Pre-operative examination of the vessels - diagnostic evaluation prior to permanent access selection

Date written: Jan 2012
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GUIDELINES

a. Pre-operative ultrasound should be performed where there are no obvious veins on clinical examination, or there are any concerns about size or patency (Level II evidence)

SUGGESTIONS FOR CLINICAL CARE
(Suggestions based on level III and IV evidence)

• Venography or another imaging modality such as CT or MRI should be used in those patients in whom there is the potential for central venous stenosis, in particular those with prior subclavian vein catheterisation or pacemaker insertion. The effect of radiographic contrast on pre-dialysis renal failure should also be taken into consideration in the choice of imaging modality. (Level III evidence)
• Veins of adequate size (probably >2.5mm) identified on US should be used. (Level III evidence)
• Arteries with adequate size and flow identified on US should be used (probably >2mm). (Level III evidence)

IMPLEMENTATION AND AUDIT

1. Audit the assessment of arterial and venous anatomy on the section of vessels in AVF formation.

BACKGROUND

The native arteriovenous fistula (AVF) is the vascular access of first choice for haemodialysis due to less risk of infection and death[1] However primary failure (failure of the created AVF to be suitable for dialysis) in native fistulae is a major problem, leading to increased use of catheters. There are a number of pre-operative investigations that can be used to increase the chance of primary fistula function

This objective of this guideline is to examine the use of diagnostic tests such as ultrasound and venography to determine access creation.

SEARCH STRATEGY

Databases searched: MeSH terms and words for dialysis were combined with MeSH terms and text words for fistula and then combined with MeSH terms and text words for ultrasonography and phlebography. The search was carried out in Medline (1950-June Week 3, 2008). The Cochrane Renal Group Trials Register was also searched for trials not indexed in Medline. An update search was conducted in Medline (2008 – November 2011) using the same MeSH terms and textwords.
Date of initial search: June 2008
Date of update search: 4 November 2011

WHAT IS THE EVIDENCE?

Venographic assessment of veins

In a study of patients with established fistulas and fistula malfunction, of 12 patients with documented subclavian vein stenosis, 11 had previous ipsilateral subclavian vein catheterisation. Of 35 patients with no documented subclavian vein stenosis, 12 had previous ipsilateral subclavian vein catheterisation.[2]

In a pre-operative study, 62 subclavian veins were evaluated with venography. Of those patients with a previous or current ipsilateral subclavian vein catheterisation, there was a 40% prevalence of moderate or severe subclavian vein stenosis, compared to no stenosis in those patients without ipsilateral subclavian vein catheterisation.[3]

A study of 100 patients dialysed either by a subclavian or internal jugular catheter (50 in each group) showed that 42% of the subclavian group had a stenosis of the subclavian/brachio-cephalic vein, compared to 10% of the internal jugular group. There were more right-sided catheters however in the internal jugular group.[4] A similar study also showed 50% of patients with temporary subclavian vein catheters had strictures of their subclavian veins, whereas none of the internal jugular catheter patients had stenoses in their venous access return.[5]

Cardiac pacemakers, inserted along the subclavian vein can also cause central venous stenosis. [6] Venography can also be used to assess patency and size of veins for fistula formation.[7]

Ultrasound evaluation of vessels

Three randomised studies have assessed the effect of ultrasound vein mapping on AVF primary patency. The largest study from Birmingham UK randomised 218 patients into two groups; a clinical group and ultrasound group. All patients had both clinical assessment and ultrasound assessment prior to surgery, but in the clinical group the operating surgeon was not informed of the ultrasound results. In this group 101 patients went on to undergo access surgery. In the U/S group the surgeon was informed of the ultrasound result and 107 patients underwent surgery. The incidence of immediate thrombosis was significantly lower in the ultrasound group (4% versus 11%, P=0.028), although the overall rate of primary failure at 1 year (thrombosis, failure to mature) was not significantly different (65% ultrasound vs 56%, P=0.081). Assisted primary survival at 1 year was significantly improved in the ultrasound group, 80% vs 65% (P=0.012) [8]

The second RCT assessed patients who were “clinically feasible” for a radio-cephalic forearm AV fistula with all patients undergoing ultrasound assessment[9]. In group A (52 patients), the ultrasound was not seen by the surgeons. In 39 patients (75%), fistulas were satisfactorily formed, and these patients had no ultrasound abnormalities. The other 13 (25%) had immediate failure. Ultrasound had shown cephalic vein changes on ultrasound in eight and decreased radial artery flow in five. In group B (72 patients) the ultrasound was reviewed by the surgeon prior to AVF formation. Only 4 (6%) failed immediately in this group and all of these had decreased radial artery flow (P=0.002 vs group A). Unfortunately long-term outcomes were not reported in the study.

Similarly the third RCT assessed the effect of ultrasound in 70 patients with clinically acceptable vessel anatomy. Subjects were randomised to either to undergo surgery with no further investigation, or undergo ultrasound examination with surgery guided by the ultrasound findings. The use of ultrasound to guide the access formation had no benefit in terms of access patency and intervention-free patency.[10]

Historical comparison studies have also shown increased primary patency rates and an increase in native fistulas compared to grafts when ultrasound has been used. Pre-study, the AVF rate was 14%; post was 63% including over half of these in arms that would not have been used previously on clinical examination alone. The minimum requirement for vein for a fistula was >2.5mm or >4 for a graft. There also had to be no stenosis/occlusion and good drainage. For the artery, the lumen had to be >2mm, with a patent palmar arch and a pressure difference <20mmHg between the arms.[11] In a further
historical study, 52 patients with mapping underwent surgery. The unsuccessful exploration rate fell from 11% to 0%. The planned surgical procedure changed in 31% (16/52). The AVF rate increased from 32% to 58%. They ignored any forearm cephalic vein <2.5mm and radial artery <2mm.[12]

A study from the University of Birmingham, Alabama compared a historical group over 2 years with a group that underwent sonographic study of their veins prior to surgery. In the ultrasound group, the number of fistulas rose to 64% of their vascular access procedures, compared to 34% in the historical control group. Adequacy for dialysis for their native fistulas also improved, from 46 to 54% [13].

A further historical control group study from Thailand also suggested that those with favourable physical examination did not benefit from ultrasound examination. In their group, those with unfavourable physical examination could be spared unnecessary procedures by the use of ultrasound [14]

Another study looked at 44pts who on physical examination were feasible for a radio-cephalic AVF. In 19 pts (43%) the cephalic vein measured <2mm; of these only 16% (3/18) developed a mature AVF. In 25 pts (57%) the cephalic vein measured >2mm; of these 76% (19/25) developed a mature AVF. Maturation was designated as the ability to dialyse at 3 months.[15]

A study from Houston looked at 426 arms in 290 patients using ultrasound. They found a variable insertion of the basilic vein into the brachial venous system with 34% having a low insertion of the vein. They suggest that if usage of the basilic vein is contemplated, sonography may help to plan the type of access [16]

SUMMARY OF THE EVIDENCE

Venographic assessment of veins

Previous central vein catheterisation, particularly subclavian, for temporary dialysis access or for cardiac pacemakers, has an increased incidence of subclavian vein stenosis. Patients with a history of subclavian vein catheterization should undergo imaging of their central veins on the ipsilateral side

Ultrasonic evaluation of vessels

Pre-operative ultrasound mapping improves immediate failure of AVF and assessed patency at 1 year. There appears to be no benefit of ultrasound in patients with clinically good vessels. Other studies have looked at the size requirement for both veins and arteries, with different criteria. It would appear that veins <2mm are unlikely to be usable for AV fistula formation. There are many papers suggesting that pre-operative mapping is useful, but with no comparisons. Those listed are a mixture of historical comparisons and a few randomized trials. Many papers however come from the US, with traditionally a very low rate of fistula formation and should be interpreted with a view to the Australian situation. Other situations where ultrasound imaging is likely to be useful are in subjects with previous surgery or trauma to the limb.

WHAT DO THE OTHER GUIDELINES SAY?

Kidney Disease Outcomes Quality Initiative:[17]
A. Venography prior to placement of access is indicated in patients with the following:
1. Oedema in the extremity in which an access site is planned (Evidence)
2. Collateral vein development in any planned access site (Evidence)
3. Differential extremity size, if that extremity is contemplated as an access site (Evidence)
4. Current or previous subclavian catheter placement of any type in venous drainage of planned access (Evidence)
5. Current or previous trans-venous pacemaker in venous drainage of planned access (Evidence)
6. Previous arm, neck, or chest trauma or surgery in venous drainage of planned access (Opinion)
7. Multiple previous accesses in an extremity planned as an access site (Opinion)
B. Additional or alternate imaging techniques are indicated in selected cases where multiple previous vascular accesses have been placed or when residual kidney function makes contrast studies undesirable. Appropriate techniques include:
1. Doppler ultrasound (Evidence)
2. Magnetic Resonance Imaging (Opinion)

C. Arteriography or Doppler examination is indicated when arterial pulses in the desired access location are markedly diminished (Opinion)

**UK Renal Association**: No recommendation.

**Canadian Society of Nephrology**: Venography is indicated in patients with the following (Evidence: level III):
- oedema in the extremity in which an access site is planned,
- collateral vein development in any planned access site,
- differential extremity size, if that extremity is contemplated as an access site,
- current or previous subclavian catheter placement of any type in venous drainage of planned access,
- current or previous trans-venous pacemaker in venous drainage of planned access,
- previous arm, neck, or chest trauma or surgery in venous drainage of planned access, or
- multiple previous accesses in an extremity planned as an access site.

Additional or alternate imaging techniques are indicated when previous multiple vascular accesses have been placed or when residual renal function makes contrast studies undesirable. Appropriate diagnostic techniques may include:
- venography using CO2 or Doppler ultrasound or
- venous mapping using Doppler ultrasound.

**European Renal Best Practice Guidelines**: Guideline 2.1. Clinical evaluation and non-invasive ultrasonography of upper extremity arteries and veins should be performed before vascular access creation (Evidence level II).

Guideline 2.2. Central vein imaging is indicated in patients with a history of previous central vein catheters (Evidence level IV).

**International Guidelines**: No recommendation.

**SUGGESTIONS FOR FUTURE RESEARCH**

1. Conduct a randomised trial of clinically obvious vessels to see if they are actually usable or whether a better option becomes more apparent with use of ultrasound.
2. An RCT to see if ultrasound can be used to detect central stenosis, rather than using venography and saving on contrast exposure.

**CONFLICT OF INTEREST**

Christine Russell and Kevan Polkinghorne have no relevant financial affiliations that would cause a conflict of interest according to the conflict of interest statement set down by KHA-CARI.
REFERENCES

## APPENDICES

### Table 1. Characteristics of included studies

<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Participants</th>
<th>Follow up (months)</th>
<th>Comments and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Venographic assessment of veins</td>
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</tbody>
</table>
| Schwab et al (1988)[2] | 47 (23 males, 24 females) | Retrospective case review. Single centre, USA | Adult haemodialysis patients (22 to 79 years old) underwent upper arm venography to evaluate fistula dysfunction | N/A | - 12 (26%) patients (mean fistula age 17.0 months) had subclavian vein stenosis (SVS). All 12 (100%) patients had previously undergone subclavian cannulation on the side of the fistula.  
- 11/12 patients had elevated venous dialysis pressure (196 ± 8.9 mmHg)  
- 11 patients with SVS underwent percutaneous transluminal angioplasty (PTA), improving venous dialysis pressure and restoring fistula patency.  
- 35 (74%) patients (mean fistula age 5.8 months) did not have SVS, even though 12 (34%) patients (mean venous dialysis pressure 113 ± 2.3 mmHg) had previously undergone subclavian cannulation on the side of the fistula.  
- SVS is a common problem. Elevated dialysis pressure is a sensitive indicator for this problem |
| Surratt et al (1991)[3] | 43 (19 men, 24 females) | Retrospective case review. Single centre, USA | Haemodialysis patients (11 to 84 years of age) underwent upper extremity venograms before arteriovenous graft placement | N/A | - A total of 62 extremities were included.  
- 35 extremities (56%) had prior or existing subclavian catheters; 4/35 (11%) showed subclavian occlusion with collaterals; 10/35 (29%) showed >50% subclavian vein stenosis  
- That is, 40% prevalence of stenosis or occlusion  
- The other 27 extremities (without prior or existing subclavian catheters) did not show stenosis or occlusion. Indicating a statistically significant difference between the two groups (P<0.001)  
- It is encouraged that sites other than the subclavian vein be used for temporary dialysis |
| Schillinger et al (1991)[4] | 100 (50 in each group) | Cross-sectional. Single centre, France | Angiography of the subclavian-brachiocephalic vein was conducted in all patients receiving dialysis via subclavian or internal jugular catheter. | N/A | - There was no significant difference between the groups in terms of age, gender, duration of catheter insertion and the number of dialysis sessions, type and brand of catheters, number with inadequate flow and catheter infections.  
- Cannulation side was the only thing that differed. Cannulation on the left side presents more risks than the right side (65.8% vs 45.6% respectively; P=NS)  
- In the subclavian group there were 42% with stenosis compared with |
<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Participants</th>
<th>Follow up (months)</th>
<th>Comments and Results</th>
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</thead>
</table>
| Cimochowski et al (1990)[5] | 52 (32 subclavian, 20 internal jugular) | Cross-sectional. Single centre, USA | Chronic haemodialysis patients with a subclavian or internal jugular catheter underwent venography | N/A | only 10% in the internal jugular group (p<0.001)  
- Severity of strictures for subclavian vs internal jugular route: <50%: 16% and 2% respectively; ≥50%: 22% and 8% respectively  
- This reinforces the preference for use of the internal jugular versus subclavian for venous access |
| Korzets et al (1991)[6] | 2 cases | Case report. Single centre, Israel | Two haemodialysis patients (mean age 76 years) with permanent cardiac pacemakers | N/A | Subclavian vein stenosis was asymptomatic until arteriovenous grafts were constructed to commence dialysis  
- Both patients experienced severe arm oedema |
| Ferring et al (2010)[8] | 218 | RCT, single centre, UK | Patients with end-stage renal disease who were referred for AVF formation. | 40 | End points were AVF failure and survival rates  
- U/S group had a significantly lower AVF failure rate: 4% vs 11% (clinical group), P=0.028.  
- Among the failed AVFs, those in the U/S group had less thrombosis (38% vs 67%, P=0.029)  
- Primary AVF survival at 1yr was not statistically different: 65% (U/S gp) and 56% (clinical gp), P=0.08  
- Assisted primary AVF survival at 1yr was better for the U/S gp 80% vs 65% (clinical), P=0.012.  
- The number needing pre-operative U/S to prevent one AVF failure was 12. |
<p>| Mihmanli et al (2001)[9] | 124 GpA = 52 | RCT. Single centre, Turkey | Patients (age 19 to 74 years) with end-stage renal disease underwent Colour Doppler | Not Stated | No indication of how patients were randomised; no blinding with respect to assessors; no follow-up conducted only immediate post- |</p>
<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Participants</th>
<th>Follow up (months)</th>
<th>Comments and Results</th>
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</table>
| **GpB = 72** | | Ultrasonography (CDUS) before surgical assessment. Patients were then randomly assigned into group A (AVF constructed based on physical examination) or group B (AVF constructed based on CDUS results) | | op assessment | 13/52 (25%) of patients had non-functioning fistulae in Gp A compares with 4/72 (6%) of patients in Gp B (P=0.002)  
62% (8/13) in Gp A were found to have chronic thrombotic changes in the cephalic vein  
38% (5/13) in Gp A were found to have decreased volume flow in the radial artery (mean flow rate 175 ± 7.2 mL/min) compared to four patients in Gp B (190.5 ± 6.5 mL/min)  
The mean flow rate for the successful fistulae in Gp A and B were: 358.6 ± 45.6 mL/min and 366.2 ± 44.2 mL/min respectively  
There was an overall significant difference of P<0.05 between the two groups  
Colour Doppler Ultrasonography is a useful non-invasive procedure for evaluating the cephalic vein and radial artery prior to arteriovenous fistula creation. |
| **Nursal et al (2006)[10]** | 80 | RCT. Single centre, Turkey | Patients requiring haemodialysis access underwent a physical examination (PE) to determine the location for AVF placement. Participants were divided into the PE group or the PUSM group (Preoperative Ultrasonography Mapping) | Unclear | There were no differences between the PE group and M group with respect to: immediate thrill 24/35 (69%) vs 26/33 (79%) P=0.34 respectively; thrill on first postoperative day 20/34 (59%) vs 24/32 (75%) P=0.16 respectively; frequency of interventions 8/35 (23%) vs 7/35 (20%) P=0.77 respectively; planned site (P=0.78) and actual surgical site (P=0.6)  
There were no significant differences in ultrasonographic parameters between the two groups after AVF placement  
There was no difference between the groups for intervention-free AVF survival, P=0.77 and for cumulative AVF survival, P=0.92. |
| **Silva et al (1998)[11]** | 172 | Prospective cohort. Single centre USA | All patients (mean age 63 years) requiring haemodialysis access underwent preoperative duplex ultrasound (DU) evaluation of arteries and veins in upper extremities | 15.2 | Historical comparator group  
108/172 (63%) of patients had suitable veins for autogenous fistulae (AF); 52/172 (30%) were suitable for arteriovenous grafts (AVG) and 12/172 (7%) had to have a permanent catheter (PC)  
Early failure rate were: 8.3% (9/108) for AF and 7.6% (4/52) for AVG  
Primary cumulative patency rates at 12 and 21 months were: 83% and 73% for AVF respectively and 74% and 62% for AVG respectively  
7/12 PCs failed during follow-up, absolute patency rate of 42%  
During the pre-intervention period 183 procedures were performed: 25 (14%) AF; 114 (63%) AVG and 44 (24%) PC. The early failure rate was 38% for AF and 11% for AVG  
The accuracy of duplex ultrasound compared with intraoperative
<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Participants</th>
<th>Follow up (months)</th>
<th>Comments and Results</th>
</tr>
</thead>
</table>
| Robbin et al (2000)[12] | 70    | Prospective cohort. Single centre USA | Patients needing haemodialysis access underwent ultrasonographic assessment of the vessels in the upper extremities. | 5                  | Findings was 98%.  
  - Routine non-invasive assessment is recommended to maximise opportunities for AF  
  - Historical comparator group; no description of group given; potential confounders may have been present at the time  
  - Planned AVF increased from 126/395 (32%) (no previous mapping) to 30/52 (58%)  
  - 52 procedures were conducted and 16/52 (31%) of patients had changes in the surgical procedures performed: 8/52 (15%) had an AVF instead of the planned AVG; the access was placed in the opposite arm to the initially planned arm in 3/52 (6%) patients; 1/52 (2%) access was changed from upper arm to a forearm graft; 1/52 (2%) access was changed from an arm to a thigh graft; and 3/52 (6%) were spared from a negative forearm exploration  
  - Brachiocephalic vein and/or superior vena cava stenosis was detected with ultrasonography in 3/5 (60%) cases  
  - Negative exploration rate decreased from 28/256 (11%) to 0/52 (0%) |
| Allon et al (2001) [13] | 217   | Prospective cohort. Single centre, USA | Patients requiring vascular accesses underwent pre-operative vessel mapping | 17                 | Vascular mapping resulted in 30% more fistula placement compared to the historical control period (64% vs 34%, P<0.001)  
  - 77% of patients (107/139) without a previous vascular access, had a fistula created  
  - There was a non-significant increase in initial adequacy for dialysis from 46% to 54%, (P=0.34)  
  - Fistula placement was significantly lower in females (OR 0.35; 95%CI: 0.20, 0.62, P<0.001) and in black patients (OR 0.19; 95%CI:0.009, 0.42, P<0.001) |
| Siribumrungwong et al (2010) [14] | 55 patients (63 operations) | Retrospective cohort. Single centre, Thailand | Patients requiring vascular access. Group 1 - physical examination of vessels only; Group 2 –vessel mapping was done if no suitable vessels were identified physical examination alone | 38                 | 27operations in Group 1 (43%) and 36 in Group 2 (57%)  
  - In patients with a favourable physical examination there was no significant difference in unsuccessful operation (13% vs 0%, P=0.226); maturation (90% vs 94%, P=1.0) or those needing a second operation (25% vs 0%, P=0.067) for Group 1 and Group 2 respectively  
  - Amongst those with an unfavourable physical examination, vessel mapping significantly decreased the rate of unsuccessful operation (27% vs 0%, P=0.037) for Gp1 and Gp2 respectively. The proportion of patients needing a second operation was less in Grp 2 (10%) compared with 36% in Gp 1 (P=.0151). The rate of maturation between the two groups was the same (P=1.00) |
<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Participants</th>
<th>Follow up (months)</th>
<th>Comments and Results</th>
</tr>
</thead>
</table>
| Mendes et al (2002)[15] | 48 | Prospective cohort. Single centre USA | Patients (mean age 55.5 years) requiring arteriovenous fistula formation underwent ultrasonographic vein assessment | 3 | - Successful maturation of AVF was achieved in 22/44 (50%) of the procedures  
- Cephalic veins with a minimal diameter of ≤2.0mm were used for anastomosis in 19 patients (43%) but 3/19 (16%) led to a functional access  
- The remaining 25/44 (57%) patients had minimal cephalic diameter >2.0 mm which led to 19/25 (76%) successful fistula maturation (P=0.0002). 6/25 (24%) had failure.  
- In patients with a minimal cephalic vein size of ≤2.0mm, a procedure other than wrist fistula should be considered |
| Anaya-Ayala et al (2011) [16] | 290 (426 = arms mapped) | Retrospective & prospective study. Single centre, USA | Patients with end-stage renal disease (mean age 56 ± 17 yrs) requiring haemodialysis underwent vessel mapping. | 57 | - Anatomical description of the basilic-brachial junction was identified as: Type 1 – junction at the axillary level with paired brachial veins (66%); Type 2 – junction at mid or lower section of upper arm with brachial vein duplication above that level (17%); and Type 3 – junction same as Type 2 but no duplication of brachial vein above that level (17%). |
### Table 1a. Characteristics of included RCT

<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>N</th>
<th>Study Design</th>
<th>Setting</th>
<th>Participants</th>
<th>Intervention (experimental group)</th>
<th>Intervention (control group)</th>
<th>Follow up (months)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferring et al (2010)</td>
<td>218</td>
<td>Randomised controlled trial</td>
<td>Single centre, UK</td>
<td>Patients requiring AVF creation</td>
<td>Surgeon was given the preoperative U/S mapping results.</td>
<td>Surgeon was not given the preoperative U/S mapping results.</td>
<td>40</td>
<td>Both groups had a clinical assessment and preoperative ultrasound vessel mapping</td>
</tr>
<tr>
<td>Mihmanli et al (2001)</td>
<td>124</td>
<td>Randomised controlled trial</td>
<td>Single centre, Turkey</td>
<td>Patients requiring AVF creation</td>
<td>Surgeon was given the preoperative U/S mapping results.</td>
<td>Surgeon was not given the preoperative U/S mapping results.</td>
<td>Not known</td>
<td>All patients had physical examination of the vessels and preoperative ultrasound vessel mapping</td>
</tr>
<tr>
<td>Nursal et al (2006)</td>
<td>80</td>
<td>Randomised controlled clinical trial</td>
<td>Single centre, Turkey</td>
<td>Patients requiring haemodialysis access creation</td>
<td>Physical examination of upper extremity + preoperative ultrasonography mapping</td>
<td>Physical examination of upper extremity</td>
<td>Unclear</td>
<td>10 patients were excluded due to protocol violation. Results for ultrasonographic parameters only given up to one month post avf placement</td>
</tr>
</tbody>
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### Table 2a. Methodological quality of randomised trials

<table>
<thead>
<tr>
<th>Study ID (author, year)</th>
<th>Method of allocation concealment *</th>
<th>Blinding (participants)</th>
<th>Blinding (investigators)</th>
<th>Blinding (outcome assessors)</th>
<th>Intention-to-treat analysis †</th>
<th>Loss to follow up (%)</th>
<th>Comments ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferring et al (2010)[8]</td>
<td>Computer-generated random sequence. Consecutively numbered sealed envelopes</td>
<td>yes</td>
<td>Yes</td>
<td>Unclear</td>
<td>Yes</td>
<td>10%</td>
<td>-</td>
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<tr>
<td>Mihmanli et al (2001)</td>
<td>Not specified</td>
<td>No</td>
<td>Unclear</td>
<td>Unclear</td>
<td>No</td>
<td>Unknown</td>
<td>-</td>
</tr>
<tr>
<td>Nursal et al (2006)[10]</td>
<td>Random number generator</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Unclear</td>
<td>No</td>
<td>0%</td>
<td>-</td>
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</table>

* Choose between: central; third party (e.g. pharmacy); sequentially labelled opaque sealed envelopes; alternation; not specified.
† Choose between: yes; no; unclear.
‡ Quality score – “How successfully do you think the study minimised bias?” Choose between: very well (+); okay (Ø); poorly (−).
### Table 3a. Results and quality rating for dichotomous outcomes

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Study ID (author, year)</th>
<th>Intervention group (no. of patients with events/no. of patients exposed)</th>
<th>Control group (no. of patients with events/no. of patients exposed)</th>
<th>Relative risk (RR) [95% CI]</th>
<th>Risk difference (RD) [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate failure</td>
<td>Ferring et al (2010) [8]</td>
<td>4/112</td>
<td>12/106</td>
<td>0.32 [0.11, 0.94]</td>
<td>-0.08 (-0.15, -0.01)</td>
</tr>
<tr>
<td></td>
<td>Mihmanli et al (2001)</td>
<td>4/72</td>
<td>13/52</td>
<td>0.22 [0.08, 0.64]</td>
<td>-0.19 [-0.32, -0.07]</td>
</tr>
<tr>
<td>Primary failure</td>
<td>Ferring et al (2010) [8]</td>
<td>24/112</td>
<td>33/106</td>
<td>0.69 [0.44, 1.08]</td>
<td>-0.10 (-0.21, 0.02)</td>
</tr>
<tr>
<td>Primary AVF survival at one year</td>
<td>Ferring et al (2010) [8]</td>
<td>73/112</td>
<td>59/106</td>
<td>1.17 (0.94, 1.46)</td>
<td>0.10 (-0.03, 0.22)</td>
</tr>
<tr>
<td>Immediate thrill</td>
<td>Nursal et al (2006) [10]</td>
<td>26/33</td>
<td>24/35</td>
<td>1.15 [0.86, 1.53]</td>
<td>0.10 [-0.11, 0.31]</td>
</tr>
<tr>
<td>Thrill on first postoperative day</td>
<td>Nursal et al (2006) [10]</td>
<td>24/32</td>
<td>20/34</td>
<td>1.27 [0.90, 1.80]</td>
<td>0.16 [-0.06, 0.39]</td>
</tr>
<tr>
<td>Frequency of interventions</td>
<td>Nursal et al (2006) [10]</td>
<td>7/35</td>
<td>8/35</td>
<td>0.88 [0.36, 2.15]</td>
<td>-0.03 [-0.22, 0.16]</td>
</tr>
<tr>
<td>Proportion with patent AVFs</td>
<td>Nursal et al (2006) [10]</td>
<td>23/35</td>
<td>23/35</td>
<td>1.00 [0.71, 1.40]</td>
<td>0.00 [-0.22, 0.22]</td>
</tr>
<tr>
<td></td>
<td>Mihmanli et al (2001)</td>
<td>68/72</td>
<td>39/52</td>
<td>1.26 [1.07, 1.49]</td>
<td>0.19 [0.07, 0.32]</td>
</tr>
</tbody>
</table>

### Table 3b. Results and quality rating for continuous outcomes

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Study ID (author, year)</th>
<th>Intervention group (mean [SD])</th>
<th>Control group (mean [SD])</th>
<th>Difference in means (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachial artery flow (ml/min)</td>
<td>Nursal et al (2006) [10]</td>
<td>479.8 (305.8)</td>
<td>479.1 (206.5)</td>
<td>0.70 [-121.55, 122.95]</td>
</tr>
<tr>
<td>Radial artery flow (ml/min)</td>
<td>Nursal et al (2006) [10]</td>
<td>204.9 (161.8)</td>
<td>293.5 (176.5)</td>
<td>-88.60 [-167.93, -9.27]</td>
</tr>
<tr>
<td>Efferent vein flow (ml/min)</td>
<td>Nursal et al (2006) [10]</td>
<td>513.0 (348.3)</td>
<td>441.0 (319.4)</td>
<td>72.00 [-84.56, 228.56]</td>
</tr>
</tbody>
</table>