the placement of a covered stent in the affected segment.[257,265] An advantage is that it allows the treatment of associated stenoses at the same time, without the need for the placement of a central venous catheter. Disadvantages include possible difficulty in the puncture of the segment with a stent and the need to combine partial excision of the aneurysm or haematoma to allow cannulation of the vessel. Despite the good results described in a published case series,[266] the strength of evidence on the use of these devices does not allow a recommendation for their systematic use and further studies are required.

Arterial aneurysms

Aneurysmal degeneration in the donor artery to the AVF is a rare complication, with an approximate incidence of 4.5%. The most common location is in the distal segment of the brachial artery.[267]

The indication for surgical treatment is the presence of complications or large aneurysms (> 30 mm) where it is technically feasible.[255]

Being a rare entity, and many cases being asymptomatic, the evidence in the literature regarding treatment is scarce and limited to case series with small numbers of patients.

Pseudoaneurysms or false aneurysms

Treatment of post-puncture pseudoaneurysm in the native AVF:

- Conservative management: ultrasound-guided external manual compression
- Percutaneous treatment
- Surgery
- Endovascular treatment

Treatment of post-puncture pseudoaneurysm in prosthetic AVF: repeated puncture of a prosthesis in one area causes structural damage in the structure of the PTFE and can lead to the loss of structural integrity.[269]

Incorrect clinical practice can thus produce pseudoaneurysms associated with cannulation of a vascular prosthesis, with or without infection. These may develop the same complications as the native AVFs (rapid growth, compression of neighbouring structures, spontaneous rupture).[259] This may be an incidental finding with a small pseudoaneurysm that can remain stable over time. It can be managed conservatively with ultrasound surveillance and avoiding puncture of the affected area.[260]

The indications for treatment of prosthetic pseudoaneurysms include:[228,260,269]

- Fast growth
- Size greater than twice the diameter of the prosthesis
- Presence of skin trophic disorders
- Signs of infection
- Significant shortening of the puncture path

Because of the underlying damage to the wall of the prosthesis, the treatment goal is repair. Both surgical and endovascular techniques have been described.

Treatment of anastomotic pseudoaneurysm

Early anastomotic pseudoaneurysm (hours or days after completion) is related to surgical technique, while after the postoperative period a pseudoaneurysm is usually associated with an infection involving the suture line.[259]

In both circumstances the repair of the pseudoaneurysm must be performed by surgical intervention. The placement of a stent graft is contraindicated due to the high risk of infection. If it occurs postoperatively, surgical revision is performed. If it occurs in relation to an infection, the infected graft must be removed, with reconstruction of the AVG if this is technically feasible.[266] The Shojaiefard et al.[268] series of eight patients with anastomotic pseudoaneurysms treated surgically had a technical success of 88%, with a primary patency of 88% at 15 months.

Recommendations

- Symptomatic arterial aneurysms should be treated by resection and arterial reconstruction. *(Class IIa recommendation/Level C evidence)*
- In venous aneurysms, surgical treatment is indicated if associated with significant stenosis, necrosis or compromised skin with risk of rupture of the aneurysm. *(Class IIa recommendation/Level C evidence)*
- In patients with uncomplicated, small pseudoaneurysm of a prosthetic graft, avoid puncturing the site and monitor stability with DDUS. *(Class IIb recommendation/Level C evidence)*
- In the presence of a pseudoaneurysm of a prosthetic with complications, excision of the affected segment is recommended while maintaining patency of access if technically feasible. *(Class IIa recommendation/Level C evidence)*
- Use of an endovascular stent graft is feasible. *(Class IIb recommendation/Level C evidence)*
- In patients with pseudoaneurysms that affect the anastomosis of the AVF, surgical revision is recommended, and this should be regarded as a vascular access infection. *(Class IIa recommendation/Level C evidence)*

Vascular access steal – diagnosis and treatment

Vascular access steal (VAS) is defined as the development of ipsilateral ischemic symptoms in the presence of a functioning AVF or AVG for haemodialysis. VAS following creation of a vascular access for haemodialysis occurs in 5–10% of patients with brachial artery platforms but very rarely (< 1%) occurs in patients with RCAVF. Other descriptions of this condition include dialysis access steal syndrome (DASS), distal hypoperfusion ischaemic syndrome or access-related hand ischaemic (ARHI). Patients at high risk for VAS include elderly patients, female patients, patients with multiple prior vascular access, patients with peripheral arterial disease or who have had previous vascular surgery, patients who have had previous VAS, patients who smoke and patients with diabetes mellitus. No test reliably predicts the development of VAS. It can be limb-threatening and therefore requires prompt evaluation, and treatment where indicated. The incidence of symptomatic peripheral ischaemia to the hand or arm (pain, necrosis in one or more fingertips) is increasing, but it is still uncommon (1–4%).[270]

ARHI was first described by Storey et al. after the creation of a RFAVF (Brescia-Cimino-Appel access) in 1969.[271] VAS is more likely to develop following the creation of an AVG for haemodialysis, especially arm or proximal forearm AVGs. Symptoms develop fairly rapidly following the creation of a vascular access in about 10% of patients, however most of them resolve spontaneously. Approximately 50–65% will become symptomatic in the first 30 days. However, symptoms or complications may develop months or years later in 25% of cases.[272,273]

A feature of VAS is the flow reversal in the inflow artery distal to the anastomosis (ranging from 73% in AVFs to 95% in AVGs), and reduction in digital pressures in the affected hand in 80% of cases.[272]

Clinical severity of VAS is graded as follows:[274]

- Grade 0: No steal
- Grade 1: Mild-cool extremity, few symptoms, flow augmentation with access occlusion
- Grade 2: Moderate-intermittent ischaemia only during dialysis, claudication
- Grade 3: Severe-ischaemic pain at rest, tissue loss.

Adequate preoperative work-up is advisable to prevent VAS. This includes clinical appraisal of upper limb pulse status, measuring brachial pressures, detecting supra clavicular bruits and performing the Allan's test. Diagnostic appraisal must include upper limb Doppler pressures (brachial; radial and ulna arteries). The measurement of the digital-brachial index has not reliably predicted who will develop significant VAS. The presence of abnormal findings (such as incomplete palmar arch; significant BP or Doppler pressure discrepancies > 20 mmHg) mandates further evaluation including exertional, and/or dynamic Doppler testing, duplex arteriography, computed tomographic angiography (CTA).

Catheter angiography should be reserved for cases that require further angiographic definition and percutaneous endo-interventions prior to vascular access creation.

Treatment strategies for established VAS depend on the clinical severity grading, and whether the flow in the vascular access is either low, normal or near normal or high. Patients with grade 0 or 1 VAS can be treated expectantly.

Patients with grade 2 VAS occasionally need treatment. Treatment for 3 VAS is mandatory. A pretreatment upper limb angiography is mandatory before any treatment is envisaged. Treatment strategies are generally based on vascular access flow patterns and include: simple angioplasty or stenting; distal revascularisation and interval ligation (DRIL); revision using distal inflow (RUDI); proximalisation of arterial inflow (PAI); banding; or ligation. For proximal arterial occlusive disease, procedures include angioplasty and or stenting, or surgical bypass procedures.

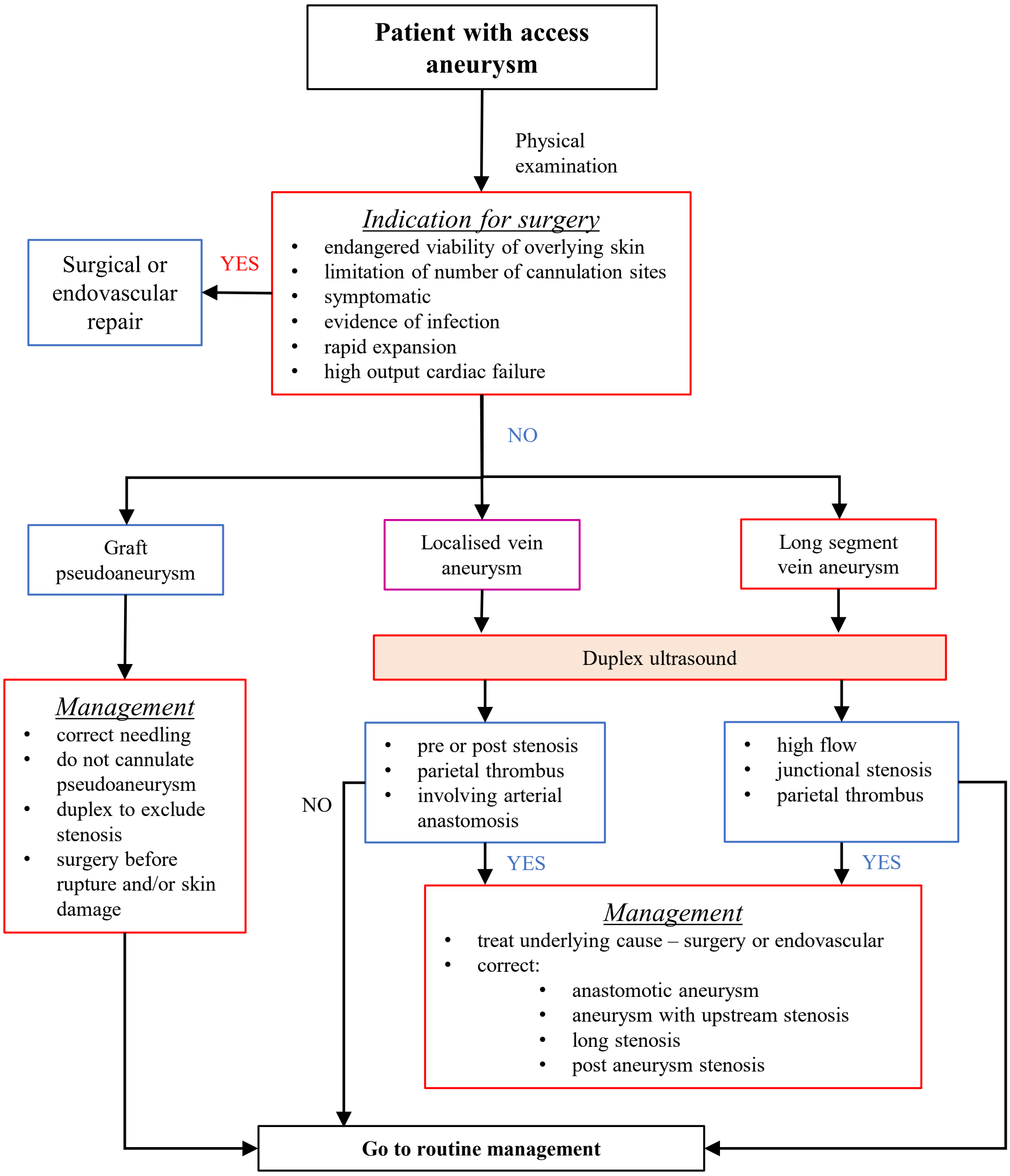

Figure 1: An approach to vascular access aneurysms

Ligation

Ligation finds its niche in normal-flow RCAFVs with VAS associated with reversal of flow in the radial artery, or delayed contrast perfusion > 10 seconds, in the presence of an intact palmar arch and ulna artery. Ligation of the radial artery distal to the fistula produces good technical and clinical results. Ligation of the hand AVF or AVG may be the only option available. This obviously necessitates the creation of a new AVF or AVG.

Distal revascularisation and interval ligation

The DRIL procedure is the most well-established and studied intervention for VAS generally associated with brachial AVFs or AVGs. The procedure entails the ligation of the artery distal to the fistula, and a vein or prosthetic bypass from the brachial artery at least 5–10 cm proximal to the fistula to the dominant outflow artery (radial or ulnar artery). Symptomatic relief has been reported in 83–100% of patients undergoing the DRIL procedure for VAS. Patency rates reported range from 73–93%.[275-278]

Revascularisation using distal inflow

The RUDI procedure is also generally employed for brachial-based AVFs or AVGs with associated VAS. The fistula is ligated, and a vein graft is anastomosed end to side to the smaller calibre radial or ulna arteries distally, and to the vein proximally.

The radial or ulna arteries must be > 2 mm in calibre and free of calcification. The procedure has the advantage of preserving axial arterial flow in the event the graft occludes. The numbers reported here are smaller than DRIL but symptomatic improvement rates approach 100%. Patency rates range from 74–87%.[278-280]

Proximalisation of the arterial inflow

The PAI procedure may be useful for VAS associated with both low flow and high flow vascular access. Here the anastomosis is relocated to the proximal brachial artery using a smaller calibre prosthetic graft (4–5 mm graft). The PAI procedure has similar efficacy to DRIL but avoids ligation of the axial artery. Symptomatic improvement is reported in 91–100%, with complete resolution of symptoms reported in 82–84%. Patency rates range from 62–90% at one year to 78% at three years.[281,282]

Surgical banding and plication

The aim of surgical banding or plication is to increase resistance to flow thereby improving distal perfusion to the hand. It is indicated for high-flow AVFs or AVGs associated with VAS. Banding employs a (ePTFE) wrap to narrow the outflow tract approximately 10 mm in length. Plication is suture-based.

Digital photophlethysmography (PPG) or pulse oximetry is generally recommended and employed to guide the degree of narrowing. The problem with banding is the disturbingly high access thrombosis rates (19–90%). Banding is rarely reported as a treatment option these days.[253,283-285]

Minimally invasive limited ligation endoluminal-assisted revision procedure (MILLER)

The MILLER procedure offers an alternative to traditional banding procedures for treating VAS to improve accuracy in the degree of outflow tract narrowing using an inflated angioplasty balloon at the point of ligation. A suture is then tied around the vein approximated to the size of the balloon, generally 3–5 mm balloon. Studies reporting on MILLER include both VAS and high-flow access patients. Symptom relief is reported in 75–95% of patients. Access patency rates reported range from 52–100% (primary patency rates), to 25–90% (secondary patency rates).[275,286-288]

Recommendations

- Symptomatic or complicated VAS associated with high-flow > 1 500–4 000 ml, access should be treated with procedures that reduce access flow. *(Class I recommendation/Level C evidence)*
- The DRIL procedure should be considered for brachial-based access with normal access flow, presenting with symptomatic or complicated VAS. *(Class IIa recommendation/Level C evidence)*

Management of cephalic arch stenosis and occlusion

Haemodialysis vascular access dysfunction is a major cause of morbidity and hospitalisation in the haemodialysis population. Stenosis in an AVF can occur anywhere in the fistula, but there are specific locations to a fistula type. Cephalic arch stenosis is a relatively common complication in patients with brachiocephalic vein fistula, comprising 30–55% of all brachiocephalic stenosis sites[289] and may lead to loss of vascular access. This is in contrast to proximal swing point in the transposed BBAVF, or juxta-anastomotic segment in the radiocephalic fistula.

Multiple hypotheses have been put forward to explain the aetiology. Its course in the deltopectoral groove, turning beneath the clavicle and sharply piercing the clavipectoral fascia, result in turbulence and high wall shear stress resulting in intimal injury and failure of positive vascular remodelling.[290] Peri junctional high number of valves, which hypertrophy with high blood flow after fistula creation, may also result in luminal diameter reduction.[291] Venous diameter before creation of fistula of less than 2.2 mm also predisposes to arch stenosis and occlusion.[292]

Treatment with PTA has poor results, with 6-month primary patency 42% and 26% at one year,[293] which is well below the DOQI guideline of 50%. Resistant lesions may be managed with high pressure PTA but are vulnerable to rupture (6%) and accelerated neointimal hyperplasia as a result of trauma. Peripheral cutting balloons create microsurgical incisions in the vascular wall, with the least amount of radial force, and thereby reduce the amount of trauma to the wall from high pressure. Despite its theoretical benefit, they have not demonstrated improved patency rates, and have been associated with dissections and early failure.[294] The drug-coated balloons (DCBs) show promise but only short to intermediate term data are currently available to support their use.[295] Suboptimal angioplasty outcomes and complications (resistant lesions and rupture) have resulted in the use of stents. Restenosis rates are much higher in the bare metal stent group, 70%, compared to covered stent group, 18%. Primary patency rates at six and 12 months for bare metal stents compared to covered stents, are 39% and 82% and 0% and 32% respectively.[253] Placement of stents should not be beyond the cephalic/axillary confluence to avoid jeopardising future use of basilic or axillary vein. The surgical intervention options are either transposition of cephalic vein to axillary or basilic veins,[296,297] or patch angioplasty with primary patency rates of 70% at six months and 60% at one year.[298,299]

Recommendations

- Initial treatment of cephalic arch stenosis should be with PTA± stenting. *(Class IIb recommendation/Level C evidence)*
- DCB should be considered over Plain Old Balloon Angioplasty (POBA). *(Class IIa recommendation/Level C evidence)*
- Covered stents should be used over bare metal stents. *(Class IIa recommendation/Level C evidence)*

Venous hypertension

Venous hypertension (VH) is a distressing complication following the AVF. These complications may occur for anatomical reasons and more frequently due to the increasing utilisation of central venous catheters especially subclavian as a vascular access for haemodialysis. Most common complications of venous hypertension are oedema of soft tissue and collateral circulation at the level of the shoulder or wrist.[300]

The incidence is 8–12% in brachiocephalic AVF, 1–3% in radiocephalic AVF.[301] Associated studies involved small patient numbers, do not compare the different treatment modalities, and do not evaluate the treatment outcomes in a standardised manner.

Pathophysiology

Venous hypertension due to venous stasis can be categorised as central venous hypertension, which is due to stenosis or occlusion of superior vena cava or brachiocephalic trunk. Peripheral venous hypertension is due to stenosis at juxta-anastomotic site, causing intimal hyperplasia with resultant arterialisation of venous system of forearm and hand.

Aims of management

The main aims of management is to preserve the patency of the AVF, resolve the VH and reduce oedema by means of open surgical or percutaneous technique.[302]

Surgery is difficult to perform due to the extensive oedema, thickening of the skin and there is a high risk of bleeding when VH is present. Further, the AVF salvage rate is low.

Due to advances in digital subtraction angiography (DSA), it is now easier to plan access to small vessels of low calibre. Percutaneous treatment of VH is emerging as a single time, safer, easier, and minimally invasive procedure for VH. PTA balloon dilatation and endovascular stenting is a safer alternate to surgery with the advantage of preservation of AVF, but it still has unimpressive long-term patency rates.[302-307] When salvage options are exhausted angiographic embolisation of the AVF is another minimally invasive modality that can be used.[307] Bakken et al. in 2007 evaluated the patency rates at three, six and 12 months; they were 58%, 45%, 29% and 76%, 62%, 53% respectively.[303]

It was observed that the subgroup of VH patients with elastic lesions were unresponsive to BD and required repeated interventions to maintain the patency over the long term. Endovascular bare metal stents (BMS) have been proposed and are being used widely to overcome this problem.

Ozkan et al. in 2013 used metallic stents to treat peripheral venous stenosis in 21 patients with VH and reported 1-year primary patency rates of 76.2% and 2-year secondary patency rates of 65.5%. These results were comparable to those after PTA and surgical shunt revision.[306]

Recommendations

- CT venography should be the first-line investigation to evaluate central venous stenosis or thrombosis. *(Class IIa recommendation/Level B evidence)*
- DDUS is recommended in the early phase of VH to evaluate peripheral stenosis or occlusion. *(Class IIa recommendation/Level B evidence)*
- PTA should be attempted as a primary intervention for central and peripheral stenosis/occlusion to relieve VH. *(Class IIa recommendation/Level C evidence)*
- For significant recoil of central venous stenosis, repeat PTA or stenting should be considered. *(Class IIb recommendation/Level C evidence)*
- Embolisation and/or surgical ligation should be considered as first-line intervention for collateral, accessory veins. *(Class IIb recommendation/Level C evidence)*

Renal access – new technologies

With the rising incidence of haemodialysis worldwide, there is an ever-increasing need for creative, durable means of access. Although an AVF is the recommended access due to its associated low mortality, morbidity, and cost compared with other access types,[308] following AVF creation between 20 and 60% does not successfully mature or are rendered unsuitable for haemodialysis. However, novel technologies introduced recently have the potential to change how autogenous fistulae are created and to improve their durability.

Pharmacological interventions

Porcine pancreatic lipase has been shown to result in elastin fragmentation and decreased intimal hyperplasia when applied to the surface or adventitia of blood vessels.[309] By applying human pancreatic elastase (HPE) at the time of surgery, the hope is that HPE will assist with fistula maturation and overall patency. An optimised, double-blinded study[310] of HPE was performed on patients undergoing radiocephalic or brachiocephalic AVF creation to assess safety and efficacy of the product. The primary efficacy measure of unassisted primary patency was not significantly different between groups, however, HPE use was associated with improved unassisted maturation at three months.[311] Further, a subgroup of patients undergoing placement of a radiocephalic fistula did demonstrate a statistically significant increase in primary patency at three years.[312]

The effect of HPE on AVG has also been investigated.[57] Outcomes were reported after 12 months and showed a non-significant benefit in favour of treatment.

Conduits

More recently, phase-2 trial results have been published for bioengineered human acellular dialysis graft.[313] These conduits are produced by culturing human smooth muscle cells on a polymer scaffold. The conduit is subsequently decellularised. After implantation, there is colonisation of host cells, essentially resulting in a population of cells consistent with a vessel undergoing remodelling. In the combined results of two phase-two studies, with 60 total patients, these conduits had 28% 1-year primary patency, 38% assisted primary patency, and 89% secondary patency, with only three infections. Although there was some aneurysmal formation, it mostly seemed to be limited to cannulation sites.

Minimally invasive creation of arteriovenous fistulae

The possibility of creating an AVF percutaneously has remained an elusive goal. In theory, creating a fistula without traditional open surgery may reduce vessel trauma, thereby reducing the stimulus for intimal hyperplasia that is associated with fistula maturation failure,[311] with concomitant reduced morbidity and improving patient acceptance and fistula use. Within the past couple of years, the possibility of percutaneous AVF creation has become a reality.

In June 2018 the United States Food and Drug Administration (FDA) granted marketing approval for two catheter-based systems for the percutaneous creation of AVF: Ellipsys Vascular Access System® (Avenu Medical) and the everlinQ endoAVF® (TVA Medical).[314]

The Ellipsys Vascular Access System® uses a single catheter that is advanced over wire through an appropriate perforating vein into the proximal radial artery. The catheter device is deployed, sandwiching the vessel wall surfaces of the artery and vein. Utilising electrocautery, the device creates an elliptical anastomosis.[315]

The Ellipsys Vascular Access System® was approved based on a non-randomised, multi-centre study[316] of 103 patients of which 92 patients (89.3%) met the criteria for a usable AVF within three months after the procedure. Almost all patients, however, (96.1%) required an additional procedure (such as PTA) in the first 12 months to maintain the fistula.

The everlinQ® system, on the other hand, uses two catheters with embedded magnets and specifically aligned components to allow radiofrequency cutting between the two catheters. The arterial catheter is advanced into the proximal ulnar artery just distal to the antecubital space, whereas the venous catheter is placed in the nearby ulnar vein. Deep perforating veins allow flow to more superficial median antecubital, cephalic, and basilic veins, with coiling utilised to redirect flow from the brachial vein system.

The everlinQ endoAVF® system FDA approval was based on a non-randomised, multi-centre study[317] of 60 patients and supporting data from three other studies.[318-320] In the main study, 52 patients (86.7%) met the criteria for a usable AVF within three months after the procedure. As with the Ellipsys System®, almost all patients (96.7%) required an additional procedure at the time the fistula was created, while 28.3% of patients required an additional procedure, such as PTA, in the first 12 months to maintain the fistula.

Both devices are contraindicated, or should not be used, for creation of anastomoses in vessels that are less than 2 mm in diameter or too far apart.

Yang et al. compared AVF post-creation procedures and their associated Medicare reimbursement in patients with surgical fistulae to patients with endoAVF. They estimated the average first-year cost per patient-year associated with post-creation procedures was $11 240 lower for endoAVF than surgical AVF.[321]

Novel devices

The VasQ® is an external support device that slides over the outflow vein, which is then brought over the anastomosis on completion, with the goal of minimising flow disturbances at the anastomosis, in order to reduce neointimal hyperplasia at the anastomotic site. In an uncontrolled study of 20 patients designed to evaluate safety, primary AVF patency rates at six months were 79% with no serious device-related complications.[322]

The Optiflow® device (Bioconnect Systems) is an internal insert designed to minimise the need for anastomotic suturing. It is composed of non-thrombogenic polyurethane material, and has an angulated design used to standardise the surgical anastomosis and to optimise flow through this area. The potential advantage of this device is standardisation of the anastomosis and flow characteristics, thereby removing technical variability and potentially improving outcomes.[311] The OPEN study demonstrated the short-term success of the device in terms of maturation and patency.[323] The data suggested efficient dialysis could be achieved with these AVFs. Additionally, primary patency was reported at 78% for 90 days with no serious device-related adverse events. An internal needle guide, Venous Window Needle Guide® (VWING), device provides an alternative to superficialisation of deep AVF. The device is conceptually like a pole vault box; it is a metal guide box that is implanted in one or two locations on fistulae that are too deep. The device is effective for a depth range of 6 mm to 15 mm, is designed to be palpable through the skin and guides the needle to the designated cannulation sites. In two combined clinical trials, the device maintained continued ability to access the designated sites for 65% of enrolled patients.[324] Only one of the 54 patients required removal of the device for infection, with another seven patients having devices removed for cannulation difficulties.

The Surfacer® Inside-Out® Access Catheter System is a novel device allowing physicians to insert a guidewire through the femoral vein in the groin area and, using fluoroscopy, navigate it up through the torso with an exit point in the jugular vein. It is designed to reliably, efficiently, and repeatedly gain central venous access for patients with upper body venous occlusions or other conditions that preclude central venous access by conventional methods. The SAVE-US trial is a pre-market investigational device exempt (IDE) study evaluating the safety and efficacy of the Surfacer® Inside-Out Access® Catheter System. Thirty patients will be enrolled at up to 10 centres in the USA with additional centres in Europe and the results are eagerly awaited.[325]

Future directions

Vascular access is the lifeline of the haemodialysis patient. In recent years, many new technologies have been introduced to overcome less-than-ideal AVF surgical outcomes.

Endovascular techniques have increased the ability to mature and maintain vascular access. A number of conduits and devices, as well as pharmacological agents, that are recently available or on the horizon show promise to significantly impact the field. As with transplant itself, a comprehensive multidisciplinary approach is required, not only to optimise outcomes, but also to maintain a comprehensive program for dialysis access surgical care.

Recommendations

- Pharmacological means of assisting fistula maturation has shown promise and can be considered at the time of fistula creation. *(Class IIb recommendation/Level B evidence)*
- Bioengineered conduits are currently under investigation and cannot be recommended outside the scope of a clinical trial. *(Class IIb recommendation/Level C evidence)*
- Minimally invasive methods of creating AVF appear feasible and cost-effective in selected patients. *(Class IIa recommendation/Level B evidence)*
- Novel internal and external anastomotic support devices can be considered at the time of surgical creation of an AVF. *(Class IIb recommendation/Level C evidence)*
- An internal needle guide device can be considered as an alternative to surgical superficialisation in fistulae that are too deep. *(Class IIb recommendation/Level C evidence)*

Vascular access – superior vena cava syndrome

Superior vena cava (SVC) syndrome is the result of stenosis or occlusion of the SVC or bilateral brachiocephalic veins. Signs and symptoms of venous congestion of the head, neck, and upper extremities make up SVC syndrome.

Diagnostic evaluation

The diagnosis is confirmed by angiography – the gold standard. Based on the extent of venous occlusion, as defined by bilateral upper extremity venography, Stanford and Doty[326] described four venographic patterns of SVC syndrome, each having a different venous collateral network depending on the site and extent of SVC obstruction. Type I is partial and type II is complete or near-complete SVC obstruction, with flow in the azygos vein remaining antegrade. Type III is 90–100% SVC obstruction with reversed azygos blood flow. Type IV is extensive mediastinal central venous occlusion with venous return occurring through the inferior vena cava.

Accuracy of colour flow DUS is limited by the presence of bony thorax. CT venography is an effective tool in defining the SVC in selected cases, especially prior to aggressive interventions for recanalisation. Magnetic resonance angiography to evaluate central veins has a limited role due to the potential risk of nephrogenic systemic fibrosis from gadolinium use in patients with advanced kidney dysfunction.

Management endovascular

PTA results in various studies are highly variable and the technical failure rate ranges from 10–30%. Patency rates after PTA alone are generally poor (28.9% at 180 days, and 25% at one year).[327] Elastic recoil of central veins, as demonstrated by intravascular ultrasound, is probably the culprit. PTA with high pressure balloons has shown better results (primary patency of 60% at six months and 30% at 12 months).[328] Significant secondary patency approaching 60% at 12 months can be achieved with repeated PTA without stent placement.

Marginal outcomes of PTA alone have prompted a recommendation of stent placement as a primary measure for SVC. However, stent shortcomings make this practice a rather aggressive approach. PTA with stent placement is recommended for elastic vein recoil leading to significant residual stenosis after PTA or for lesions recurring within three months after PTA.

Open surgery

For replacement of the SVC or the innominate vein in patients with benign disease, autogenous spiral saphenous vein graft (SSVG) is the first choice.

Of the available prosthetic materials, externally supported ePTFE is used for large vein reconstruction almost exclusively because of low thrombogenicity. Surgical repair offers better patency rates but requires sternotomy with its associated morbidity and mortality.

Recommendations

- Venography is recommended to evaluate central venous stenosis PTA as primary. *(Class I recommendation/Level C evidence)*
- Treatment of symptomatic central venous outflow disease is recommended, with repeat interventions if indicated. *(Class I recommendation/Level C evidence)*
- Stenting or repeat PTA should be considered if there is significant elastic recoil of the central vein after PTA or if the stenosis recurs within three months. *(Class IIa recommendation/Level C evidence)*
- The use of stent grafts may be considered for the treatment of central vein stenosis. *(Class IIa recommendation/Level C evidence)*

Monitoring/surveillance protocol post intervention of central veins, arteriovenous fistula and arteriovenous grafts

Vascular access is the lifeline of the haemodialysis patient. Stenotic lesions account for most of the fistula and graft thrombosis. Untreated stenoses may progress and eventually lead to thrombosis. A combination of physical examination and arteriovenous testing has been used to evaluate for a stenosis of an AVF or AVG. Early corrective intervention may prevent thrombosis and the associated complications and thus help maintain functional access. There has been a lot of controversy regarding the best method of surveillance as well as the benefit of surveillance since the publication of the KDOQI guidelines in 2006.[329] The European Society for Vascular Surgery (ESVS) strongly recommends the use of clinical monitoring. They also recommend monthly surveillance using access flow measurement for AVGs and a 3-monthly interval of surveillance for AVFs.[166]

There is a lack of evidence to guide the exact follow-up for patients who underwent an intervention of an AVF, AVG or central venous obstruction. It is important to have a multidisciplinary approach to access maintenance and include the patient, nursing staff, nephrologist and access surgeon to be able to identify lesions early so that appropriate intervention can be done to prolong access lifespan.

Recommendations

- A persistent decrease in the effective dialysis dose or a decrease in blood flow within the vascular access should be evaluated for a significant stenosis. *(Class IIa recommendation/Level B evidence)*
- Routine surveillance for AVG cannot be recommended above clinical monitoring to prevent thrombosis. *(Class I recommendation/Level B evidence)*
- Routine surveillance for AVF may be used to prevent thrombosis but is unlikely to improve fistula lifespan. *(Class IIa recommendation/Level B evidence)*
- A repeat venogram and PTA is recommended at 3–6 months after intervention for central venous occlusion or stenosis to prevent restenosis. *(Class IIa recommendation/Level C evidence)*
- Patients with multiple recurrent stenosis or thrombosis at the costoclavicular junction should be investigated for thoracic outlet syndrome. *(Class IIb recommendation/Level C evidence)*

Definitions

- Monitoring – physical examination of the vascular access to detect signs of dysfunction.
- Surveillance – the periodic evaluation of the vascular access with special instrumentation to detect the presence of dysfunction.
- Diagnostic testing – specialised testing to confirm the cause of dysfunctional access (usually angiography).
- Maintenance – intervention is done to improve function and prevent loss of a functional access (prior to thrombosis).
- Salvage – intervention to recover a thrombosed access or fistula that is failing to mature.[329]

Clinical monitoring

Physical examination

The physical examination is probably the most important tool to assess a patient for access dysfunction. It is non-invasive, inexpensive, effective and does not require specialised equipment. Regular education and training can equip the dialysis nursing staff and even the patient to arteriovenous clinical clues to a possible underlying stenosis.[330]

A comparison between physical examination results and angiography was studied. Although the numbers were small, physical examination was shown to be an accurate predictor of a significant stenosis. This correlation was highest in detecting vein graft anastomotic stenosis. The physical examination results were also sensitive to detect intra-graft stenosis but to a lesser degree.[126,241]

Dialysis complications

Whenever there are signs of dialysis dysfunction a stenotic lesion must be suspected. Other features of a dysfunctional access include a prolonged bleeding time, poor pump speeds, thrombus extraction through the cannula and difficulty cannulating the access.[330,331]

Dialysis dose

A sudden decrease in the normal dialysis dose achieved may alert the clinician to an underlying pathological stenosis. The urea reduction ratio (Kt/V) is dependent on a number of factors but the vascular access function will play a role. Whenever there is a significant decrease in dose achieved ($Kt/V > 0.2$) and other causes are excluded, the access should be evaluated.[166,331]

Surveillance

Several tests have been developed to investigate and survey the patency of an AVF or AVG. These tests are based on flow measurements, direct arteriovenous and pressure measurement.

Blood flow (Qa)

The average QA in a well-functioning AVF is 500–800 ml/minute and 600–1 000 ml/minute in an AVG.[330] A significant stenosis may be present when there is a decrease in the QA through the fistula or graft. Different methods of measuring flow have been developed. Most methods will deliver similar results.[332] The dilution method described by Krivitski is most commonly used. It is done using a saline bolus and arteriovenous sensors on the dialysis lines. A clearance curve is generated and can then be used to calculate the flow rate.[333] Serial measurements are more helpful than individual measurements. Flow less than 500 ml/minute in an AVF or less than 600 ml in an AVG, or a decrease in flow more than 25% from the baseline is concerning for a significant stenosis. In some observational studies flow monitoring has a positive predictive value of 87–100% to detect a significant lesion.[333-335]

Duplex ultrasound

The intra-access flow rate can be determined by using DUS peak systolic velocity (PSV). A ratio of more than 2.0 across a lesion correlates with a significant stenosis.[336] The accuracy is operator dependent and should be performed by experienced personnel. The additional benefit of ultrasound is that ultrasound can directly visualise lesions and give further anatomical information. Serial measurements will again be more valuable to detect a progressive stenosis.

Magnetic resonance angiography (MRA) has also been used to evaluate the flow in a vascular access, but is expensive, time consuming and limited by contrast use that carries a risk of causing nephrogenic systemic fibrosis. It is thus not used routinely as a screening tool.[166]

Static venous pressures are measured prior to the initiation of dialysis. Individual measurements are less useful than monitoring trends. The venous pressure (VP) has a direct correlation with the mean arterial pressure (MAP). A ratio of VP/MAP has been designed.[329] The 2006 KDOQI guidelines recommended referral once a ratio of 0.5 is reached. There is still controversy whether surveillance using VP is really predictive of a thrombosis. In a recent trial the VP/MAP correlation was confirmed.[332] The diameter ratio of the artery and vein was however shown to be a very important factor when determining the significance of the VP/MAP ratio. When the artery/vein ratio is high (larger artery compared to the vein), the 0.5 threshold is reached earlier with only a 39% stenosis. But with a low ratio the stenosis can be 72% before the 0.5 threshold is reached. Taken into account, the artery and vein ratio may improve the accuracy of this surveillance method to predict critical stenosis and subsequent thrombosis. But the ideal timing of measurements as well as threshold for intervention still needs to be investigated in further trials.[332]

Success of PTA

Successful PTA defined by KDOQI guidelines is a residual stenosis less than 30%,[329] but there may still be recoil later resulting in poor secondary patency. A recent trial has investigated the sensitivity of this value. Pullback catheter pressures were measured after achieving the 30% target with PTA. They found that 18% of the lesions still had a significant drop in pressure that required further PTA.[337]

The secondary patency is closely related to the degree of residual stenosis. A difference in the intervention-free and graft survival was demonstrated in patients who had a complete resolution versus a residual stenosis.[338,339] A durable outcome is more likely if the flow rate returns to normal or to the baseline level after the PTA.[340] Some clinical improvement should also be evident. The vascular access lifespan can be prolonged by optimising the treatment at the time of intervention.

Predictors of early restenosis

Repeat interventions are often needed. The healing process after PTA is complex and recoil and restenosis cannot always be predicted. The type of access is important as AVFs generally maintain patency better than AVGs after intervention.[334] A matured fistula will do better than a maturing fistula. Interventions for salvage have a lower patency than those done for maintenance. Other factors predicting patency include the number of stenotic lesions and location of fistula.[341]

These factors should be taken into account when deciding on the follow-up plan. A shorter follow-up will be appropriate if there is a higher risk for restenosis. An individualised strategy may be better than a standard follow-up period for all patients.

Central venous stenosis

These lesions are difficult to treat as they require very large balloons (to achieve adequate PTA) and have a high degree of elastic recoil. Patients with central venous obstruction generally require multiple interventions.[342] PTA and stenting are now commonplace to overcome the recurrent stenosis.[343] The ideal timing of surveillance and subsequent intervention is not well established. The reported 6-month patency rates after intervention vary widely. With PTA alone, 6-month patency rate ranges 23–60% in retrospective series. When a bare metal stent is placed this improves to 55–100% at six months and 81% when a stent graft is placed.[344] More recently drug-eluting balloons and covered stents have been used to try and improve the durability of the intervention. New data suggest than a program of early (< 6 months) reintervention in patients who had a central venous stenosis may lead to less repeated interventions and a higher patency later on. Secondary patency rates close to 100% may be achieved by early reintervention.[345]

More complex cases need closer follow-up and more aggressive intervention to prevent a complete occlusion. Long term outcomes with randomised trials will still need to be conducted to better understand the ideal timing of surveillance in this group.

Surgery is not often needed but with failure of endovascular treatment one needs to consider venous bypass to overcome the lesion and allow for the possibility to create future vascular access on the affected side.[343]

Thoracic outlet syndrome

Patients with repeated access thrombosis and significant arm symptoms should be evaluated for thoracic outlet syndrome and may require a thoracic decompression. A series of 10 cases were reported where a mean of 2.3 PTA attempts were unsuccessful. These patients had significant arm symptoms and dialysis dysfunction. Nearly all the patients had complete resolution of symptoms with a thoracic outlet decompression in the form of rib resection, venolysis and scalenectomy.[351] In another series of five patients with subclavian stenosis at the costoclavicular junction reported primary and primary assisted patency rates of 15.5 and 18.4 months respectively after first rib resection.[347]

Systematic reviews and meta-analyses regarding surveillance in haemodialysis vascular access

The role of surveillance of vascular access as primary or as secondary prevention of thrombosis is evolving. Initial non-randomised studies showed promise in reducing the complications of thrombosis and extending access lifespan when VP and Qa measurements were combined with intervention.[348,349] This led to the KDOQI guidelines recommending intervention based on these parameters. These recommendations have been controversial as the quality of evidence was poor.

Three systematic reviews and meta-analyses were conducted to assess the value of surveillance. They did show a decrease in AVF thrombosis with surveillance, but it did not translate into an increased fistula lifespan.[350] There was no statistically significant difference using surveillance for AVGs. The overall quality of the studies was moderate to poor with small numbers and incomplete data. Further randomised trials will be needed before a recommendation can be made regarding surveillance.

The current role of surveillance

The understanding of pressure measurements and factors that influence the values has challenged the previous intervals for surveillance. The VP/MAP intervention threshold of 0.5 will not hold true for all patients, and variables like the artery vein diameter ratio will need to be taken into account when deciding on intervals between surveillance. Some of the concerns for using these surveillance tests as screening have been highlighted in recent review articles. Our understanding of the pathophysiology that leads to eventual thrombosis and access loss is not complete. There is an interplay between numerous variables that are difficult to measure and thus using a test as a screening tool without all the necessary information is not reliable.[126] Some patients' access will thrombose prior to the current thresholds and others will remain patent despite meeting criteria for intervention.[126] When the World Health Organization recommendations for screening tests are applied to the current Qa and VP measurements they do not meet the criteria.[351]

Stenosis and occlusions of access

Stenosis related to intimal hyperplasia is probably the most common thrombotic complication of dialysis access.[352,353] The use of PTA has increased, although open surgical options (patch angioplasty) have also been advocated.[354] They have resulted in relatively poor outcomes with high re-occlusion rates.

More recently, drug-coated balloons (DCBs) PTA has been suggested to decrease proliferation of smooth muscle cells in these stenoses.[355-357]

DCB with Paclitaxel have shown encouraging results with freedom from restenosis at 12 months between 67–88% in some series as compared to conventional PTA of 38%.[356-360]

Performing routine repeat PTA with a DCB, may prevent permanent stenosis and potentially provide a cure for such stenosis.[361] This procedure needs further evaluation before its widespread use can be recommended.

Recommendations

- Conventional PTA can be used to treat significant access stenosis. *(Class IIb recommendation/Level C evidence)*
- DCB PTA should be used to treat significant access stenosis.*(Class IIa recommendation/Level C evidence)*

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Notes