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Vascular access surveillance

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GUIDELINES

Arteriovenous graft (AVG)

a. Regular Access Blood Flow (Qa) or Doppler ultrasound stenosis (DUS) screening increases the detection of AVG stenosis compared to dynamic venous pressure (DVP)/clinical examination. (Level II evidence)

b. Regular Qa screening with pre-emptive angioplasty does not reduce AVG thrombosis or prolong AVG survival. (Level I & II evidence)

c. Whether regular DUS screening with pre-emptive angioplasty reduces AVG thrombosis or prolongs survival is not known. (mixed results, Level I & II evidence)

d. Whether regular Qa or DUS screening coupled with pre-emptive surgical repair reduces AVG thrombosis or prolongs survival is not known.

e. Regular static venous pressure (SVP) screening with pre-emptive angioplasty does not reduce AVG thrombosis or prolong survival. (Level II evidence)

Arteriovenous fistula (AVF)

a. Regular Qa screening increases the detection of AVF stenosis compared to clinical examination/low arterial pressure/recirculation alone. (Level II evidence)

b. Regular Qa screening with pre-emptive repair (either angioplasty or surgery) reduces AVF thrombosis (Level I & II evidence) and may prolong AVF survival. (Level II evidence)

SUGGESTIONS FOR CLINICAL CARE

(Suggestions are based on Level III and IV evidence)

AVG

- **There is no evidence (Level I or II) to refute or support DVP-based screening**

AVF

- **Screening with DVP has little or no role (Opinion)**
- **There is no evidence (Level I or II) to refute or support DUS-based screening**
- **Optimal Qa thresholds, frequency of monitoring and cost effectiveness have not yet been determined**

BACKGROUND

The development of progressive vascular access stenosis with the subsequent failure of the access (thrombosis and/or revision) contributes significant morbidity to patients on haemodialysis. The maintenance of vascular access in haemodialysis patients is estimated to account for at least 25% of all hospital admissions in the USA[1,2] and 18% in Canada.[3] The total annual global cost of vascular access morbidity has been estimated to account for 14% to 17% of all spending on haemodialysis per year at risk.[4] Costs are also higher for catheters and AVG compared to AVF.[3–5] Finally, the use of catheters is also associated with higher morbidity and mortality compared to the use of AVF.[6–8] Therefore, the ability to identify a vascular access at risk for failure through the detection of a significant access stenosis is considered an important clinical goal as the identified vascular access could ideally be repaired electively to prevent failure and interruption to the dialysis treatment.

The objectives of this guideline are to review the evidence that vascular access surveillance or screening for significant vascular access stenosis, with subsequent elective repair, will improve vascular access survival. For a screening programme to be successful, two important elements are needed. Not only should the screening test be efficient at detecting the presence of an underlying significant stenosis, it should also be subsequently demonstrated that correction of the stenosis results in a reduction in vascular access thrombosis rates and/or prolongs access survival.

SEARCH STRATEGY

Databases searched: MeSH terms and text words for haemodialysis were combined with MeSH terms and text words

for arteriovenous shunt surgical, arteriovenous fistula and combined with MeSH terms and text words for pathologic constriction, stenosis, thrombosis, graft occlusion and blood flow velocity. The search was carried out in Medline (1966 – August, Week 4, 2007). The Cochrane Renal Group Trials Register was also searched for trials not indexed in Medline. **Date of search:** 31 August 2007.

WHAT IS THE EVIDENCE?

A large number of methods have been advocated as a screening test for vascular access stenosis. These include pressure measurements such as dynamic venous pressure (DVP) and static venous pressure (SVP), using doppler ultrasound to screen for an underlying stenosis (DUS), and the measurement of vascular access blood flow (Qa). In order to interpret the rationale for these techniques, an understanding of the haemodynamics of both normal and stenotic AVG and AVF is essential.

Vascular access haemodynamics

In AVF, blood flow in radiocephalic AVF is approximately 700 to 1100 mL/min while in upper arm AVF, flows are much higher, ranging from 1100 to 2000 mL/min but can also reach over 3 L/min.[9–11] Blood flow in normal AVG is 600–800 mL/min in straight grafts from the radial artery, rising to approximately 1000 mL/min for forearm loops.[12–14] Upper arm AVG blood flow is higher and can reach up to 3000 mL/min.[15]

Although the range of blood flow in AVF is similar to AVG, the relationship between pressure and flow is not.[16,17] Arteriovenous grafts, by their very nature, have only one draining outlet (the venous anastomosis). Most of the arterial pressure in AVG is dissipated across the two anastomoses,[18] with the pressure gradient generated larger than in AVF (around 40%) [Figure 1]. It follows that any obstruction to outflow from the AVG will result in an increase in the intra-access pressure with a corresponding reduction in blood flow (Figure 2).[16]

In the radiocephalic AVF the blood returns to the heart by multiple collaterals and not just the main draining vein. Intra-access pressure in AVF falls to around 20% in the earliest segment of the AVF with the drop in pressure over the rest of the AVF remaining low (about 10%) [Figure 1]. As a result of the low resistance and presence of the collateral veins, a venous stenosis can cause a reduction in blood flow but without the corresponding increase in access pressure (Figure 2).[16] This relationship becomes important when using pressure measurements to detect stenosis in AVF. Whether this relationship persists in AVF in the upper arm position has not been examined. However, given the more distal location it is possible that the pressure/flow relationship is more like AVG.

Based on the knowledge of access haemodynamics, access surveillance can be performed by using either pressures or blood flow as a surrogate marker to detect the presence of stenosis or by directly screening for the presence of a stenosis itself.

Blood flow screening: techniques

Vascular access blood flow can be measured by a number of different techniques but is broadly categorised into those using indicator dilution techniques, or those directly estimating Qa using either Doppler ultrasound or magnetic resonance imaging (MRA).[19] Krivitski elegantly described and validated the application of dilution principles to measure vascular access blood flow.[20,21] According to the dilution method, blood flow (Q) is given by:

$$Q = V/S$$

where V is the amount of injected indicator that completely mixes in the blood flow stream Q; S is the area under the dilution curve which is equal to the average concentration of indicator in the blood multiplied by the duration of the curve. By reversing the dialysis blood lines (inducing access recirculation) and measuring both the blood flow in the tubing and the changes in ultrasound velocity induced by a saline bolus (using ultrasound probes attached to the blood line) access blood flow (Qa) is equal to:

$$Qa = Qb * (Sv/Sa - 1)$$

where Qb is the venous line blood flow and Sv/Sa is the ratio of areas under the dilution curves recorded by matched arterial (Sa) and venous dilution sensors generated by the saline bolus injection. The above equation can then be rewritten into the now widely recognised form:

$$Qa = Qb * (1/R - 1)$$

where R is the fractional access recirculation caused by the reversal of the dialysis lines. Following the initial description of the technique by Krivitski using saline as the indicator, others demonstrated the measurement of access blood flow based on different blood properties such as electrical impedance (conductivity),[22] optical properties (haemocrit)[23,24] and temperature.[25] Newly developed recent techniques include the variable flow Doppler method,[26] the transcutaneous flow monitor [27] and the glucose pump test,[28] which do not require the reversal of the dialysis lines to perform the measurements.

The ultrasound dilution velocity method is the most well-validated method for measuring access blood flow[20,21,29,30] and is considered to be the gold standard method.[14,31] Following the initial description of the method, using both bench and animal models of haemodialysis,[20,21] four factors have been identified that directly influence the accuracy of the measurements.[30,32] Firstly, thorough mixing of the indicator is required, which is influenced by both the distance between and orientation of the needles where the arterial needle must be placed in the direction of the incoming flow. In AVF, the two needles must be in sequence or series with the arterial needle in the main branch of the AVF. Secondly, the second pass of the indicator due to cardiopulmonary recirculation will produce errors if it is

incorporated into the measurement. Cardiopulmonary recirculation (CPR) increases as Qa increases (CPR = Qa/CO) and if incorporated, will cause an underestimation of the true Qa value. Thirdly, the reversal of the blood lines that is required to perform the measurement will also influence the access blood flow result. Using mathematical modelling and comparing to the flow measured directly by an implanted transit-flow probe, Qa determined by the dilution method was found to underestimate the true access flow by an average of 40–60 mL/min.[30] Others have also confirmed these both theoretically by using haemodynamic calculations and in vitro, in a bench model of haemodialysis.[33] Finally, Qb must be measured accurately as readings from the dialysis blood pump have been shown to overestimate delivered Qb flow by between 10% to 20%.[34] The ultrasound dilution method is the only method that directly measures Qb instead of using the dialysis blood pump readings. In addition, injection of the fluid bolus into a venous port close to the access can also cause significant errors in the Qb measurement and therefore the Qa estimate. This was eliminated by moving the bolus injection to prior to the venous bubble trap.

As the dilution techniques are performed while the patient is undergoing the haemodialysis treatment, the haemodynamic state of the patient at the time of the test can influence the result of the test.[35–37] Therefore, it is recommended that flow measurements be performed only in the first 1.5 hours into the treatment when the blood pressure is usually stable.

Doppler ultrasound measures blood flow velocity and not blood flow directly. In order to determine blood flow, cross-sectional area needs to be estimated. The estimated flow can be inaccurate due to the operator dependence on determining the blood velocity, and subject error in estimating the cross sectional error and the Doppler angle.[38–40] Four studies have compared Qa determined by ultrasound dilution to that by ultrasound.[29,41–43] Three compared flow by correlation coefficients only and thus did not assess agreement between the methods.[29,41,42] The fourth study however, was well performed, comparing the two methods with the intraclass correlation coefficients (ICC) and Bland and Altman limits of agreement.[43] The investigators used the same ultrasound machine to estimate flow by conventional Doppler and quantitative colour velocity index (CVI-Q), which is not as operator dependant and is associated with less error.[42,43] Compared to ultrasound dilution, convention Doppler performed very poorly with an ICC of 0.10 and demonstrated significant bias with an increasing difference between the two as the mean Qa increased. Qa estimated using CVI-Q faired better with the ICC 0.56 and no systematic bias on the Bland and Altman plot.

Access flow can also be measured by MRA. However as this technique is expensive and cannot be performed during dialysis it is impractical as a screening tool. Nevertheless, two studies have assessed MRA, comparing it to dye dilution techniques,[44] and ultrasound dilution.[45] All studies used correlation coefficients to compare the techniques, with coefficients ranging from 0.84 to 0.86.

Blood flow surveillance: randomised controlled trials

Prospective studies have established an association between Qa and the risk of thrombosis and/or the presence of a stenosis.[46–51] The risk of thrombosis differs depending on access type, with AVG at risk of thrombosis at higher flows (cut offs 500 to 750 mL/min)[46,47] compared to AVF where thresholds are lower (300 to 500 mL/min).[50]

Five RCTs including a total of 520 patients have examined the effect of Qa surveillance and pre-emptive repair (angioplasty in the majority of studies) on vascular access thrombosis rates (Table 1).[52–56] Overall, the RCTs are of variable quality and used different monitoring frequencies and flow thresholds for the triggering of investigation. Note that all trials measured Qa using ultrasound dilution. Follow-up ranged from 6 months to 5 years. One further RCT examined the ability of Qa surveillance to detect AVF stenosis but was not powered to assess AVF outcomes.[48] This study demonstrated that the addition of Qa monitoring doubled the detection of a significant AVF stenosis compared to the control group although this did not reach statistical significance (HR 2.27, 95% CI 0.85, 5.98, P = 0.09).

Sands *et al.*[54] assessed both SVP and Qa surveillance. Both AVF and AVG were included in the study with results presented separately. A significant reduction in thrombosis rates in both AVG (2.5 vs 0.2 per patient years, $P < 0.01$) and AVF (0.27 vs 0.17 per patient years, $P < 0.05$) was seen. However, although there were two separate intervention groups (SVP and Qa screening), the two groups were combined in the presentation of the results. Thus, it is difficult to determine which method provided the benefit. In addition, both the AVG and AVF control groups had an unusually high thrombosis rate, which magnified the benefit seen in this small study.

Smits *et al.*[55] in two separate studies, compared either Qa surveillance alone or Qa surveillance and DVP to DVP alone in patients with AVG. The primary end-point in the study was defined as a thrombotic episode without a preceding positive test. This unfortunately lead to the exclusion of 21 of the 42 thrombotic episodes which occurred after a positive screening test but before the planned intervention, thus reducing the power of the study. No difference was seen between the thrombosis rates between the two groups in each of the studies.

Ram *et al.*[53] performed an RCT in AVG with three arms – a control group (clinical examination and DVP), a monthly Qa surveillance group and a 3-monthly ultrasound stenosis screening group. Results of the ultrasound arm are discussed below. Intervention rates in the Qa group were significantly higher in the screening group compared to the control, indicating that screening detected 'significant' AVG stenoses. However, despite this, the thrombosis rate was significantly higher in the Qa group compared to the control group (0.91 vs 0.68 per patient years, P = 0.02), the results largely driven by multiple thromboses in three AVGs.[53] Overall, the two-year graft survival was no different between the groups. Moist *et al.* [52] also compared clinical and DVP to monthly Qa surveillance in AVG alone. Similar to the previous study, despite the significantly higher rate in

intervention in the Qa group, no significant difference was seen in the thrombosis rates between the two groups. In both these studies, assessment of the vascular access was performed blind to the surveillance assignment.

Finally, Tessitore *et al.*[56] examined subjects with stenotic AVF. Blood flow was measured using ultrasound dilution on a 3-monthly basis. Randomisation was by coin toss and there was no blinding of surveillance allocation. Arteriovenous fistula failure, which included thrombosis and access abandonment, was significantly longer in the Qa group compared to the control group (HR for failure control vs treatment = 3.93, 95% CI 1.42, 10.93). Specific thrombosis rates were not reported. The same group also reported a further RCT which randomised functioning but stenotic AVF to angioplasty or no treatment. This study also demonstrated significantly improved AVF survival with the angioplasty procedure.[57]

Doppler ultrasound stenosis screening: randomised controlled trials

Doppler ultrasound is a non-invasive procedure that in addition to the measurement of Qa can provide anatomic information on the vascular access. As such, it has been advocated as a screening technique to identify accesses at risk of thrombosis by identifying the anatomic presence of a significant stenosis. The main disadvantage is that it requires specialised equipment, skill, and is expensive.

Six RCTs[53,58–62] assessing the effect of DUS screening for stenosis combined with either angioplasty or surgical repair on access thrombosis and survival have been performed (Table 2). All trials excluded AVF. Mayer *et al.*[60] randomised 70 patients with new PTFE AVG to either 3-monthly clinical examinations or 3-monthly Doppler ultrasound examination in the first year and subsequent yearly examinations. Ultrasound screening resulted in a significantly longer secondary AVG patency at 6 months post-AVG implantation but this did not persist at 12 months of follow-up. This was not at the cost of more frequent re-operations in the surveillance group where 77% of the control group required reoperation versus 43% in the surveillance group. In addition, the number of secondary procedures was significantly less in the surveillance group (0.7 versus 1.6 per patient, P = 0.05). The higher procedure rate in the control group was accounted for by a much higher thrombosis rate compared to the surveillance group (42 versus 2, respectively). All interventions in this study were surgical.

Lumsden *et al.*[58] screened all patients for the presence of a significant (>50%) stenosis, randomising those with a significant stenosis detected (confirmed on angiogram) to receive either prophylactic angioplasty or observation. Ultrasound scanning was continued every 2 months. Both 6- and 12-month patency rates were no different between the two groups. Subsequent to the initial report, Martin *et al.*[63] presented a sub-analysis assessing only new AVG enrolled in the study. Only 21 patients from the original 64 patients had new AVG, 8 in the treatment group, 13 in the control group. In this subgroup, there was a significant prolongation of AVG patency (P = 0.035) and a reduction in thrombosis rate in the treatment group (0.10 versus 0.44 thrombosis per patient-dialysis year).

In the study by Ram *et al.*[53] patients were randomised to 3-monthly DUS screening. The ultrasound screening group had the highest pre-emptive angioplasty rate and a trend to a longer thrombosis-free survival (P = 0.10). However, neither event-free survival nor 2-year AVG survival (62% versus 64%) were significantly better in the ultrasound group.

Malik *et al.*[59] randomised 192 subjects to either regular ultrasound examinations performed every 3 months in addition to 'traditional screening' (consisting of regular access examination, DVP monitoring and access flow) or the traditional screening only. Blood flow was also calculated using the velocity readings from the ultrasound assessments. Subjects were referred for intervention if a 'significant stenosis' (not defined in the paper) was detected with or without a decrease in blood flow or if a 'non-significant stenosis' was detected with a blood flow decrease of >25%. Thus the study tested a combination of stenosis screening and blood flow reductions. Subjects in the ultrasound screening group had a significantly longer access patency compared to the usual screening group (P < 0.001) with a higher rate of interventions (2.1 versus 1.3 per graft).

Robbins *et al.*[61] randomised 126 patients with AVG to either regular 4-monthly ultrasound surveillance in addition to clinical monitoring or to clinical monitoring alone for AVG stenosis. While the frequency of pre-emptive graft angioplasty was 64% higher in the ultrasound group (1.05 vs 0.64 events per patient-year, P < 0.001) due to an increase in the detection of AVG stenosis, the cumulative graft survival was similar (median survival 38 versus 37 months for the ultrasound and control groups, respectively, P = 0.93). The thrombosis rates were also not different (0.67 vs 0.78 per patient-year ultrasound and control groups, respectively, P = 0.37).

Finally, Sands *et al.*[62] prospectively randomised 55 patients to screening with colour flow Doppler ultrasound. Patients with stenosis ≥50% underwent angiography ± angioplasty. The ultrasound group had a significantly lower thrombosis rate (19.2 vs 126.2/100 patient years, P < 0.05) and intervention rate (21 vs 138.8/100 patient years, P < 0.05). This study is published only in abstract form.

Blood flow surveillance and doppler ultrasound stenosis screening: systematic review

One systematic review has assessed the effect of screening using access blood flow measurements and DUS on vascular access outcomes.[64] The review included all 11 RCTs detailed above plus an RCT of preemptive PTCA, as the AVF stenosis were detected by blood flow screening. A total of 1,164 participants were included in the review. Outcomes assessed were access thrombosis, access loss (defined as access abandonment) and resource use. Outcomes for AVG and AVF were reported separately.

For AVG, no reduction was seen in either the risk of thrombosis (RR 0.94, 95% C.I. 0.77 – 1.16, 6 trials) or

access loss (RR 1.08, 95% C.I. 0.83 – 1.40, 4 trials). Access screening significantly increased the number of angioplasties (relative rate 1.29, 95% C.I. 1.04 – 1.60, 5 trials) while the number of catheter insertions was significantly reduced (relative rate 0.59, 95% C.I. 0.37 – 0.93, 1 trial).

In contrast to AVG, a significant reduction in AVF thrombosis was seen with screening (RR 0.47, 95% C.I. 0.28 – 0.77, 4 trials), In the 2 trials that reported access loss, no effect was seen in screening (RR 0.65, 0.28 – 1.51). One trial reported both a reduction in catheter insertions (relative rate 0.20, 95% C.I. 0.04 – 0.88) and hospitalisations with screening (relative rate 0.37, 95% C.I. 0.16 – 0.87).

Other screening techniques: randomised controlled trials

Numerous other techniques have been advocated for use in screening for vascular access stenosis. These include physical examination, the measurement of access recirculation (AR), DVP and/or SVP. Of these techniques, only SVP has been the subject of randomised trials. Physical examination of the access remains very important with physical findings suggesting a significant venous stenosis include oedema of the access extremity, prolonged bleeding post-venipuncture and changes in the physical characteristics of the pulse or thrill.

AR resulting in reduced dialysis efficiency occurs when the dialysed blood, returning via the venous needle of the extracorporeal circuit is taken up again through the arterial needle, by-passing the systemic circulation. It occurs once Qa within the AVG or AVF is less than the dialyser blood flow (Qb).[65] The presence of AR signifies reduced Qa resulting from the presence of a haemodynamically significant stenosis. The clinical usefulness of AR measurements in AVG surveillance is limited as the risk of thrombosis in AVG is high once Qa is reduced to 500–800 mL/min, a range of blood flow which is too high to cause AR. Unlike AVG, AVF blood flow can decrease to lower than prescribed dialyser blood flow while still maintaining patency. Thus, the measurement of AR can be a useful tool to detect AVF stenosis although there have been no RCTs performed to date. The measurement of AR using saline dilution failed to detect a significant number of patients with documented low AVF blood flow (low specificity) and thus does not add any extra benefit to Qa monitoring.[51,66,67]

Venous pressure is measured either at the venous drip chamber during dialysis (DVP) or with the blood pump stopped (SVP). The standardised methods for measuring both DVP and SVP are outlined in detail in the NFK-KDOQI guidelines.[19] Schwab *et al.*[68] first described an association between raised DVP and the presence of AVG stenosis at the venous anastomosis and subsequently developed a screening/monitoring protocol.[69] Serial measurements need to be performed with the trend being more important than single values and note that any lesions within the body of an AVG will not be detected if it is proximal to the venous needle.[66] Screening using DVP has not been assessed in an RCT and is often used as the control screening technique. The measurement of intra-access pressure has also been described but not tested by an RCT.[66,70] Dember *et al.*[71] performed an RCT of SVP monitoring versus clinical evidence of access dysfunction in AVG. Screening using SVP with angioplasty did not prolong AVG survival with a trend to a poorer outcome in the SVP group (HR 1.75, 95% CI 0.80, 3.83, P = 0.16). After adjustment for gender, diabetes, PVD, and access location, the SVP group has a significantly greater risk of access abandonment (HR 2.91, 95% CI 1.17, 7.20, P = 0.02) despite a significantly higher intervention rate. With the presence of collaterals preventing the rise in venous pressure with a reduction on Qa due to a stenosis, using DVP to detect significant stenoses in AVF is not recommended.

SUMMARY OF THE EVIDENCE

Blood flow surveillance: AVG

For AVG, three of the four RCTs did not demonstrate a benefit of Qa surveillance despite significantly higher intervention rates in the surveillance groups.[52,53,55] The only positive trial was small and suffers from significant methodological issues. In all three negative trials, there were more interventions performed in the Qa surveillance groups compared to the control groups suggesting that more stenosis were detected. This was particularly evident in the two most recent studies.[52,53] In addition, the studies of Ram *et al.*[53] and Moist *et al.*[52] both performed pre-emptive angioplasty exclusively, while in the study by Smits *et al.*[55] over 90% of the interventions were using angioplasty. The negative results raise questions regarding the efficacy of the angioplasty procedure in the Qa group. An increase in Qa immediately post-angioplasty and not necessarily radiological success, predicts outcome post-angioplasty.[72,73] Only Moist *et al.*[52] reported Qa results post-PCTA procedure and there was no difference between the two groups in terms of a post-angioplasty rise in Qa (although this was not measured immediately post-procedure). Finally the only systematic review also failed to show a benefit of screening on AVG thrombosis or survival.[64] There is evidence that surgical revisions may be superior to angioplasty in the treatment of AVG thrombosis but whether this applies to the treatment of AVG stenosis is unknown.[74] Thus, currently blood flow screening with percutanous angioplasty of any underlying stenosis cannot be recommended on the basis of the current RCTs.

Blood flow surveillance: AVF

For AVF, two trials demonstrate a significant reduction in thrombosis rate or AVF survival with Qa surveillance.[54,56] A third trial,[57] while not assessing a surveillance technique per se, provides evidence for the benefit of angioplasty in prolonging AVF survival. Hence, these studies provide preliminary evidence for a survival benefit for AVF screening. This data is supported by the results of the systematic review suggesting a benefit of screening in AVF on thrombosis.[64]

However, a larger multi-centre study would need to be performed in order to conclusively confirm the previous results and in particular assess AVF survival (loss). For example, assuming an annual AVF thrombosis/revision rate of 12% to 15% per year[75] at least 300 subjects in each arm would be needed to detect a reduction of 30% (RR 0.70, 90% power) in AVF thrombosis/revision rates as a result of Qa screening.[48] In addition, whether AVF screening is cost effective also needs to be determined using data from a suitably powered RCT.[76]

Doppler ultrasound screening: AVG

Two of the six trials[59,62] using DUS in AVG demonstrated a significant increase in patency rates while a third[60] demonstrated a significant reduction at 6 months but not at 12 months follow up. In addition, a sub-analysis of the study by Lumdsen *et al*. assessing only the new AVG (n=21)[63] demonstrated a significant prolongation of AVG patency (P = 0.035) and a reduction in thrombosis rate in the treatment group (0.10 versus 0.44 thrombosis per patient-dialysis year). The three other trials did not demonstrate a survival benefit for DUS screening. A further analysis of the study by Ram *et al*.[53] suggests that while not prolonging AVG survival, screening reduced morbidity and costs through the reduction in thrombosis (non significant in the study) and less interruption to the haemodialysis treatment.[77] Like the discussion of the trials using Qa surveillance above, the largely negative results of the trials raises questions about the efficacy of angioplasty to correct the underlying stenosis although the only study to use surgery also did not demonstrate a conclusive survival benefit.[60] These conclusions are also supported by the results of the systematic review of the RCTs.[64]

Doppler ultrasound screening: AVF

There have been no RCTs of DUS screening in AVF.

Other screening techniques

While DVP monitoring is widely practised, there have been no randomised trials assessing the benefits of DVP screening on AVG outcome. Static venous pressure did not result in an AVG survival benefit in the one trial performed to date.[71] Dynamic venous pressure should not be used in AVF.

WHAT DO THE OTHER GUIDELINES SAY?

Kidney Disease Outcomes Quality Initiative:[19]
GUIDELINE 4. DETECTION OFACCESS DYSFUNCTION:
MONITORING, SURVEILLANCE, AND DIAGNOSTIC TESTING
4.1 Physical examination (monitoring): Physical examination should be used to detect dysfunction in fistulae and grafts at least monthly by a qualified individual. (B)
4.2 Surveillance of grafts: Techniques, not mutually exclusive, that may be used in surveillance for stenosis in grafts include:
4.2.1 Preferred:
4.2.1.1 Intra-access flow by using 1 of several methods that are outlined in Table 7 using
sequential measurements with trend analysis. (A)
4.2.1.2 Directly measured or derived static venous dialysis pressure by 1 of several methods. (A) (Protocol provided in Table 8 for using transducers on HD machines to measure directly; criteria in Table 9 for derived methods.)
4.2.1.3 Duplex ultrasound. (A)
4.2.2 Acceptable:
4.2.2.1 Physical findings of persistent swelling of the arm, presence of collateral veins, of collateral veins, prolonged bleeding after needle withdrawal, or altered characteristics of pulse or thrill in the pulse or thrill in a graft. (B)
4.2.3 Unacceptable:
4.2.3.1 Unstandardized dynamic venous pressures (DVPs) should not be used. (A)
4.3 Surveillance in fistulae: Techniques, not mutually exclusive, that may be used in surveillance for stenosis in AVFs include:
4.3.1 Preferred:
4.3.1.1 Direct flow measurements. (A)
4.3.1.2 Physical findings of persistent swelling of the arm, presence of collateral veins, prolonged bleeding after needle withdrawal, or altered characteristics of pulse or thrill in the outflow vein. (B)
4.3.1.3 Duplex ultrasound. (A)
4.3.2 Acceptable:
4.3.2.1 Recirculation using a non–urea-based dilutional method. (B)
4.3.2.2 Static pressures (B), direct or derived. (B)
4.4 When to refer for evaluation (diagnosis) and treatment:
4.4.1 One should not respond to a single isolated abnormal value. With all techniques, prospective trend analysis of the test parameter has greater power to detect dysfunction than isolated values alone. (A)
4.4.2 Persistent abnormalities in any of the monitoring or surveillance parameters should prompt referral for access imaging. (A)
4.4.3 An access flow rate less than 600 mL/min in grafts and less than 400 to 500 mL/min in fistulae. (A)
4.4.4 A venous segment static pressure (mean pressures) ratio greater than 0.5 in grafts or fistulae. (A)
4.4.5 An arterial segment static pressure ratio greater than 0.75 in grafts. (A)

UK Renal Association:[78]
Guideline 7.7 Investigation of the AVF or graft to assess for evidence of arterial or venous stenoses or access recirculation is required if there is a significant fall in the blood flow rate that can be achieved, a reduction in delivered dialysis dose or a persistent rise in venous pressure in sequential dialysis sessions.

Canadian Society of Nephrology:[79]
1. Measure access flow bimonthly in AV fistulae and venous pressure (grade D) or access flow monthly in AV grafts (grade D).
2. Perform angiography if fistula flow decreases to <500 ml/min or drops >20% from baseline (grade D); if AV graft flow decreases to <650 ml/min or drops >20% from baseline (grade D).

European Best Practice Guidelines:[80]
Guideline 5.1. Prior to any cannulation, autogenous arteriovenous fistulae and grafts should be assessed by physical examination (Evidence level IV).
Guideline 5.2. Objective monitoring of access function should be performed at a regular base by measuring access flow (Evidence level II).

International Guidelines: No recommendation.

IMPLEMENTATION AND AUDIT

Screening either by directly measured blood flow or by Doppler ultrasound will depend on the availability and direct costs of the screening techniques.

SUGGESTIONS FOR FUTURE RESEARCH

1. Conduct an adequately powered RCT of blood flow screening with repair in AVF.
2. Conduct an adequately powered RCT of blood flow screening with surgical repair in AVG.

CONFLICT OF INTEREST

Kevan Polkinghorne has no relevant financial affiliations that would cause a conflict of interest according to the conflict of interest statement set down by CARI.

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APPENDICES

Table 1 Randomised controlled trials assessing the effect of access blood flow surveillance on the access thrombosis rates*

Study ID	Access type	Number	Control group	Surveillance group	Qa threshold[f]	Blinding	Intention-to-treat analysis	Intervention	Thrombosis rate[a]	Follow-up
Sands *et al.*[54] 1999	AVF	68	Nil[b]	SVP + Qa[b]	<750	NS	NS	PCTA	0.27 vs 0.17†	6 months
	AVG	35	Nil[b]	SVP + Qa[b]	<750	NS	NS	PCTA	2.5 vs 0.2†	6 months
Smits *et al.*[55] 2001	AVG	53	DVP	Qa	<600	NS	No	PCTA[d]	0.19 vs 0.24	37.8 pt-years
		72	DVP	DVP + Qa	<600	NS	No	PCTA[d]	0.32 vs 0.28	42.7 pt-years
Ram *et al.*[53] 2003[c]	AVG	101	Clinical + DVP	Qa	<600	Yes	Yes	PCTA	0.68 vs 0.91†	2 years
Moist *et al.*[52] 2003	AVG	112	Clinical + DVP	Clinical + Qa	<650 or 20%↓	Yes	Yes	PCTA	0.41 vs 0.51	1 year
Tessitore *et al.*[56] 2004	AVF	79	Clinical	Qa	<750 or 25%↓	No	Yes	PCTA[d]	HR 3.93‡[e]	5 years

*Measured by ultrasound dilution; AVG = arteriovenous graft; AVF = arteriovenous fistula; Qa = access blood flow (all measured using ultrasound dilution); SVP = Static venous pressure; DVP = Dynamic venous pressure; PCTA = Percutaneous transluminal angioplasty; NS = Not Stated; [a]Control versus treatment rate per patient-years; [b]DU also performed every 6 months in all patients; [c]results here for the Qa arm versus control; [d]10% had further surgical intervention; [e]Overall failure including thrombosis and abandonment HR control vs treatment (95% CI 1.42, 10.93); [f]mL/min, all measured monthly except Smits *et al.* 8 weekly and Tessitore *et al.* 3 monthly; †P < 0.05; ‡P < 0.01

Table 2 Randomised controlled trials assessing the effect of ultrasound stenosis screening on AVG patency or thrombosis

Study ID	Number	Control group	Surveillance group	Blinding	Intention-to-treat analysis	Intervention	Patency[a]	Follow-up
Mayer *et al.*[60] 1993	70	Clinical	3 monthly USS	No	Yes	Surgery	80% versus 62%	2 years
Lumsden *et al.*[58] 1997	64	No intervention	3 monthly USS	No	Yes	PCTA	51% vs 47%	2 years
Sands *et al.*[62] 1997	55	Examination	USS	NS	NS	PCTA	126 vs 19[b]*	NS
Ram *et al.*[53] 2003[c]	101	Clinical + DVP	3 monthly USS	Yes	Yes	PCTA	34% vs 36%[d]	2 years
Malik *et al.*[59] 2005	192	Clinical/DVP/Qa	3 monthly USS + Clinical/DVP/Qa	No	NS	PCTA	RR control 3.75[e]**	2 years
Robbin *et al.*[61] 2006	126	Clinical	4 monthly USS	No	Yes	PCTA/Surgery	38 months vs 37 months[f]	2 years

PCTA = percutaneous transluminal angioplasty; DVP = dynamic venous pressure; USS = Doppler ultrasound; NS = Not stated; [a]Treatment versus control, 12 month patency unless otherwise stated; [b]per 100 patient years; [c]results here for the USS arm versus control; [d]patency defined as thrombosis or need for pre-emptive PCTA; [e]Patency data not presented in report, unadjusted relative risk of access failure in control was 3.75 (95% CI 1.7, 8.1); [f]cumulative survival; *P < 0.05; **P < 0.001

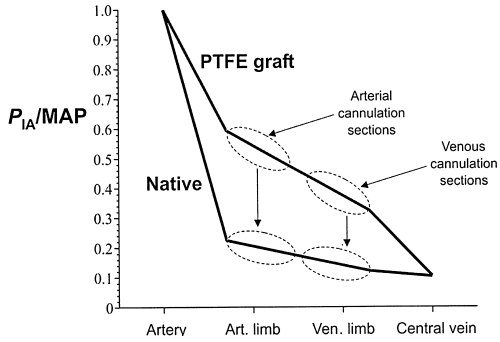

Fig. 1 Pressure profiles of AVG and AVF. See text for discussion. From Besarab A, Frinak S. Strategies for the prospective detection of access dysfunction. In Conlon P, Schwab S and Nicholson M ed. Hemodialysis Vascular Access: Practice and Problems. Oxford University Press Oxford, 2000, pp 157–182.

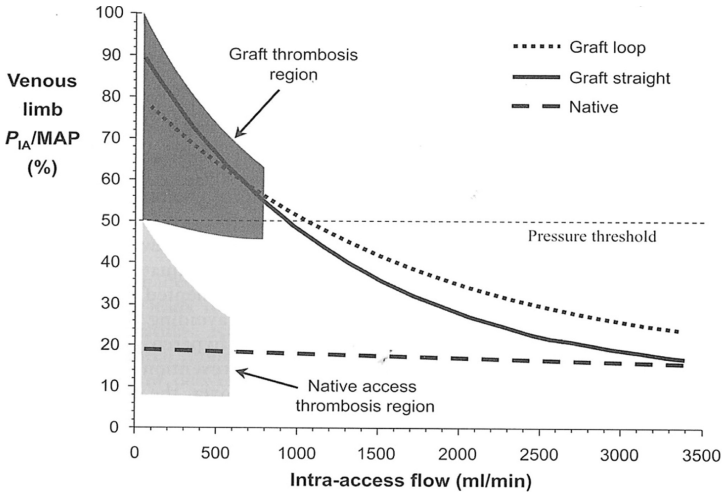

Fig. 2 The relationship between venous limb intra-access pressure and blood flow in a permanent vascular access and the areas associated with risk of thrombosis. Note the differing profiles between AVG and AVG. From Besarab A, Frinak S. Strategies for the prospective detection of access dysfunction. In Conlon P, Schwab S and Nicholson M ed. Hemodialysis Vascular Access: Practice and Problems. Oxford University Press Oxford, 2000, pp 157–182.