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[Intervention Review]

Preoperative vascular access evaluation for haemodialysis patients

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ABSTRACT

Background

Haemodialysis treatment requires reliable vascular access. Optimal access is provided via functional arteriovenous fistula (fistula), which compared with other forms of vascular access, provides superior long-term patency, requires few interventions, has low thrombosis and infection rates and cost. However, it has been estimated that between 20% and 60% of fistulas never mature sufficiently to enable haemodialysis treatment. Mapping blood vessels using imaging technologies before surgery may identify vessels that are most suitable for fistula creation.

Objectives

We compared the effect of conducting routine radiological imaging evaluation for vascular access creation preoperatively with standard care without routine preoperative vessel imaging on fistula creation and use.

Search methods

We searched Cochrane Kidney and Transplant's Specialised Register to 14 April 2015 through contact with the Trials' Search Co-ordinator using search terms relevant to this review.

Selection criteria

We included randomised controlled trials (RCTs) that enrolled adult participants (aged ≥ 18 years) with chronic or end-stage kidney disease (ESKD) who needed fistulas (both before dialysis and after dialysis initiation) that compared fistula maturation rates relating to use of imaging technologies to map blood vessels before fistula surgery with standard care (no imaging).

Data collection and analysis

Two authors assessed study quality and extracted data. Dichotomous outcomes, including fistula creation, maturation and need for catheters at dialysis initiation, were expressed as risk ratios (RR) with 95% confidence intervals (CI). Continuous outcomes, such as numbers of interventions required to maintain patency, were expressed as mean differences (MD). We used the random-effects model to measure mean effects.

Main results

Four studies enrolling 450 participants met our inclusion criteria. Overall risk of bias was judged to be low in one study, unclear in two, and high in one.

There was no significant differences in the number of fistulas that were successfully created (4 studies, 433 patients: RR 1.06, 95% CI 0.95 to 1.28; $I^2 = 76\%$); the number of fistulas that matured at six months (3 studies, 356 participants: RR 1.11, 95% CI 0.98 to 1.25; $I^2 = 0\%$); number of fistulas that were used successfully for dialysis (2 studies, 286 participants: RR 1.12, 95% CI 0.99 to 1.28; $I^2 = 0\%$); the number of patients initiating dialysis with a catheter (1 study, 214 patients: RR 0.66, 95% CI 0.42 to 1.04); and in the rate of interventions required to maintain patency (1 study, 70 patients: MD 14.70 interventions/1000 patient-days, 95% CI -7.51 to 36.91) between the use of preoperative imaging technologies compared with standard care (no imaging).

Authors' conclusions

Based on four small studies, preoperative vessel imaging did not improve fistula outcomes compared with standard care. Adequately powered prospective studies are required to fully answer this question.

PLAIN LANGUAGE SUMMARY

Preoperative vascular access evaluation for haemodialysis patients

Vascular access is required for people on haemodialysis to connect with the dialysis machine. Compared with other types of vascular access, there is wide acceptance that arteriovenous fistulas (fistulas) provide best outcomes for patients because there is less likelihood of infection and clotting.

Fistulas can take a long time to mature enough to be used for dialysis and many fail. Mapping blood vessels using medical imaging techniques before a fistula operation may help surgeons plan the best fistula location by selecting the best blood vessels to create the fistula. This may enhance the likelihood that the fistulas will mature and stay open and available for dialysis use ('patency').

For this review, we searched the literature published up to April 2015 and found four studies that involved 450 participants which met our inclusion criteria. The included studies compared the proportions of fistulas that matured when evaluation was carried out before surgery using medical imaging techniques with standard care (no imaging).

Our analysis found that vessel imaging before surgery did not improve the rate of fistulas that matured. Further research in this area involving more participants may be beneficial to better understand if imaging before surgery could help to increase the success of fistulas for people who need haemodialysis.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Preoperative vessel imaging by ultrasound mapping versus standard preoperative care for arteriovenous access creation in haemodialysis patients

Preoperative vessel imaging by duplex ultrasound mapping versus standard preoperative care for arteriovenous access creation in haemodialysis (HD) patients

Patient or population: HD patients with arteriovenous fistulas

Intervention: routine preoperative vessel imaging by ultrasound versus standard preoperative care

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Standard care	Vessel imaging by ultrasound				
Fistulas created Assessed by surgeon ¹ Follow-up: 1 day	Study population		RR 1.02 (0.94 to 1.12)	433 (4)	⊕⊕⊕⊕ very low ^{2, 3}	
	909 per 1000	927 per 1000 (855 to 1000)				
	Moderate risk					
	953 per 1000	972 per 1000 (896 to 1000)				
Fistulas matured Clinical assessment by experienced HD nurse ⁴ Follow-up: 6 to 12 months	705 per 1000	782 per 1000 (690 to 881)	RR 1.11 (0.98 to 1.25)	356 (3)	⊕⊕⊕⊕ low ^{3,5}	
Fistulas used for dialysis Clinical assessment by HD nurse Follow-up: 6 to 24 months	716 per 1000	802 per 1000 (709 to 917)	RR 1.12 (0.99 to 1.28)	286 (2)	⊕⊕⊕⊕ low ^{3,6}	
Rate of interventions required to maintain patency (per 1000 patient-days) Follow-up: 6 months		Mean rate of interventions required to maintain patency (/1000 patient-days) in the intervention groups was 14.7 higher (7.51 lower to 36.91 higher)		70 (1)	⊕⊕⊕⊕ very low ^{3,6}	

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **RR:** Risk ratio

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Surgically created fistula, absence of AVF thrombosis on the day of surgery, or inadequate vein found at surgery

² Outcome assessed by surgeons who were not blinded to treatment allocation in two studies.

³ The effect estimate has relatively large CIs

⁴ All fistulas were considered mature that did not suffer from immediate failure on the day of surgery, early thrombosis, and failure to mature

⁵ Nursal 2006 assessed at high risk of bias; Zhang 2006 assessed at unclear risk of bias.

⁶ Nursal 2006 assessed at high risk of bias.

BACKGROUND

Description of the condition

In 2011, the global prevalent dialysis population was estimated at 2.2 million people and continues to grow ([Hemodialysis Industry Report 2013](#)). Haemodialysis is a costly therapy that places significant burden on global healthcare systems.

Haemodialysis treatment requires creation and use of a reliable vascular access. Optimal permanent vascular access maximises patients' quality of life, provides long-term complication-free patency, and is cost-effective ([Lok 2012](#)). Arteriovenous fistulas (fistulas) are widely accepted as optimal vascular access. Observational study data suggest that fistulas provide long-term patency, low thrombosis and infection rates, require few interventions, and are relatively low cost ([Churchill 1992](#); [Kherlakian 1986](#); [Manns 2005](#)).

Despite the United States' Fistula First Initiative, many US centres have been unable to achieve recommended targets for fistula use ([Gold 2006](#); [Mokrzycki 2006](#)). Challenges exist in meeting targets, in part, due to the acute and urgent nature of some patients' need for immediate vascular access to start haemodialysis; and compounded by central venous catheters being the only readily available choice until either a fistula or arteriovenous graft (graft) can be created ([Jindal 2006](#)).

Fistula placement can be very challenging, especially given the increasing numbers of elderly haemodialysis patients with significant comorbidities and complex situations ([Chan 2007](#); [Lok 2007](#); [Lok 2012](#); [NKF-K/DOQI 2001](#)).

Increasing fistula prevalence is compromised by the high failure-to-mature rate. Fistula maturation failure rates have been reported at between 9% and 70% ([Allon 2002](#); [Hakaim 1998](#); [Lee 2011](#); [Lok 2003](#); [Lok 2006](#)). A recent meta-analysis showed that approximately 23% (CI 18% to 28%) of fistulas never mature sufficiently for dialysis use ([Al-Jaishi 2014](#)).

There may be significant clinical consequences for patients whose fistulas fail to mature: catheters must be temporarily placed, which can cause complications, and patients may need multiple interventional procedures including angioplasty to facilitate fistula maturation.

Description of the intervention

Patient history and physical examination are the most important first steps in assessing the course of action both before access placement and when evaluating an established access with problems ([Lok 2012](#)). It requires a detailed evaluation of the arterial and venous system in both extremities, taking into consideration the significance of previous chest and upper extremity surgery, pacemakers, presence of oedema and collateral vein formation suggesting central vein pathology ([Beathard 2002](#)). Indeed, the basic preoperative vascular access assessment is via physical examination ([Lok 2012](#)). Physical examination preoperatively and/or postoperatively has been shown to have a 70% to 80% success rate in predicting an adequate fistula ([Fullerton 2002](#); [Ravani 2002](#); [Robbin 2002](#); [Robbin 2006](#)). Additionally, a preoperative scoring system was developed that stratifies the patient's risk for fistula failure into four categories: low (24%), moderate (34%), high (50%), and very high (69%) ([Lok 2006](#)). The clinical predictors that were

associated with failure of fistula maturation were aged ≥ 65 years, peripheral vascular disease, coronary artery disease, and non-white race ([Lok 2006](#)). Further research is required to investigate whether the use of this scoring system results in increased rates of fistula maturation and use.

A strategy to improve outcomes is to map vessels before surgery using imaging techniques to determine those vessels most likely to result in functional fistulas ([Malovrh 2003](#); [Malovrh 2006](#); [Mihmanli 2001](#); [Robbin 2000](#)). The impact of this technique is unclear and optimal vessel imaging techniques have yet to be established ([Allon 2001](#); [Gibson 2001](#); [Patel 2003](#); [Ravani 2002](#); [Rayner 2004](#)).

The most extensively studied technique, duplex doppler ultrasonography (duplex US), has been applied to measure vessel diameter with the aim of optimising access placement and increase the likelihood of fistula maturation ([Brown 2006](#)). It has been reported that a radial artery less than 2 mm diameter is unlikely to form a fistula that will mature sufficiently to support blood pump rates required for adequate haemodialysis ([Davidson 2005](#); [Kamienski 1976](#)). Selective use of duplex US for patients whose forearm anatomy could not be defined by physical examination resulted in creation of fistulas in 80% of people with comparable patency rates to those programs where all patients received preoperative imaging ([Wells 2005](#); [Wells 2006](#)). However, the accuracy of duplex US has been reported to be highly operator-dependent; [Patel 2003](#) found that 32% required further venography.

Other imaging techniques have limitations: magnetic resonance venography is costly and has limited availability ([Jungling 2003](#)); and use of contrast dye angiography may be problematic for people with chronic kidney disease who have residual kidney function ([Lok 2012](#)).

Suitability criteria for vessel identification in fistula creation are complex and not well established ([Lockhart 2004](#); [Malovrh 2003](#); [Malovrh 2006](#); [Peterson 2008](#); [Singh 2007](#); [Yerdel 1997](#)). The impact of routine preoperative vascular access evaluation using radiological imaging for fistula creation may increase maturation rates and enhance patient-related outcomes for people who need haemodialysis.

Why it is important to do this review

Identification of effective procedures to increase fistula maturation and patency rates will provide significant clinical and resource benefits, as well as improve patient-centred outcomes by reducing infection and thrombosis risk, reducing hospital admissions and procedures, and improving haemodialysis adequacy.

OBJECTIVES

We compared the effect of conducting routine radiological imaging evaluation for vascular access creation preoperatively with standard care without routine preoperative vessel mapping on fistula creation and use.

METHODS

Criteria for considering studies for this review

Types of studies

All randomised controlled trials (RCTs) and quasi-RCTs (RCTs in which allocation to treatment was obtained by alternation, use of alternate medical records, date of birth or other predictable methods) that studied routine preoperative vascular access evaluation by radiological imaging on arterio-venous access creation and use compared with standard preoperative care without radiological imaging.

Types of participants

- Patients (≥ 18 years) with ESKD who required permanent haemodialysis access (fistula or graft), including predialysis patients, haemodialysis patients, peritoneal dialysis patients or transplant patients who required chronic haemodialysis.

Types of interventions

Routine preoperative evaluation by radiological imaging

- Doppler ultrasound
- Duplex ultrasound
- Venous mapping (venogram)
- Arterial mapping (angiogram)
- Magnetic resonance imaging (MRI)
- Computed tomography (CT) scan.

Standard preoperative care

- Physical examination
- Non-invasive or non-imaging scoring systems
- No preoperative evaluation.

Types of outcome measures

- Of the patients who attempted a fistula, the proportion in whom the attempt was successful
- Number of fistulas surgically created that matured
 - Note: definition of fistula maturation varies in the literature and among studies. A fistula is defined as mature if it can function in 2/3 dialysis runs within a month by six months after creation (allowing for intervention to facilitate its maturation) at the prescribed blood flow rate and dialysis duration (typically blood flow of 300 to 450 mL/min for 3.5 to 4.0 hours) (Lee 2011)
- Number of fistulas used by three and six months (time frame is a given time following fistula creation or following haemodialysis initiation)
- Number of patients who were initiated on haemodialysis with catheter (pre-dialysis population) (Lee 2011)
- Rate of interventions required to attain fistula functionality (number of interventions/ access/ patient-time)
- Proportion of AV fistulas and grafts created.

Search methods for identification of studies

Electronic searches

We searched Cochrane Kidney and Transplant's Specialised Register to 14 April 2015 through contact with the Trials Search Co-ordinator using search terms relevant to this review. The Specialised Register contains studies identified from the following sources.

1. Monthly searches of the Cochrane Central Register of Controlled Trials (CENTRAL)
2. Weekly searches of MEDLINE OVID SP
3. Handsearching of kidney-related journals and the proceedings of major kidney conferences
4. Searching of the current year of EMBASE OVID SP
5. Weekly current awareness alerts for selected kidney journals
6. Searches of the International Clinical Trials Register (ICTRP) Search Portal and ClinicalTrials.gov.

Studies contained in the Specialised Register are identified through search strategies for CENTRAL, MEDLINE, and EMBASE based on the scope of Cochrane Kidney and Transplant. Details of these strategies, as well as a list of handsearched journals, conference proceedings and current awareness alerts, are available in the Specialised Register section of information about [Cochrane Kidney and Transplant](#).

See [Appendix 1](#) for search terms used in strategies for this review.

Searching other resources

1. Reference lists of review articles, relevant studies and clinical practice guidelines.
2. Letters seeking information about unpublished or incomplete studies to investigators known to be involved in previous studies.

Data collection and analysis

Selection of studies

The search strategy described was used to obtain titles and abstracts of studies relevant to the review. Titles and abstracts were screened independently by two authors, who discarded studies that were not applicable; however, studies and reviews that potentially included relevant data or information on studies were retained initially. Two authors independently assessed retrieved abstracts, and if necessary, the full text of these studies to determine which satisfied inclusion criteria.

Data extraction and management

Data extraction was carried out independently by two authors using standard data extraction forms. Studies reported in non-English language journals were translated before assessment. Where more than one publication of one study existed, reports were grouped together and the publication with the most complete data was used in the analyses. Where relevant outcomes were only published in earlier versions these data were used. Any discrepancies between published versions were to be highlighted.

Assessment of risk of bias in included studies

The following items were independently assessed by two authors using the risk of bias assessment tool (Higgins 2011) (see Appendix 2).

- Was there adequate sequence generation (selection bias)?
- Was allocation adequately concealed (selection bias)?
- Was knowledge of the allocated interventions adequately prevented during the study?
 - Participants and personnel (performance bias)
 - Outcome assessors (detection bias)
- Were incomplete outcome data adequately addressed (attrition bias)?
- Are reports of the study free of suggestion of selective outcome reporting (reporting bias)?
- Was the study apparently free of other problems that could put it at a risk of bias?

Measures of treatment effect

For dichotomous outcomes (fistula and graft creation, catheter used, fistula mature at six months following creation, fistula used within three months of starting dialysis) results were expressed as risk ratio with 95% confidence intervals (CI). Where continuous scales of measurement were used to assess the effects of treatment (rate of intervention, access-days, patient-days) the mean difference (MD) was used, or the standard mean difference (SMD) if different scales were used.

Dealing with missing data

Any further information required from the original author was requested by written correspondence (e.g. emailing and/or writing to corresponding author/s) and any relevant information obtained in this manner was included in the review. Evaluation of relevant quantitative data was carefully performed (e.g. data on screened, randomised patients, as well as intention-to-treat, as-treated and per-protocol population). Attrition rates, for example drop-outs, losses to follow-up and withdrawals were investigated. Issues of missing data and imputation methods (for example, last-observation-carried-forward) were critically appraised (Higgins 2011).

Assessment of heterogeneity

Heterogeneity was analysed using a Chi² test on N-1 degrees of freedom, with an alpha of 0.05 used for statistical significance and with the I² test (Higgins 2003). I² values of 25%, 50% and 75% correspond to low, medium and high levels of heterogeneity.

Assessment of reporting biases

Funnel plots were to be used to assess for the potential existence of small study bias; however, the small number of included studies meant this was not feasible (Higgins 2011).

Data synthesis

Data were pooled using the random-effects model but the fixed-effect model was also used to ensure robustness of the model and to reduce susceptibility to outliers.

Subgroup analysis and investigation of heterogeneity

Subgroup analysis was planned to explore possible sources of heterogeneity (participant criteria, study quality). Heterogeneity among participants could be related to age, etiology of ESKD, and co-morbidities. Heterogeneity in treatments could be related to vascular access history. Adverse effects were to be tabulated and assessed with descriptive techniques, as they are likely to be different for the various pre-operative evaluations used. Where possible, the risk differences with 95% CI were to be calculated for each adverse effect, either compared to no treatment or to another intervention.

Sensitivity analysis

We planned to perform sensitivity analyses to explore the influence of the following factors on effect size:

- Repeating the analysis excluding unpublished studies
- Repeating the analysis taking account of risk of bias, as specified
- Repeating the analysis excluding any very long or large studies to establish how much they dominate the results
- Repeating the analysis excluding studies using the following filters: language of publication, source of funding (industry versus other), and country.

Sensitivity analyses could not be performed due to the lack of data.

RESULTS

Description of studies

Results of the search

Our search identified 239 records (Figure 1). Of these, 227 studies were excluded because they evaluated other interventions involving different patient populations (e.g. transplant population) or were not RCTs. We found 12 reports of nine studies that potentially met our inclusion criteria. Following full text assessment, we included four studies (Ferring 2010; Nursal 2006; Smith 2014; Zhang 2006), excluded four studies (Köksoy 1995; Mayer 1993; Mihmanli 2001; Veroux 2013), and could not classify one as results were not available (Koumoutsea 2010).

Figure 1. Study flow diagram

Included studies

We included four studies (450 participants). See [Characteristics of included studies](#).

- [Ferring 2010](#) was conducted in the United Kingdom and involved 218 adult ESKD patients who required permanent haemodialysis access. They compared standard preoperative care (106 patients) to preoperative vessel imaging by vascular doppler ultrasound using a portable ultrasound scanner (112 patients). Recruitment began 31 August 2004 and was complete by 30 September 2006. [Ferring 2010](#) defined maturation failure as those fistulas inadequate for haemodialysis after initial surgical formation, including all immediate failure on the day of surgery, early thrombosis, and failure to mature. A fistula was adequate for dialysis if used for at least six consecutive 4-hour dialysis sessions by two needle cannulation without assistance from a catheter, with a minimum blood pump rate of 200 mL/min after the third session. Loss to follow-up was 11%, which was not reported separately between the treatment and control arms.
- [Nursal 2006](#) was conducted in Turkey and involved 70 adult ESKD patients who required permanent haemodialysis access. They compared standard preoperative care (35 patients) to preoperative vessel imaging by colour doppler ultrasound using Acuson (Mountain View, CA) 128XP/4 system with a 7 MHz linear probe (35 patients). Recruitment began 1 March 2003 and was complete by 1 March 2004. [Nursal 2006](#) defined maturation as all fistulas that did not experience primary failure (excluding immediate failure). Loss to follow-up was not reported.
- [Smith 2014](#) was conducted in the United Kingdom and involved 94 ESKD patients who required permanent haemodialysis access. They compared standard preoperative care (47 patients) to preoperative vessel imaging by routine duplex ultrasonography using a Sonosite L38e 10-5-MHz linear

transducer (47 patients). Recruitment began 1 March 2010 and was complete by 1 January 2012. [Smith 2014](#) defined primary failure as thrombosis within 30 days of fistula creation.

- [Zhang 2006](#) was conducted in China and involved 68 adult ESKD patients who required permanent haemodialysis access. They compared standard preoperative care (35 patients) to preoperative vessel imaging by colour doppler ultrasound using a HP Image Point Hx colour doppler ultrasound machine with a 7 to 10 MHz linear probe (33 patients). Recruitment began 1 April 2003 and was complete by 1 March 2004. [Zhang 2006](#) defined maturation failure as the inability to obtain permanent access blood flow rate of 200 to 300 mL/min on dialysis. Loss to follow-up in the intervention arm was 45% and not reported in the control arm.

When comparing the baseline patient age of the study sample in the four studies, [Ferring 2010](#) had higher median ages in the intervention and control arms (69 and 67 years respectively) than mean ages in [Nursal 2006](#) and [Zhang 2006](#) (65.5 and 51.2 years respectively). The proportion of patients with hypertension at baseline in [Nursal 2006](#) was higher (91% intervention, 82% control) than in [Ferring 2010](#) (77% intervention, 74% control). Proportions of patients with cardiac disease and diabetes were similar between both arms within and between the [Zhang 2006](#) and [Ferring 2010](#) studies. Baseline comorbidities were not reported in [Zhang 2006](#).

Excluded studies

One study assessed postoperative imaging as opposed to preoperative imaging ([Mayer 1993](#)) and one study was only available as an abstract and was a subset of a larger study yet to be published ([Koumoutsea 2010](#)). [Mihmanli 2001](#) did not measure outcomes past 24 hours; and [Köksoy 1995](#) was not a RCT.

Risk of bias in included studies

Risk of bias of the included studies is summarised in [Figure 2](#) and [Figure 3](#). Overall, [Ferring 2010](#) was found to be at low risk of bias,

[Smith 2014](#) and [Nursal 2006](#) were unclear, and [Zhang 2006](#) was at high risk of bias.

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies

Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Ferring 2010	+	+	+	+	-	+	+
Nursal 2006	+	?	?	?	+	?	?
Smith 2014	?	+	?	?	+	-	?
Zhang 2006	-	-	-	-	-	-	-

Allocation

In terms of allocation concealment, [Ferring 2010](#) was at low risk of bias, [Smith 2014](#) and [Nursal 2006](#) had an unclear risk of bias, and [Zhang 2006](#) was at high risk of bias. [Zhang 2006](#) did not appear to have generated a randomisation sequence or to have taken adequate measures to limit selection bias.

Blinding

For blinding of participants, personnel, and outcome assessors, [Ferring 2010](#) was at low risk of bias. [Nursal 2006](#) and [Smith 2014](#) had unclear risk of bias, and [Zhang 2006](#) was at high risk of bias. [Zhang 2006](#) does not appear to have blinded their personnel or their participants to limit bias.

Incomplete outcome data

For incomplete outcome data, two of the four studies had low risk of bias and two of three studies had high risk of bias. In [Ferring 2010](#), 22/218 patients were lost to follow-up (11%); loss to follow-up was not reported separately for control and intervention arms. [Smith 2014](#) had no patients lost to follow up. Losses to follow-up were not reported in [Nursal 2006](#). [Zhang 2006](#) reported 14/68 patients were lost to follow-up, all in the intervention group (20% at 6 months). Reasons for loss to follow-up in [Zhang 2006](#) included: transfer to other haemodialysis centres, kidney transplantation, and death. However, to assess the risk of bias associated with this loss to follow-up in the [Zhang 2006](#) study, it is important to understand the distribution of loss to follow-up between groups, but this was not possible. As the effect estimates were small, the potential impact of any imbalance of follow-up between arms on the results of the

two outcomes (proportion of fistulas matured and proportion of patients using a catheter at dialysis initiation) may be significant.

Selective reporting

We assessed [Ferring 2010](#) to be at low risk of reporting bias, [Nursal 2006](#) was unclear, and [Smith 2014](#) and [Zhang 2006](#) were at high risk of bias. [Zhang 2006](#) did not appear to have blinded outcome assessors, nor were all prespecified outcomes reported.

Other potential sources of bias

[Ferring 2010](#) was assessed to be at low risk of bias, [Nursal 2006](#) and [Smith 2014](#) were unclear, and [Zhang 2006](#) was at high risk of bias.

Effects of interventions

See: [Summary of findings for the main comparison Preoperative vessel imaging by ultrasound mapping versus standard preoperative care for arteriovenous access creation in haemodialysis patients](#)

The four included studies ([Ferring 2010](#); [Nursal 2006](#); [Smith 2014](#); [Zhang 2006](#)) compared routine preoperative vessel imaging with standard preoperative care without routine preoperative vessel imaging.

There was no significant difference in the number of fistulas that were successfully created between the intervention and control groups ([Analysis 1.1](#) (4 studies, 433 patients): RR 1.06, 95% CI 0.95 to 1.28; $I^2 = 76\%$). There was significant heterogeneity.

There were no significant differences in the number of fistulas that matured at six months between intervention and control groups ([Analysis 1.2](#) (3 studies, 356 participants): RR 1.11, 95% CI 0.98 to 1.25; $I^2 = 0\%$).

There was no significant difference in the number of fistulas that were used successfully for dialysis between the intervention and control groups ([Analysis 1.3](#) (2 studies, 286 participants): RR 1.12, 95% CI 0.99 to 1.28; $I^2 = 0\%$).

[Ferring 2010](#) reported no significant difference in the number of patients initiating dialysis with a catheter between the intervention and control groups ([Analysis 1.4](#) (1 study, 214 patients): RR 0.66, 95% CI 0.42 to 1.04).

[Nursal 2006](#) reported no significant difference in the rate of interventions required to maintain patency between the intervention and control groups ([Analysis 1.5](#) (1 study, 70 patients): MD 14.70 interventions/1000 patient-days, 95% CI -7.51 to 36.91).

Subgroup analyses could not be conducted due to the limited number of studies included. Sensitivity analyses using fixed rather than random-effects models were conducted. Across all outcomes, none changed significantly under the fixed-effects assumptions (data not shown); the direction or statistical significance of the effect estimates did not change ([Thabane 2013](#)).

DISCUSSION

Summary of main results

Overall, there was uncertainty surrounding the benefits versus harms of preoperative vessel imaging, as the pooled effect

estimates did not achieve statistical significance. Results are summarised in [Summary of findings for the main comparison](#).

Overall completeness and applicability of evidence

A recent standardized definition of a mature fistula is one that can function in two thirds (66.6%) of dialysis runs within a month by six months after its creation, allowing for intervention to facilitate its maturation, at the prescribed blood flow rate and dialysis duration (typically blood flow of 300 to 450 mL/min for 3.5 to 4.0 hours) ([Lee 2011](#)). The outcome definitions in the included studies are not entirely consistent with this definition, as the standardised definition was published in 2011, after the four studies were conducted. [Ferring 2010](#) defined a mature fistula as those fistulae that were adequate for haemodialysis after initial surgical formation, excluding all immediate failure on the day of surgery, early thrombosis, and failure to mature. Fistulas were considered usable for dialysis if they “were used for at least six consecutive 4-hour dialysis sessions by two needle cannulation without assistance from a catheter, with a minimum blood pump rate of 200 mL/min after the third session.” [Nursal 2006](#) was unclear in their definition: all fistulas that did not experience primary failure (excluding immediate failure) were considered mature. [Smith 2014](#) captured primary failure at 30 days, defined as thrombosis within 30 days. They also measured fistula-related complications and interventions within 90 days; however, they did capture outcomes past 3 months so could not be included in the maturation outcome. [Zhang 2006](#) defined a mature fistula as one that attained permanent blood flow of 200 to 300 mL/min. Differences in outcomes definitions may limit the applicability of this evidence. The definition of a mature fistula is strikingly different in the studies included in the analysis, which limits the validity of combining the results of the three main studies reporting this outcome into a single pooled estimate. Therefore the results of the pooled estimate for this outcome must be interpreted with caution. Additionally, the effect of the timing of fistula attempt relative to the start of dialysis on the utility of preoperative vessel imaging could not be assessed in this meta-analysis due to a lack of available data.

Quality of the evidence

The quality of the evidence was assessed as low for proportions of fistulas matured, used for dialysis, and patients requiring a catheter. For the outcome of fistula maturation, [Zhang 2006](#) (which was assessed to be at high risk of bias), was weighted at approximately 30%. The directionality and statistical significance of the results were identical using a fixed-effects model (data not shown).

[Ferring 2010](#) was the only study that rigorously measured this outcome. For outcome of the proportion of fistulas that were used for dialysis, [Ferring 2010](#) accounted for most of these results at a weight of 63%. Results from [Nursal 2006](#) could not be included in this analysis because this study assumed that patent fistulas were used for dialysis, and therefore did not actually measure this outcome. [Zhang 2006](#) and [Ferring 2010](#) measured and considered fistulas mature if they were used for dialysis. For the proportion of patients requiring a catheter for dialysis initiation outcome, [Ferring 2010](#) was the only study that reported this outcome. For all three of these outcomes there was insufficient quality of evidence to be certain of the findings.

Further, the quality of evidence for the outcomes of the proportions of fistulas created and rate of interventions required to maintain patency were assessed to be very low on the grade scale. For the outcome of the proportion of fistulas that were successfully created, [Ferring 2010](#) and [Zhang 2006](#) were weighted at approximately 45% each and there was significant heterogeneity between studies used in this analysis. The rate of interventions required to maintain patency outcome was not decreased by preoperative vessel imaging when compared to standard care. In contrast, the trend appears to be the reverse, the rate of interventions required to maintain patency was lower in the control group of [Nursal 2006](#), the only study to report this outcome. There are a number of possible explanations for this finding. The initial imaging may have prompted subsequent surveillance in the intervention group whereby subclinical stenosis were identified and intervened on; such subclinical lesions would have remained undetected in the control group. Also, intervention can cause endothelial injury and stenosis, leading to a cycle of requiring further intervention and potential vessel injury. It is not clear in [Nursal 2006](#) whether research personnel were blinded to treatment allocation. For both outcomes, the reasons for downgrading were imprecision of the effect estimate (with wide confidence intervals) and high risk of bias ([Figure 2](#)).

There was a paucity of high quality evidence to answer our research question as there was only one relatively large RCT assessed at low risk of bias.

Overall the quality of evidence supporting the use of preoperative vessel imaging to improve patency rates in fistulas was very low, and the findings uncertain.

Potential biases in the review process

The limitations of the review with regard to preventing bias are outside the control of the authors: there was one abstract from which relevant data could not be obtained ([Koumoutsea 2010](#)).

Agreements and disagreements with other studies or reviews

There has been one previous systematic review addressing this research question. They conducted a systematic search of the literature for RCTs in which preoperative duplex mapping was compared with clinical evaluation. They identified three studies; two of the three studies included in our review ([Ferring 2010](#); [Nursal 2006](#)), and one excluded from our review ([Mihmanli 2001](#)). Like our systematic review, they assessed risk of bias using the Cochrane Risk of Bias Assessment tool: we have differing results for the study by [Nursal 2006](#) on the risk of bias assessment (3 of the items, were rated differently), though very similar results for [Ferring 2010](#). They conducted a meta-analysis for one outcome only: fistula formation and found no statistically significant difference between ultrasound mapping and clinical evaluation in the proportion of fistulas used for dialysis. Despite this, the authors discussed that there was likely a benefit to preoperative vessel imaging. However, we had excluded ([Mihmanli 2001](#)) because they did not evaluate outcomes past 24 hours, and as a fistula takes several months to mature sufficiently for use in dialysis, the investigators could not have captured this outcome in the 24-hour period. Overall, our review findings partially agree with that of [Wong 2013](#), in that we also found no statistically significant difference between routine ultrasound mapping and standard preoperative

care, however we included different studies and examined different outcomes. Several observational studies have suggested a possible benefit using preoperative vessel imaging to improve maturation outcomes ([Brown 2006](#); [Patel 2003](#); [Wells 2005](#); [Wells 2006](#)). Our review findings did not support these observational studies' findings.

AUTHORS' CONCLUSIONS

Implications for practice

The available evidence was not found to support preoperative vessel imaging by ultrasound mapping over standard preoperative care. This assessment of the evidence places different weights on the outcome based on their importance to the quality of life for a haemodialysis patients: a relatively high value on the proportion on the outcome of fistulas used for dialysis, and a relatively low value on the outcome of fistula creation only. Fistula creation as an outcome is of low value in itself if they are created and then do not subsequently mature adequately for haemodialysis use. The proportion of fistula created does not represent the ultimate success of the vascular access as failure to mature rates are reported to be over 50% ([Allon 2002](#); [Hakaim 1998](#); [Lee 2011](#); [Lok 2003](#); [Lok 2006](#)). Ultimately, the proportion of fistulas that were successfully used for dialysis was the outcome most highly valued in this assessment. An improvement in this outcome would provide dialysis access with low complications and prevent the adverse outcomes associated with catheter use, such as infection and thrombosis. The clinical significance of the relatively small non-statistically significant benefit seen in fistulas matured at six months is unclear and must be weighed against potential burdens to the patient and the healthcare system. Preoperative vessel imaging may lead to extra appointments, patient inconvenience, and delay surgery. Preoperative imaging was not found to reduce catheter use and may add unnecessary costs to the healthcare system.

Implications for research

The proportions of fistulas that have matured is a critically important outcome measures to be included in further studies as the rate of fistula failure following surgical creation continues to be high ([Al-Jaishi 2014](#); [NIDDK 2007](#)). Additionally, the proportion of patients requiring a catheter for dialysis is a very important patient relevant outcome, as catheters are associated with increased morbidity and mortality, especially due to the increased risk of central stenosis and infection ([Churchill 1992](#); [Kherlakian 1986](#); [Manns 2005](#); [USRDS 2011](#)). Central stenosis may prohibit optimal fistula maturation; furthermore, fistulae that are preceded by catheter use have shorter patency than fistulae without prior catheter use ([Mendelssohn 2005](#)).

The main finding of this review was to confirm a current lack of evidence to fully address this question. Of the four included studies two were not adequately powered to address outcomes. We found a lack of consensus among the included studies concerning procedures for preoperative vessel imaging, suggesting that there is need for achievement of a consensus view on standardisation of preoperative imaging techniques. Formal cost analyses have not been conducted and patients' preferences were not assessed in any of the included studies.

High quality RCTs are required to clarify these issues and answer the question of whether preoperative imaging before access creation is associated with improved fistula and patient outcomes.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Ferring 2010

Methods	<ul style="list-style-type: none"> Study design: parallel RCT Study duration: 31 August 2004 to 30 September 2006 Duration of follow-up: 40 months
Participants	<ul style="list-style-type: none"> Country: UK Setting: single centre Adult ESKD patients requiring a permanent vascular access Number: treatment group (112); control group (106) <ul style="list-style-type: none"> Hypertension: treatment group (87/112); control group (79/106) Diabetes: treatment group (18/112); control group (36/106) Cardiac disease: treatment group (33/112); control group (38/106) Median age, range (years): treatment group (69, 26 to 88); control group (67, 20 to 89) Sex (M/F): treatment group (69/43); control group (73/36) Exclusion criteria: already participated in the study; more than one previous fistula, previous up-per-arm arteriovenous graft
Interventions	<p>Treatment group</p> <ul style="list-style-type: none"> US mapping: vascular Doppler US was performed by a nephrology trainee and a vascular access nurse specialist using a portable US scanner (SonoSite 180 plus, SonoSite Inc, Bothell, WA) with a 5- to 10 MHz linear probe Standard preoperative assessment US results disclosed to the surgeon <p>Control group</p> <ul style="list-style-type: none"> US mapping: vascular Doppler US was performed by a nephrology trainee and a vascular access nurse specialist using a portable US scanner (SonoSite 180 plus, SonoSite Inc, Bothell, WA) with a 5- to 10 MHz linear probe Standard preoperative assessment US results not disclosed to the surgeon
Outcomes	<ul style="list-style-type: none"> Proportion of fistula created, matured, and used <ul style="list-style-type: none"> Maturation definition: adequate for HD after initial surgical formation, excluding all immediate failure on the day of surgery, early thrombosis, and failure to mature. Adequate if used for at least 6 consecutive 4-hour dialysis sessions by 2 needle cannulation without assistance from a catheter, with a minimum blood pump rate of 200 mL/min after the third session
Notes	<ul style="list-style-type: none"> Funding source: British Renal Society

Ferring 2010 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"An independent trial coordinator, unaware of the results of the assessments, stratified patients..." "predefined computer-generated random sequence in blocks of eight"
Allocation concealment (selection bias)	Low risk	"using four sets of consecutively numbered sealed envelopes"
Blinding of participants and personnel (performance bias) All outcomes	Low risk	The study appears to have blinded participants and personnel where possible so as to limit bias
Blinding of outcome assessment (detection bias) All outcomes	Low risk	The study appears to have blinded outcome assessors so as to limit bias
Incomplete outcome data (attrition bias) All outcomes	High risk	Loss to follow-up was 11% across both arms
Selective reporting (reporting bias)	Low risk	Prespecified outcomes of interest to this review were reported
Other bias	Low risk	Appears to be free of other sources of bias

Nursal 2006

Methods	<ul style="list-style-type: none"> Study design: parallel RCT Study duration: March 2003 to March 2004 Duration of follow-up: 6 months
Participants	<ul style="list-style-type: none"> Country: Turkey Setting: single centre Adult ESKD patients requiring permanent vascular access Number enrolled: treatment group (35); control group (35) <ul style="list-style-type: none"> Hypertension: treatment group (15/34); control group (29/35) Diabetes: treatment group (15/34); control group (13/35) Cardiac disease: treatment group (12/34); control group (9/35) Mean age $\pm$ SD (years): treatment group (56.6 $\pm$ 14.2); control group (56.5 $\pm$ 14.4) Sex (M/F): treatment group (18/17); control group (19/16) Exclusion criteria: external venous diameter < 1 mm without tourniquet; external venous diameter < 2 mm with a tourniquet; visible vein length < 5 cm; arterial pulsatile force < 2 (scale 0 to 4); inadequate hand circulation according to the Allen test; venous collateral circulation in the shoulder region, oedema
Interventions	Treatment group <ul style="list-style-type: none"> US mapping versus standard preoperative assessment: Colour Doppler US was performed with an Acuson (Mountain View, CA) 128XP/4 system with a 7 MHz linear probe. It is unclear who performed the imaging

Nursal 2006 (Continued)

	Control group
	<ul style="list-style-type: none"> Physical examination for vessel anatomy
Outcomes	<ul style="list-style-type: none"> Proportion of fistula created, matured, and used. <ul style="list-style-type: none"> Maturation definition: all fistulas that did not experience primary failure (excluding immediate failure)
Notes	<ul style="list-style-type: none"> Funding source: not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The study appears to have generated their randomisation sequence so as to limit bias. "blocked rank randomization method"
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Insufficient information to permit judgement
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Insufficient information to permit judgement
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement
Other bias	Unclear risk	Insufficient information to permit judgement

Smith 2014

Methods	<ul style="list-style-type: none"> Study design: parallel RCT Study duration: March 2010 to January 2012 Duration of follow-up: 3 months
Participants	<ul style="list-style-type: none"> Country: UK Setting: single centre Adult ESKD patients referred to vascular consultants for primary fistula formation (or primary fistula in that limb) for HD access Number enrolled: treatment group (47); control group (47) <ul style="list-style-type: none"> Hypertension: treatment group (30/47); control group (27/47) Diabetes: treatment group (15/47); control group (15/47) Mean age (years): treatment group (64.3); control group (65.3) Exclusion criteria: inability to give informed consent, age of less than 18 years at the time of referral, inability to attend follow up appointments

Smith 2014 (Continued)

Interventions	Treatment group <ul style="list-style-type: none"> Preoperative duplex US scanning Control group <ul style="list-style-type: none"> Standard preoperative assessment
Outcomes	Primary outcome is the primary failure of access, immediate/early thrombosis or failure to mature, within 30 days
Notes	https://clinicaltrials.gov/ct2/show/NCT01004627

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information to permit judgement
Allocation concealment (selection bias)	Low risk	Randomisation was done using opaque, consecutively numbered, sealed envelopes
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No blinding of personnel was reported (no participant reported outcomes were used, so participants did not require blinding)
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No blinding of outcome assessors was reported.
Incomplete outcome data (attrition bias) All outcomes	Low risk	No patients were lost to follow up.
Selective reporting (reporting bias)	High risk	Secondary outcomes listed in clinical trial registry are not all reported in the final manuscript.
Other bias	Unclear risk	Insufficient information to permit judgement

Zhang 2006

Methods	<ul style="list-style-type: none"> Study design: parallel RCT Study duration: April 2003 to March 2004 Duration of follow-up: 6 months
Participants	<ul style="list-style-type: none"> Country: China Setting: single centre Adult ESKD patients requiring permanent vascular access Number: treatment group (35); control group (33) Mean age (range): 51.2 years (18 to 82) Sex (M/F): 32/36 Exclusion criteria: not reported

Zhang 2006 (Continued)

Interventions	<p>Treatment group</p> <ul style="list-style-type: none"> Colour Doppler US was performed with an HP Image Point Hx COLOUR Doppler US machine with a 7 to 10 MHz linear probe. It is unclear who performed the imaging <p>Control group</p> <ul style="list-style-type: none"> Standard preoperative assessment
Outcomes	<ul style="list-style-type: none"> Proportion of fistula created, matured, and used <ul style="list-style-type: none"> Maturation definition: the inability to obtain permanent blood flow of 200 to 300 mL/min
Notes	<ul style="list-style-type: none"> Funding source: not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	The study does not appear to have generated their randomisation sequence to limit bias
Allocation concealment (selection bias)	High risk	The study does not appear to have taken adequate measures to limit selection bias
Blinding of participants and personnel (performance bias) All outcomes	High risk	The study does not appear to have blinded their personnel or their participants to limit bias
Blinding of outcome assessment (detection bias) All outcomes	High risk	The study does not appear to have blinded their outcome assessors so as to limit bias
Incomplete outcome data (attrition bias) All outcomes	High risk	There is significant loss to follow-up in the intervention arm of the study
Selective reporting (reporting bias)	High risk	Prespecified outcomes of interest to this review were not reported
Other bias	High risk	The study does not appear to have limited other potential sources of bias

fistula - arteriovenous fistula; ESKD - end-stage kidney disease; HD - haemodialysis; M/F - male/female; RCT - randomised controlled trial; US - ultrasound

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Köksoy 1995	Not RCT
Mayer 1993	Assessed postoperative imaging
Mihmanli 2001	Did not measure outcomes beyond 24 hours
Veroux 2013	Intervention is not preoperative vessel imaging.

RCT - randomised controlled trial

Characteristics of studies awaiting assessment *[ordered by study ID]*

Koumoutsea 2010

Methods	Study design: parallel RCT
Participants	Adult ESKD patients referred to vascular consultants for primary fistula formation (or primary fistula in that limb) for haemodialysis access - 120 patients who had BMI measurements taken
Interventions	Treatment group <ul style="list-style-type: none"> • US Control group <ul style="list-style-type: none"> • Standard preoperative assessment
Outcomes	Not enough information in abstract to determine the outcomes
Notes	Only abstract available- could not classify study without full text

fistula - arteriovenous fistula; RCT - randomised controlled trial; US - ultrasound

DATA AND ANALYSES

Comparison 1. Preoperative vessel imaging by ultrasound mapping versus standard preoperative care

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Fistulae created	4	433	Risk Ratio (M-H, Random, 95% CI)	1.06 [0.95, 1.18]
2 Matured fistulae	3	356	Risk Ratio (M-H, Random, 95% CI)	1.11 [0.98, 1.25]
3 Fistulae used for dialysis	2	286	Risk Ratio (M-H, Random, 95% CI)	1.12 [0.99, 1.28]
4 Patients initiating dialysis with CVC	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
5 Rate of interventions required to maintain patency (per 1000 patient-days)	1		Mean Difference (IV, Random, 95% CI)	Totals not selected

Analysis 1.1. Comparison 1 Preoperative vessel imaging by ultrasound mapping versus standard preoperative care, Outcome 1 Fistulae created.

Analysis 1.2. Comparison 1 Preoperative vessel imaging by ultrasound mapping versus standard preoperative care, Outcome 2 Matured fistulae.

Analysis 1.3. Comparison 1 Preoperative vessel imaging by ultrasound mapping versus standard preoperative care, Outcome 3 Fistulae used for dialysis.

Analysis 1.4. Comparison 1 Preoperative vessel imaging by ultrasound mapping versus standard preoperative care, Outcome 4 Patients initiating dialysis with CVC.

Study or subgroup	Ultrasound mapping	Control	Risk Ratio		Risk Ratio
	n/N	n/N	M-H, Random, 95% CI		M-H, Random, 95% CI
Ferring 2010	24/112	33/102			0.66[0.42,1.04]
			More with control	0.2 0.5 1 2 5	More with ultrasound

Analysis 1.5. Comparison 1 Preoperative vessel imaging by ultrasound mapping versus standard preoperative care, Outcome 5 Rate of interventions required to maintain patency (per 1000 patient-days).

Study or subgroup	Ultrasound mapping		Control		Mean Difference		Mean Difference	
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI	
Nursal 2006	35	19.1 (65.4)	35	4.4 (14.7)			14.7[-7.51,36.91]	
					More with control -50 -25 0 25 50		More with ultrasound	

APPENDICES

Appendix 1. Electronic search strategies

Database	Search terms
CENTRAL	<ol style="list-style-type: none"> 1. blood next vessel next prosthesis:ti,ab,kw 2. (fistula* or AVF* or graft or grafts or shunt or shunts):ti,ab,kw 3. ((vascular next access) or (venous next access)):ti,ab,kw 4. (#1 OR #2 OR #3) 5. MeSH descriptor Renal Replacement Therapy explode all trees 6. renal next replacement next therapy:ti,ab,kw 7. dialysis:ti,ab,kw 8. (predialysis or pre-dialysis):ti,ab,kw 9. (haemodialysis or hemodialysis):ti,ab,kw 10.kidney next disease*:ti,ab,kw 11.kidney next failure:ti,ab,kw 12.renal next insufficiency:ti,ab,kw 13.(CRF or CRD or CKF or CKD or ESRF or ESRD or ESKF or ESKD):ti,ab,kw 14.(#5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13) 15.MeSH descriptor Image Interpretation, Computer-Assisted explode all trees 16.computer next assisted next tomography:ti,ab,kw 17.MeSH descriptor Magnetic Resonance Imaging explode all trees 18.radiograph*:ti,ab,kw 19.angiograph*:ti,ab,kw 20.phlebograph*:ti,ab,kw 21.MeSH descriptor Ultrasonography explode all trees 22.echograph*:ti,ab,kw 23.((preoperativ* or pre-operativ*) next (care or evaluat* or assess* or "vascular access" or "venous access")):ti,ab,kw 24.(map or mapped or mapping):ti,ab,kw

(Continued)

- 25.venograph*:ti,ab,kw
- 26.((vascular next imaging) or (vessel next imaging)):ti,ab,kw
- 27.(fistulograph* or elastograph*):ti,ab,kw
- 28.(ultrasound or ultrasonogra*):ti,ab,kw
- 29.(CT or (computed next tomography)):ti,ab,kw
- 30.((magnetic next resonance) or MRA or MRI):ti,ab,kw
- 31.(duplex or doppler):ti,ab,kw
- 32.radiolog*:ti,ab,kw
- 33.x-ray*:ti,ab,kw
- 34.((resistance next index) or (resistive next index)):ti,ab,kw
- 35.Allen* next test:ti,ab,kw
- 36.capillary next refill next time:ti,ab,kw
- 37.((physical* next examin*) or (clinical* next examin*)):ti,ab,kw
- 38.((surgical next exploration) or (surgical next assessment)):ti,ab,kw
- 39.(#15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38)
- 40.(#4 AND #14 AND #39)

MEDLINE (Ovid)

1. Arteriovenous Shunt, Surgical/
2. Arteriovenous Fistula/
3. Blood Vessel Prosthesis/
4. (fistula\$ or AVF\$ or graft or grafts or shunt or shunts).tw.
5. (vascular access or venous access).tw.
6. or/1-5
7. Renal Replacement Therapy/
8. Renal Dialysis/
9. dialysis.tw.
- 10.(predialysis or pre-dialysis).tw.
- 11.(haemodialysis or hemodialysis).tw.
- 12.Kidney Diseases/
- 13.Renal Insufficiency/
- 14.exp Renal Insufficiency, Chronic/
- 15.(kidney disease or kidney failure or renal disease or renal failure).tw.
- 16.(CRF or CRD or CKF or CKD or ESRF or ESRD or ESKF or ESKD).tw.
- 17.or/7-16
- 18.exp Image Interpretation, Computer-Assisted/
- 19.exp Magnetic Resonance Imaging/
- 20.Radiography/
- 21.Angiography/
- 22.Angiography, Digital Subtraction/
- 23.Phlebography/
- 24.exp Ultrasonography/
- 25.Physical Examination/
- 26.Preoperative Care/
- 27.Diagnostic Techniques, Surgical/
- 28.(map or mapped or mapping).tw.
- 29.venogra\$.tw.
- 30.(vascular imaging or vessel imaging).tw.
- 31.(ultrasonogra\$ or ultrasound\$ or US).tw.
- 32.angiogra\$.tw.
- 33.phlebograph\$.tw.
- 34.fistulogra\$.tw.

(Continued)

- 35.elastogra\$.tw.
- 36.radiograph\$.tw.
- 37.(computed tomography or CT scan\$.tw.
- 38.(magnetic resonance or MRI or MRA).tw.
- 39.(duplex or doppler).tw.
- 40.radiologic\$.tw.
- 41.angiogra\$.tw.
- 42.x-ray\$.tw.
- 43.(resistance index or resistive index).tw.
- 44.Allen\$ test.tw.
- 45.capillary refill time.tw.
- 46.(physical\$ exam\$ or clinical\$ exam\$).tw.
- 47.((preoperativ\$ or pre-operativ\$) adj (care or evaluat\$ or assess\$)).tw.
- 48.((preoperative or pre-operative) adj (vascular access or venous access or vessel)).tw.
- 49.(surgical exploration or surgical assessment).tw.
- 50.or/18-50
- 51.and/6,17,50

EMBASE (Ovid)

1. Arteriovenous Shunt/
2. Arteriovenous Fistula/
3. Kidney Arteriovenous Fistula/
4. Blood Vessel Prosthesis/
5. (fistula\$ or AVF\$ or graft or grafts or shunt or shunts).tw.
6. (vascular access or venous access).tw.
7. or/1-6
8. exp Renal Replacement Therapy/
9. dialysis.tw.
- 10.(predialysis or pre-dialysis).tw.
- 11.(haemodialysis or hemodialysis).tw.
- 12.Kidney Disease/
- 13.Kidney Failure/
- 14.Chronic Kidney Disease/
- 15.Chronic Kidney Failure/
- 16.(kidney disease or kidney failure or renal disease or renal failure).tw.
- 17.(CRF or CRD or CKF or CKD or ESRF or ESRD or ESKF or ESKD).tw.
- 18.or/8-17
- 19.exp Computer Assisted Tomography/
- 20.exp Nuclear Magnetic Resonance Imaging/
- 21.Radiography/
- 22.Fistulography/
- 23.Contrast Radiography/
- 24.Angiography/
- 25.Digital Subtraction Angiography/
- 26.Phlebography/
- 27.exp Echography/
- 28.Physical Examination/
- 29.Preoperative Care/
- 30.Preoperative Evaluation/
- 31.(map or mapped or mapping).tw.
- 32.venogra\$.tw.
- 33.(vascular imaging or vessel imaging).tw.
- 34.(ultrasonogra\$ or ultrasound\$ or US).tw.

(Continued)

- 35.phlebograph\$.tw.
- 36.fistulogra\$.tw.
- 37.elastogra\$.tw.
- 38.radiograph\$.tw.
- 39.(computed tomography or CT scan).tw.
- 40.(magnetic resonance or MRI or MRA).tw.
- 41.(duplex or doppler).tw.
- 42.radiologic\$.tw.
- 43.angiogra\$.tw.
- 44.x-ray\$.tw.
- 45.(resistance index or resistive index).tw.
- 46.Allen\$ test.tw.
- 47.capillary refill time.tw.
- 48.(physical\$ exam\$ or clinical\$ exam\$).tw.
- 49.((preoperativ\$ or pre-operativ\$) adj (care or evaluat\$ or assess\$)).tw.
- 50.((preoperative or pre-operative) adj (vascular access or vessel)).tw.
- 51.(surgical exploration or surgical assessment).tw.
- 52.or/19-51
- 53.and/7,18,52

Appendix 2. Risk of bias assessment tool

Potential source of bias	Assessment criteria
Random sequence generation Selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence	<i>Low risk of bias:</i> Random number table; computer random number generator; coin tossing; shuffling cards or envelopes; throwing dice; drawing of lots; minimization (minimization may be implemented without a random element, and this is considered to be equivalent to being random). <i>High risk of bias:</i> Sequence generated by odd or even date of birth; date (or day) of admission; sequence generated by hospital or clinic record number; allocation by judgement of the clinician; by preference of the participant; based on the results of a laboratory test or a series of tests; by availability of the intervention. <i>Unclear:</i> Insufficient information about the sequence generation process to permit judgement.
Allocation concealment Selection bias (biased allocation to interventions) due to inadequate concealment of allocations prior to assignment	<i>Low risk of bias:</i> Randomisation method described that would not allow investigator/participant to know or influence intervention group before eligible participant entered in the study (e.g. central allocation, including telephone, web-based, and pharmacy-controlled, randomisation; sequentially numbered drug containers of identical appearance; sequentially numbered, opaque, sealed envelopes). <i>High risk of bias:</i> Using an open random allocation schedule (e.g. a list of random numbers); assignment envelopes were used without appropriate safeguards (e.g. if envelopes were unsealed or non-opaque or not sequentially numbered); alternation or rotation; date of birth; case record number; any other explicitly unconcealed procedure. <i>Unclear:</i> Randomisation stated but no information on method used is available.
Blinding of participants and personnel Performance bias due to knowledge of the allocated	<i>Low risk of bias:</i> No blinding or incomplete blinding, but the review authors judge that the outcome is not likely to be influenced by lack of blinding; blinding of participants and key study personnel ensured, and unlikely that the blinding could have been broken.

(Continued)

interventions by participants and personnel during the study

High risk of bias: No blinding or incomplete blinding, and the outcome is likely to be influenced by lack of blinding; blinding of key study participants and personnel attempted, but likely that the blinding could have been broken, and the outcome is likely to be influenced by lack of blinding.

Unclear: Insufficient information to permit judgement

Blinding of outcome assessment

Detection bias due to knowledge of the allocated interventions by outcome assessors.

Low risk of bias: No blinding of outcome assessment, but the review authors judge that the outcome measurement is not likely to be influenced by lack of blinding; blinding of outcome assessment ensured, and unlikely that the blinding could have been broken.

High risk of bias: No blinding of outcome assessment, and the outcome measurement is likely to be influenced by lack of blinding; blinding of outcome assessment, but likely that the blinding could have been broken, and the outcome measurement is likely to be influenced by lack of blinding.

Unclear: Insufficient information to permit judgement

Incomplete outcome data

Attrition bias due to amount, nature or handling of incomplete outcome data.

Low risk of bias: No missing outcome data; reasons for missing outcome data unlikely to be related to true outcome (for survival data, censoring unlikely to be introducing bias); missing outcome data balanced in numbers across intervention groups, with similar reasons for missing data across groups; for dichotomous outcome data, the proportion of missing outcomes compared with observed event risk not enough to have a clinically relevant impact on the intervention effect estimate; for continuous outcome data, plausible effect size (difference in means or standardized difference in means) among missing outcomes not enough to have a clinically relevant impact on observed effect size; missing data have been imputed using appropriate methods.

High risk of bias: Reason for missing outcome data likely to be related to true outcome, with either imbalance in numbers or reasons for missing data across intervention groups; for dichotomous outcome data, the proportion of missing outcomes compared with observed event risk enough to induce clinically relevant bias in intervention effect estimate; for continuous outcome data, plausible effect size (difference in means or standardized difference in means) among missing outcomes enough to induce clinically relevant bias in observed effect size; 'as-treated' analysis done with substantial departure of the intervention received from that assigned at randomisation; potentially inappropriate application of simple imputation.

Unclear: Insufficient information to permit judgement

Selective reporting

Reporting bias due to selective outcome reporting

Low risk of bias: The study protocol is available and all of the study's pre-specified (primary and secondary) outcomes that are of interest in the review have been reported in the pre-specified way; the study protocol is not available but it is clear that the published reports include all expected outcomes, including those that were pre-specified (convincing text of this nature may be uncommon).

High risk of bias: Not all of the study's pre-specified primary outcomes have been reported; one or more primary outcomes is reported using measurements, analysis methods or subsets of the data (e.g. subscales) that were not pre-specified; one or more reported primary outcomes were not pre-specified (unless clear justification for their reporting is provided, such as an unexpected adverse effect); one or more outcomes of interest in the review are reported incompletely so that they cannot be entered in a meta-analysis; the study report fails to include results for a key outcome that would be expected to have been reported for such a study.

Unclear: Insufficient information to permit judgement

Other bias

Bias due to problems not covered elsewhere in the table

Low risk of bias: The study appears to be free of other sources of bias.

High risk of bias: Had a potential source of bias related to the specific study design used; stopped early due to some data-dependent process (including a formal-stopping rule); had extreme baseline imbalance; has been claimed to have been fraudulent; had some other problem.

(Continued)

Unclear: Insufficient information to assess whether an important risk of bias exists; insufficient rationale or evidence that an identified problem will introduce bias.

HISTORY

Protocol first published: Issue 1, 2008

Review first published: Issue 9, 2015

Date	Event	Description
12 August 2008	Amended	Converted to new review format.

CONTRIBUTIONS OF AUTHORS

1. Study selection: SDK, AA
2. Extract data from studies: SDK, AA
3. Enter data into RevMan: SDK
4. Carry out the analysis: SDK
5. Interpret the analysis: SDK, CEL
6. Draft the final review: SDK, CEL, AA, LM
7. Disagreement resolution: CEL
8. Update the review: SDK, CEL, AA, LM

DECLARATIONS OF INTEREST

- Sarah D Kosa: none known
- Ahmed A Al-Jaishi: none known
- Louise Moist: none known
- Charmaine E Lok: any consultancy to industry conducted was not associated with this review

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- Canadian Institutes for Health Research New Investigator Program, Canada.
- Canadian Institutes for Health Research Randomized Controlled Trial Mentoring Program, Canada.

INDEX TERMS

Medical Subject Headings (MeSH)

Arteriovenous Shunt, Surgical [*methods] [statistics & numerical data]; Blood Vessels [*diagnostic imaging]; Preoperative Care [*methods]; Randomized Controlled Trials as Topic; Renal Dialysis [*methods]; Ultrasonography, Doppler, Color; Vascular Patency

MeSH check words

Adult; Aged; Humans; Middle Aged