Systematic review and meta-analysis of duplex ultrasound surveillance for infrainguinal vein bypass grafts

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ABSTRACT

Objective: Duplex ultrasound (DUS) surveillance of infrainguinal vein bypass grafts is widely practiced, but the evidence of its effectiveness compared with other methods of surveillance remains unclear.

Methods: Following an a priori protocol developed by the guidelines committee from the Society for Vascular Surgery, this systematic review and meta-analysis included randomized and nonrandomized comparative studies that enrolled patients who underwent infrainguinal arterial reconstruction and received DUS surveillance for follow-up compared with any other method of surveillance. The search included MEDLINE, Embase, Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews, Cumulative Index to Nursing and Allied Health Literature, and Scopus through November 2016. Outcomes of interest included all-cause mortality, limb viability, and graft patency reports. Meta-analysis was performed using the random-effects model.

Results: We included 15 studies. Compared with ankle-brachial index and clinical examination, DUS surveillance was not associated with a significant change in primary, secondary, or assisted primary patency or mortality. DUS surveillance was associated with a nonstatistically significant reduction in amputation rate (odds ratio, 0.70 [95% confidence interval, 0.23-2.13]). The quality of evidence was low because of imprecision (small number of events and wide confidence intervals) and high risk of bias in the primary literature.

Conclusions: A recommendation for routine DUS surveillance of infrainguinal vein grafts remains dependent on low-quality evidence. Considering that DUS offers the opportunity of early intervention and because of its noninvasive nature and low cost, vascular surgeons may incorporate DUS as they individualize the follow-up of lower extremity vein grafts. (J Vasc Surg 2017;66:1885-91.)

Autogenous vein is the preferred conduit for open surgical reconstructions in the lower extremity that require bypass grafts.[1] However, when placed in the arterial system, vein grafts can develop stenotic lesions that lead to graft thrombosis and recurrent symptoms of lower extremity ischemia.[2,3] Such lesions have been observed in 30% to 50% of vein grafts observed for up to 5 years.[2] Serial follow-up or surveillance of infrainguinal vein bypass grafts by some combination of clinical assessment, measurement of ankle-brachial index (ABI), and duplex ultrasound (DUS) scanning has been recommended to identify lesions that threaten graft patency and to facilitate selective repeated interventions to maintain graft function. Surveillance protocols have resulted in primary, assisted primary, and secondary patency rates of 61%, 77%, and 80%, respectively, at 1 year.[2]

Although the number of vein bypass grafts has decreased in recent years as the use of endovascular interventions has increased, vein grafts continue to be performed in relatively large numbers.[4] Surveillance of infrainguinal vein grafts by DUS has been strongly advocated and widely practiced; however, the clinical evidence supporting this approach has been conflicting, and the best method to monitor the patency and to optimize outcomes of these grafts remains unclear.[5-7]

To support the development of clinical practice guidelines by the Society for Vascular Surgery, we conducted a systematic review and meta-analysis to synthesize the existing evidence about the effectiveness of DUS surveillance for infrainguinal vein bypass grafts.

METHODS

This systematic review followed a protocol that was developed a priori by a panel of experts from the Society for Vascular Surgery who were tasked with developing a guideline on the topic. The reporting of this review

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follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[8]

Study eligibility. We included randomized or nonrandomized comparative studies. The search was not limited by language, sample size, or date of publications. We searched for studies that included patients who had received autologous vein grafts for lower extremity arterial reconstruction (bypass surgery) not including the aorta (ie, in the femoral or infrainguinal region) who afterward received DUS surveillance for follow-up compared with any other method of surveillance. There was no minimal follow-up period. Abstracts and titles that resulted from executing the search strategy were independently evaluated by two reviewers from this review study team for potential eligibility, and the full-text versions of all potentially eligible studies were obtained. Reviewers working in duplicate and independently considered the full-text reports for eligibility. Disagreements were harmonized by consensus and through arbitration by a third reviewer if consensus was not possible.

Literature search. The search included the electronic databases MEDLINE, Embase, Cochrane Central Register of Controlled Trials and Cochrane Database of Systematic Reviews, Cumulative Index to Nursing and Allied Health Literature, and Scopus (Appendix, online only). We expanded the search to include all languages, with latest date of inclusion to be November 2016. We also cross-referenced with previously published literature and included what was deemed eligible.

Data extraction. Using a standardized form, two reviewers independently extracted data from each study and later reconciled differences, if present. Reviewers independently determined the methodologic quality of studies and collected descriptive and outcome data. Reviewers extracted data on patient demographics and baseline characteristics, interventions compared with DUS, study design variables, sample size, length of follow-up, number of patients in each intervention, and outcomes of interest and clinically pertinent variables (eg, presence of comorbidities, indication for surgery, vessels repaired, type of vein graft used, graft anatomic location, peak systolic velocity index).

Risk of bias assessment and quality of evidence. We used the Cochrane Collaboration risk of bias assessment tool for randomized trials, focusing on randomization methods, allocation concealment, blinding, and attrition.[9] We used the Newcastle-Ottawa Scale[10] for cohort and case-control studies; for uncontrolled studies, we used the quality assessment tool for case series studies ascertained by the National Institutes of Health.[11] We graded the strength of evidence using the Grading of Recommendations Assessment, Development, and Evaluation approach.[12]

Outcomes definition. We included studies that reported any outcomes of interest: all-cause mortality; cardiovascular mortality; limb viability; functional status; quality of life; daily activities scores; and graft patency reports, such as primary patency, assisted primary patency, and secondary patency. A revised vein referred to a vein bypass graft that had undergone a local procedure to maintain patency, such as vein patch angioplasty, replacement of a short segment, or balloon angioplasty. However, this would not apply if the entire original vein graft was replaced by a new graft, in which case it would be considered a new vein graft. For postoperative graft occlusion, we extracted data from studies reporting any graft that became totally occluded (ie, no flow at all) at some time after it was placed. For postoperative graft stenosis, this referred to a graft that developed a narrowing at some time after it was placed but remained patent (ie, not completely occluded but may not be adequate for normal function). Primary patency ascertained the time interval beginning with the original operation during which a graft remains continuously patent without any interventions to maintain patency. The period of primary patency ends if an intervention is done to maintain patency or if the graft occludes. Assisted primary patency begins at the time of the original operation and refers to continuous patency but includes periods of patency after interventions intended to maintain patency. A period of assisted primary patency ends if the graft occludes. Secondary patency was defined by when a graft occludes but then has patency restored by some type of intervention (ie, secondary patency includes the period of primary or assisted primary patency plus any additional period of patency after intervention for graft occlusion). All-cause mortality was ascertained by death due to any reason; major amputation was defined as above-ankle amputations.

Statistical analysis. We extracted or calculated the rate of outcomes of interest along with the confidence interval estimated by the Jeffreys method.[13] Rates were combined using the DerSimonian and Laird random-effects methods after log transforming the rates.[14] For binary outcomes, odds ratio under 1.0 suggests lower risk associated with surveillance. The I^2 static was used to assess heterogeneity of the treatment effect among studies for each outcome. I^2 value >50% and $P < .10$ of the Cochrane Q test suggest substantial heterogeneity that is due to real differences in study populations, protocols, interventions, or outcomes. Visual inspection of funnel plots and the Egger linear regression tests were planned to evaluate potential publication bias.[15] All statistical analyses were performed using Stata version 12 (StataCorp LP, College Station, Tex).

RESULTS

The initial search resulted in 455 publications. After reviewing the abstracts, we limited the number of

Table I. Compared interventions and number of patients of included studies

Study ID	Patients, No.	Main intervention	DUS group, No.	Comparison intervention	Comparison, No.
Buth, 1991	147	DUS	108	Clinical follow-up + arteriography	108
Dalsing, 1995	143	DUS	63	Clinical follow-up + ABI	80
Davies, 2005	594	DUS	304	Clinical follow-up + ABI	290
Ferris, 2003	204	DUS	204	Arteriography	204
Golledge, 1996	110	DUS	51	Clinical follow-up + ABI	52
Idu, 1993	187	DUS	150	Clinical follow-up + ABI	37
Ihlberg, 1999	344	DUS	167	Clinical follow-up + ABI	175
Ihlberg, 1998	179	DUS	93	Clinical follow-up + ABI	86
Laborde, 1992	115	DUS	115	Clinical follow-up + ABI	115
Lewis, 1998	143	DUS	143	Clinical follow-up + arteriography	131
Lundell, 1995	156	DUS	79	Clinical follow-up + ABI	77
Moody, 1990	63	DUS	63	Clinical follow-up + ABI + arteriography	63
Polak, 1990	14	DUS	14	Clinical follow-up + arteriography	11
Stierli, 1992	41	DUS	41	Clinical follow up + ABI + arteriography	41
Visser, 2001	310	DUS	134	Clinical follow-up + ABI	130

ABI, Ankle-brachial index; *DUS,* duplex ultrasound; *ID,* identifier.

Table II. Meta-analysis results of primary outcomes of eligible studies comparing duplex ultrasound (DUS) surveillance with ankle-brachial index (ABI)

Outcomes	Effect size	95% CI	I^2	Heterogeneity (*P* value)
All-cause mortality	1	0.66-1.52	0	.859
Amputation	0.70	0.23-2.13	82.4	.001
Primary patency	.87	0.66-1.16	0.9	.365
Assisted primary patency	1.29	0.79-2.11	69.4	.011
Secondary patency	1.04	0.61-1.77	70.4	.009
Postoperative graft occlusion	0.90	0.49-1.66	59.2	.062
Postoperative graft stenosis	1.49	0.58-3.83	83.1	.001
Revised vein	1.29	0.74-2.23	0	.871
Leg salvage	1.02	0.47-2.19	57.2	.072
Reopen	1.21	0.57-2.59	0	.387

CI, Confidence interval.
P value under .05 implies that heterogeneity of results is beyond what is expected by chance.

potentially relevant publications to 123 articles. Two more publications were identified through reference review of the selected articles. These 125 articles were reviewed in full text by two reviewers. Eventually, 15 studies were included[5,6,16-29]; 110 articles were excluded for the reasons shown in Supplementary Fig 1 (online only). The baseline characteristics of participants of included studies are summarized in Supplementary Table I (online only). All studies included autologous grafts. One study[18] reported outcomes of interest in a mixed population (ie, autologous and synthetic grafts), and therefore it was deemed not eligible and excluded from the final analysis. A second study included mixed graft types but provided data for autologous grafts separately, and hence that subgroup was included.[6] Five studies were clinical trials, eight were case series, one was a case-control study, and one was a cohort study. Supplementary Table II, *A-C* (online only), shows the risk of bias assessment. The corresponding surveillance interventions used and number of patients in each study are shown in Table I. Results of each study and those of the meta-analysis are shown in Tables II and III, respectively. There was a variation in the DUS surveillance protocols in the included studies as shown in Supplementary Table I (online only). Among the identified studies, four studies used clinical follow-up with arteriography as a method of surveillance compared with DUS, whereas nine studies used a combination of clinical follow-up with ABI to compare. Two studies compared three surveillance interventions (ie, DUS vs arteriography vs ABI and clinical follow-up). Publication bias was not possible to ascertain because of an insufficient number of studies per outcome reported.

Table III. Meta-analysis results of primary outcomes of eligible studies comparing duplex ultrasound (DUS) surveillance with arteriography

Outcomes	Effect size	95% CI	I^2	Heterogeneity (*P* value)
Postoperative graft stenosis	1.20	0.55-2.59	70	.01
Revised vein	1	0.65-1.53	—	—

CI, Confidence interval.

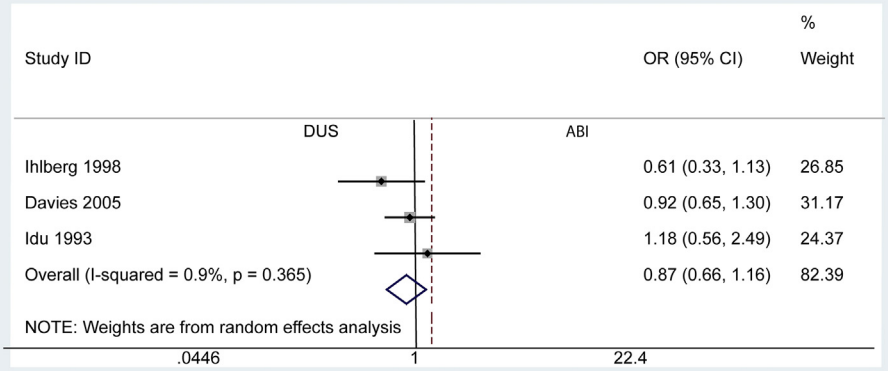

Fig 1. Meta-analysis of primary patency comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.

Meta-analysis. Compared with ABI coupled with clinical examination, DUS surveillance was not associated with a significant change in primary, secondary, or assisted primary patency or mortality (Table II; Figs 1-3; Supplementary Fig 2, online only). DUS surveillance was associated with a nonsignificant reduction in amputation rate (odds ratio, 0.70; confidence interval, 0.23-2.13; Supplementary Fig 3, online only). All other outcomes of interest did not show any significant difference (Supplementary Figs 3-7, online only). One study[16] compared DUS of infrainguinal vein bypasses with intra-arterial digital subtraction angiography as the "gold standard" to determine the severity of the stenosis. The diameter reduction measured by color flow imaging was best to identify all stenotic lesions >29% (sensitivity, 88%; specificity, 99%). Peak systolic velocity index provided optimal identification of stenoses >49% (sensitivity, 89%; specificity, 92%), and 70% to 99% stenoses were associated with increased end-diastolic velocity (sensitivity, 91%; specificity, 100%). This study supports the value of surveillance of femorodistal vein grafts and demonstrates that calculation of the degree of graft stenosis is feasible. Another study compared DUS with computed tomography angiography (CTA) for detection of stenoses in vein grafts.[30] Whereas certain DUS velocity parameters were strongly correlated with vein graft failure, there was a poor correlation between high-grade stenosis on CTA and vein graft failure. The lack of a direct correlation between DUS and CTA in this study was most likely due to the fundamental differences between these two imaging methods, with DUS assessing flow dynamics and CTA based primarily on anatomic features.

A priori established subgroup analyses (follow-up length and study design [interventional trials vs observational studies]) did not show a statistically significant difference. Other a priori clinically relevant subgroup analyses, including by type and origin of vein graft, type of occlusion site, lesion classification, presence of diabetes and other comorbidities, type of surveillance protocol, and cost-effectiveness, were not possible because of inconsistent or insufficient reporting. The quality of evidence (confidence in evidence) was lowered because of increased risk of bias, imprecision, and heterogeneity.

DISCUSSION

In this systematic review and meta-analysis, low-quality evidence suggests that the use of DUS surveillance for infrainguinal vein bypass grafts was not associated with statistically significant changes in clinical outcomes. The quality of the available evidence was low (ie, the certainty of these estimates is low, and future research will likely produce substantially different estimates).[31] DUS scanning—when it is used with appropriate velocity and image criteria—can identify lesions that threaten graft patency at an early stage, when they can be repaired by relatively simple interventions, thus avoiding graft occlusion. Patients who do not receive surveillance would be deprived of early interventions, which may provide a rationale for surveillance. Data on patient-important

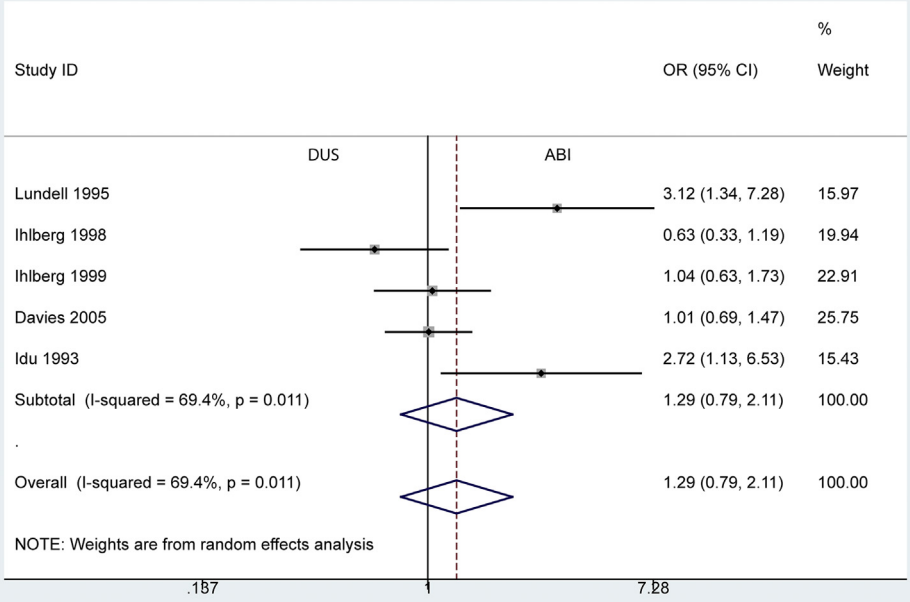

Fig 2. Meta-analysis of assisted primary patency comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.

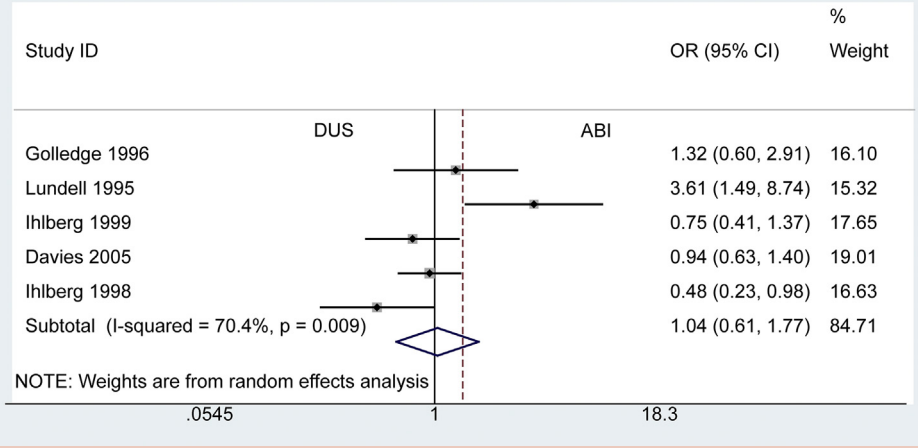

Fig 3. Meta-analysis of secondary patency comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.

outcomes, such as mortality and amputation risk, are currently limited.

The report of the Inter-Society Consensus for the Management of Peripheral Arterial Disease recommended a clinical surveillance program consisting of interval history, vascular physical examination, and measurement of ABI without routine DUS scanning.[32] However, in spite of this lack of high-quality evidence, a number of single-center studies have identified DUS velocity parameters that appear to be predictive of vein graft thrombosis.[30,33] It has been suggested that patients with these "higher risk" bypass grafts may benefit from either intervention to prevent thrombosis or a more a more rigorous surveillance protocol.[7] Recognizing the severe consequences of lower extremity vein graft failure and the challenge of restoring patency once thrombosis has occurred, many vascular surgeons have elected to use some form of DUS surveillance in their patients. The rationale for this approach is also based on the noninvasive nature and relatively low cost of a DUS surveillance program compared with other imaging modalities. In a report on performance measures for adults with peripheral artery disease from a multidisciplinary writing panel, routine surveillance with DUS was recommended after femoral-popliteal and femoral-tibial-pedal vein bypass grafts with surveillance intervals of approximately 3, 6,

and 12 months and then yearly thereafter.[34] Another multidisciplinary report described "appropriate use criteria" for arterial ultrasound and physiologic testing.[35] Surveillance with DUS scanning and ABI was considered "appropriate" after a lower extremity vein bypass graft as a postoperative baseline (within 1 month), at intervals of 6 to 8 months during the first year, and at 12-month intervals thereafter in a patient who remained asymptomatic or had stable symptoms.

The limitations of this systematic review relate to the sparse randomized evidence. Some of the included studies were older; however, the basic approach to DUS surveillance of vein grafts has not changed substantially since it was described in the 1990s.

CONCLUSIONS

A recommendation for routine DUS surveillance of infrainguinal vein grafts remains dependent on low-quality evidence. Considering that DUS offers the opportunity of early intervention and because of its noninvasive nature and low cost, vascular surgeons may incorporate DUS as they individualize the follow-up of lower extremity vein grafts. Follow-up approach can be based on patient factors and preferences, physiologic tests, and imaging modalities that they consider most likely to identify grafts at risk for failure and in need of repeated intervention.

AUTHOR CONTRIBUTIONS

Conception and design: RZ, MM
Analysis and interpretation: AAD, ZW, MM
Data collection: AAD, KM, WF, QH, RZ, LP
Writing the article: AAD, RZ, MM
Critical revision of the article: AAD, KM, WF, QH, RZ, ZW, LP, MM
Final approval of the article: AAD, KM, WF, QH, RZ, ZW, LP, MM
Statistical analysis: AAD, ZW
Obtained funding: MM
Overall responsibility: MM

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Additional material for this article may be found online at www.jvascsurg.org.

APPENDIX (online only).

Search strategy

Ovid. Database(s): Embase 1988 to 2013 Week 21, Ovid MEDLINE In-Process & Other Non-Indexed Citations and Ovid MEDLINE 1946 to Present, EBM Reviews—Cochrane Central Register of Controlled Trials April 2013, EBM Reviews—Cochrane Database of Systematic Reviews 2005 to November 2016

Search strategy:

#	Searches	Results
1	exp leg revascularization/	4109
2	blood vessel shunt/	2352
3	bypass surgery/	52985
4	exp shunting/	5158
5	exp Graft Occlusion, Vascular/	13308
6	exp Vascular Surgical Procedures/	450346
7	exp Blood Vessel Prosthesis Implantation/	87059
8	surgery.fs.	1503603
9	(bypass* or graft* or "anastomosis vascularis" or "vessel anastomosis" or "vascular anastomosis" or shunt* or revascular iz* or ((vascula* or vein* or arter* or "blood vessel*") adj3 (prosthes* or reconstruct* or repair*)) or surg* or angiosurg*).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	3909148
10	or/2-9	4653942
11	exp leg/	161355
12	exp Lower Extremity/	232645
13	exp Femoral Vein/	13773
14	(leg or legs or "lower extremit*" or femoral or infrainguinal or femoropopliteal*).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	513359
15	or/11-14	622466
16	exp Ultrasonography, Doppler, Duplex/	48701
17	ultrasonography/ or exp ultrasonography, doppler/	325262
18	ultrasonography.fs.	186692
19	(17 or 18) and (duplex or color).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	45000
20	(duplex and (ultrasound or ultrasonograph* or sonograph* or echograph* or sonogram* or ultrasonic* or echosound or doptone or echogram* or echoscop*)).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	26460
21	(color adj2 (ultrasound or ultrasonograph* or sonograph* or echograph* or sonogram* or ultrasonic* or echosound or doptone or echogram* or echoscop*)).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	37972
22	from 16 keep 1-28352	28352
23	16 not 22	20349
24	19 or 20 or 21 or 23	70690
25	24 and (surveillance or monitor*).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	5766
26	(1 and 25) or (10 and 15 and 25)	775
27	exp controlled study/	4123254
28	exp randomized controlled trial/	678724
29	((control$ or randomized) adj2 (study or studies or trial or trials)).mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	5280385
30	meta analysis/	111722
31	meta-analys$.mp.	181526
32	exp "systematic review"/	60494
33	(systematic* adj review$).mp.	141214
34	exp Cohort Studies/	1508140
35	exp longitudinal study/	970784

Continued.

#	Searches	Results
36	exp retrospective study/	763639
37	exp prospective study/	630365
38	exp comparative study/	2391280
39	exp clinical trial/	1643560
40	exp cross-sectional study/	253753
41	crossover procedure/	36920
42	exp cross-over studies/	92474
43	multivariate analysis/	170801
44	((clinical or comparative or cohort or longitudinal or retrospective or prospective or concurrent or "cross-sectional" or crossover or "cross-over") adj (study or studies or survey or surveys or analysis or analyses or trial or trials)).mp.	6843487
45	("crossover procedure" or "cross-over procedure" or "multivariate analys*").mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	350407
46	("case study" or "case studies" or "case series").mp. [mp=ti, ab, sh, hw, tn, ot, dm, mf, dv, kw, nm, kf, ps, rs, ui, tx, ct]	189082
47	case study/	1641764
48	from 47 keep 1-17680	17680
49	or/27-46	10749372
50	48 or 49	10749372
51	26 and 50	528
52	from 26 keep 401-745	345
53	limit 52 to (clinical trial, all or clinical trial, phase i or clinical trial, phase ii or clinical trial, phase iii or clinical trial, phase iv or clinical trial or comparative study or controlled clinical trial or evaluation studies or meta analysis or multicenter study or practice guideline or randomized controlled trial or systematic reviews or validation studies) [Limit not valid in Embase,CCTR,CDSR; records were retained]	115
54	51 or 53	532
55	animals/ not humans/	4425485
56	54 not 55	529
57	limit 56 to (book or book series or editorial or erratum or letter or note or addresses or autobiography or bibliography or biography or comment or dictionary or directory or interactive tutorial or interview or lectures or legal cases or legislation or news or newspaper article or overall or patient education handout or periodical index or portraits or published erratum or video-audio media or webcasts) [Limit not valid in Embase,Ovid MEDLINE(R),Ovid MEDLINE(R) In-Process,CCTR,CDSR; records were retained]	15
58	56 not 57	514
59	from 26 keep 746-775	30
60	58 or 59	527
61	remove duplicates from 60	375

Scopus.

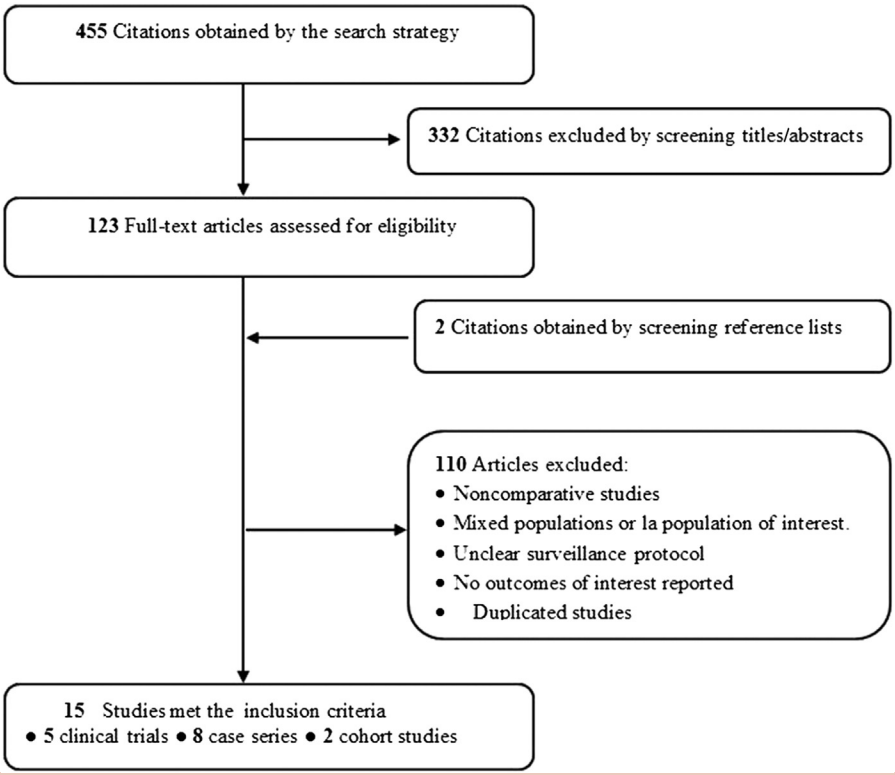
1 TITLE-ABS-KEY(bypass* or graft* or "anastomosis vascularis" or "vessel anastomosis" or "vascular anastomosis" or shunt* or revascular* or (vascula* W/3 prosthes*) or (vascula* W/3 reconstruct*) or (vascula* W/3 repair*) or (vein* W/3 prosthes*) or (vein* W/3 reconstruct*) or (vein* W/3 repair*) or (arter* W/3 prosthes*) or (arter* W/3 reconstruct*) or (arter* W/3 repair*) or ("blood vessel*" W/3 prosthes*) or ("blood vessel*" W/3 reconstruct*) or ("blood vessel*" W/3 repair*) or surg* or angiosurg*)

2 TITLE-ABS-KEY(leg or legs or "lower extremit*" or femoral or infrainguinal or femoropopliteal*)

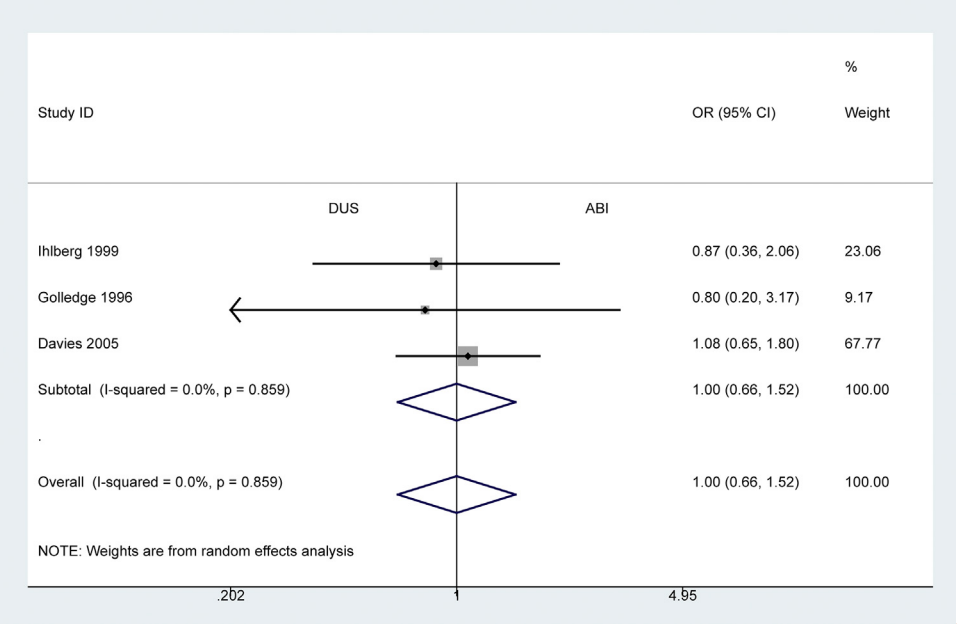
3 TITLE-ABS-KEY(duplex and (ultrasound or ultrasonograph* or sonograph* or echograph* or sonogram* or ultrasonic* or echosound or doptone or echogram* or echoscop*))

4 TITLE-ABS-KEY((color W/2 ultrasound) or (color W/2 ultrasonograph*) or (color W/2 sonograph*) or (color W/2 echograph*) or (color W/2 sonogram*) or (color W/2 ultrasonic*) or (color W/2 echosound) or (color W/2 doptone) or (color W/2 echogram*) or (color W/2 echoscop*))

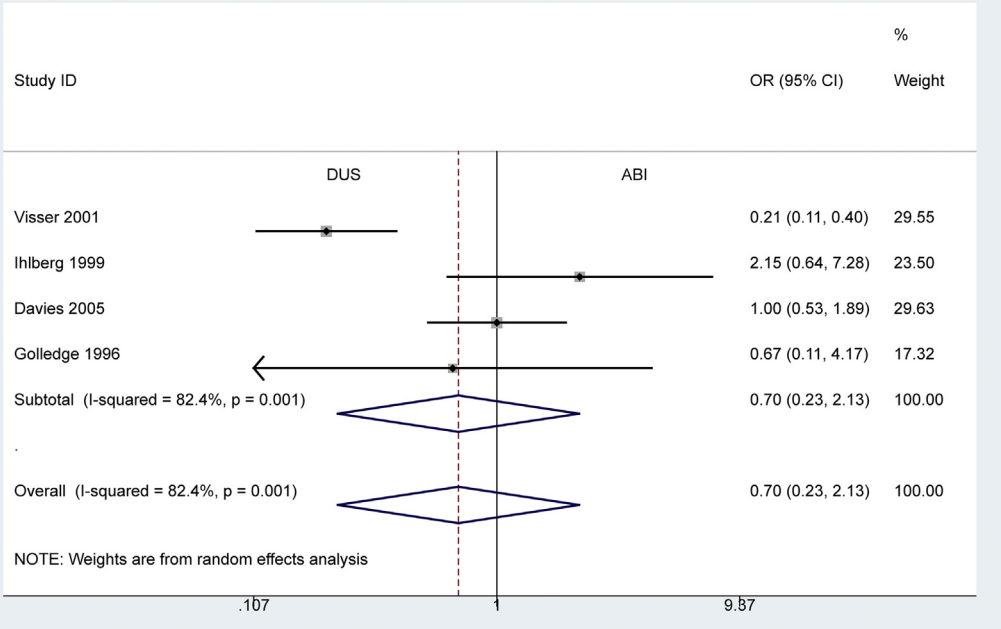
5 TITLE-ABS-KEY(surveillance or monitor*)
6 TITLE-ABS-KEY((meta W/1 analys*) OR (systematic* W/2 review*) OR (control* W/2 stud*) OR (control* W/2 trial*) OR (randomized W/2 stud*) OR (randomized W/2 trial*) or "comparative stud*" OR "comparative survey*" OR "comparative analys*" OR "cohort stud*" OR "cohort survey*" OR "cohort analys*" OR "longitudinal stud*" OR "longitudinal survey*" OR "longitudinal analys*" OR "retrospective stud*" OR "retrospective survey*" OR "retrospective analys*" or "prospective stud*" OR "prospective survey*" OR "prospective analys*" or "concurrent stud*" OR "concurrent survey*" OR "concurrent analys*" or "clinical stud*" OR "clinical trial*" or "cross-sectional stud*" or "cross-sectional analys*" or "cross-over stud*" or "cross-over analys*" or "cross-over procedure" or "crossover stud*" or "crossover analys*" or "crossover procedure" or "multivariate analys*" or "case study" or "case studies" or "case series")
7 1 and 2 and (3 or 4) and 5 and 6
8 PMID(0*) OR PMID(1*) OR PMID(2*) OR PMID(3*) OR PMID(4*) OR PMID(5*) OR PMID(6*) OR PMID(7*) OR PMID(8*) OR PMID(9*)
9 7 and not 8
10 DOCTYPE(le) OR DOCTYPE(ed) OR DOCTYPE(bk) OR DOCTYPE(er) OR DOCTYPE(no) OR DOCTYPE(sh)
11 9 and not 10



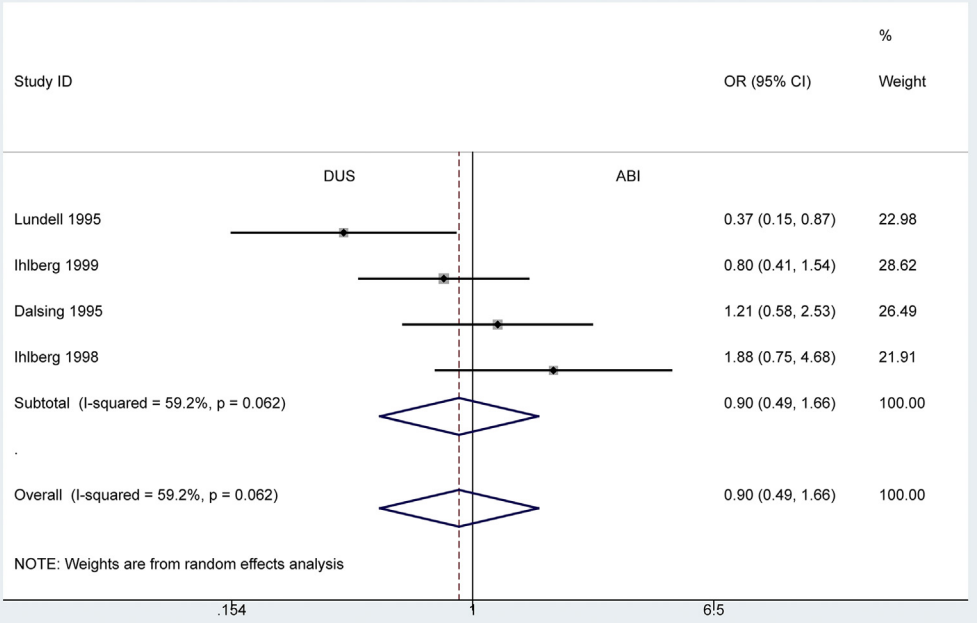
Supplementary Fig 1 (online only). Flow chart shows the literature search yield and selected studies.



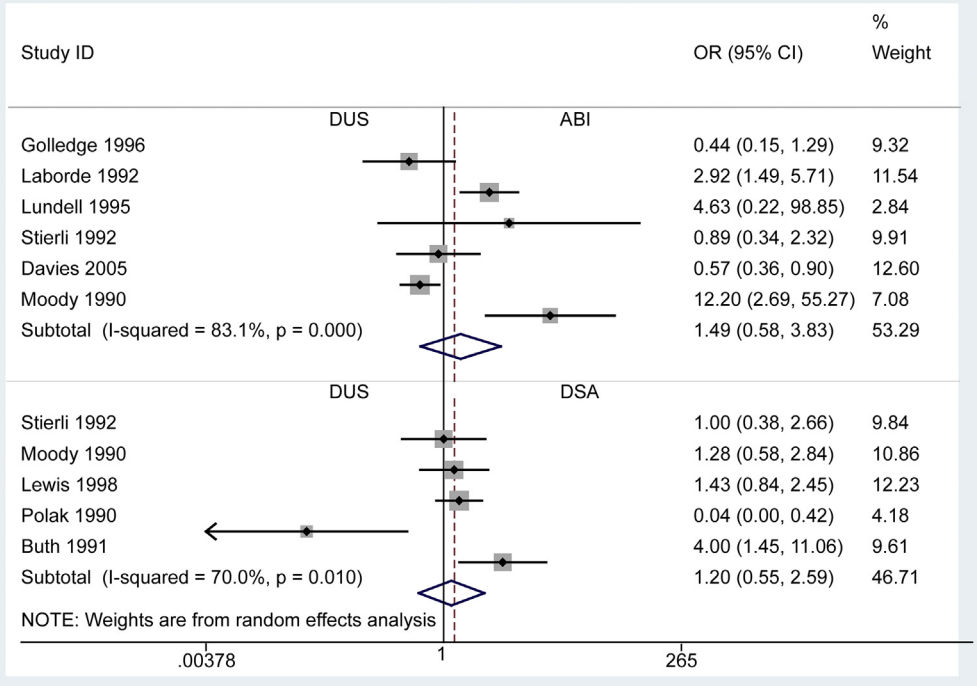
Supplementary Fig 2 (online only). Meta-analysis of all-cause mortality comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.



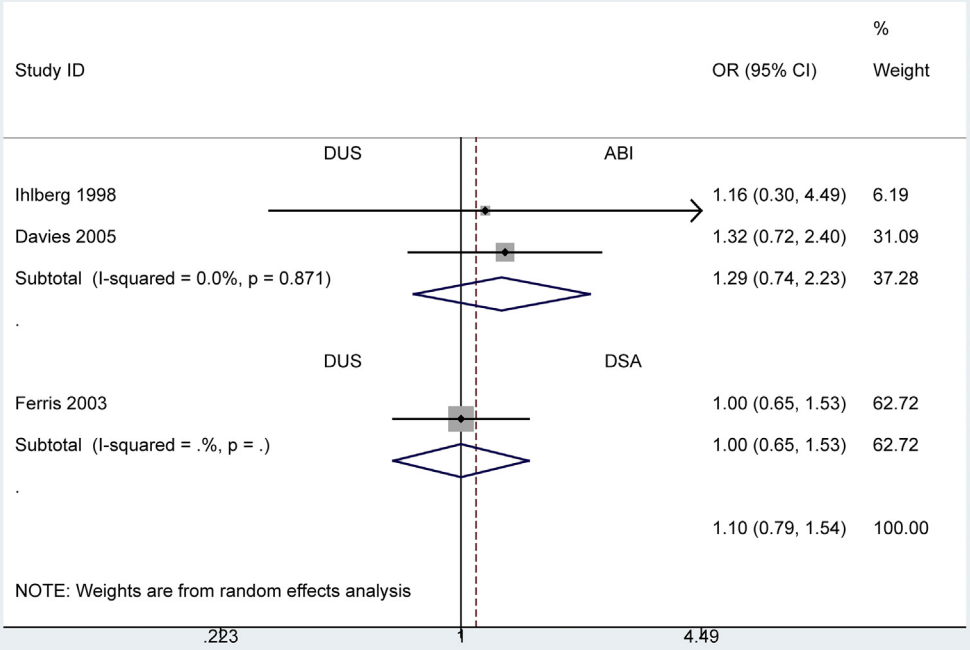
Supplementary Fig 3 (online only). Meta-analysis of amputation comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.



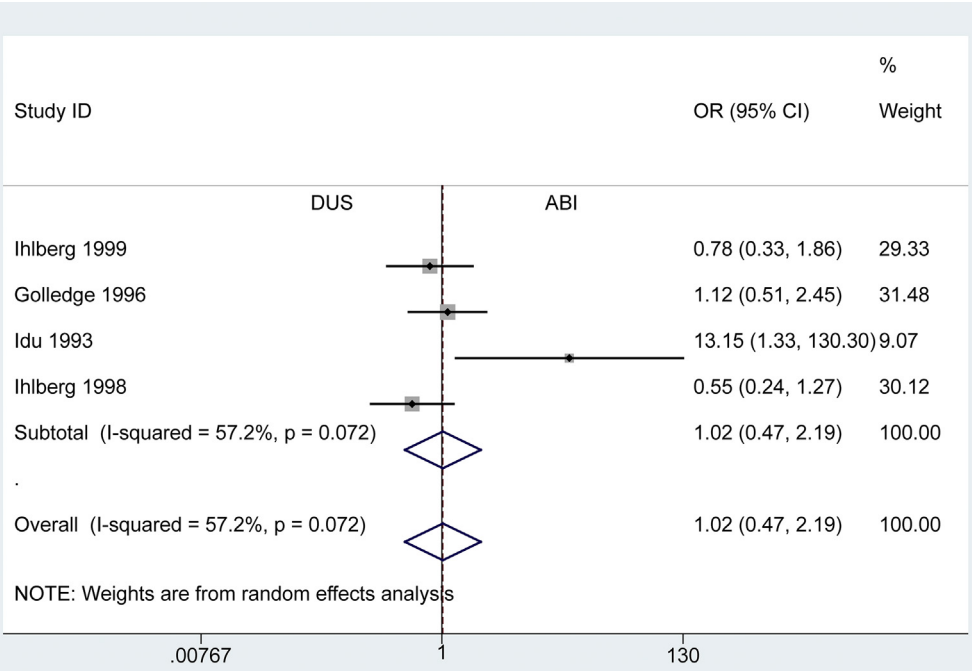
Supplementary Fig 4 (online only). Meta-analysis of postoperative graft occlusion comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.



Supplementary Fig 5 (online only). Meta-analysis of postoperative graft stenosis comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*) or digital subtraction angiography (*DSA*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.



Supplementary Fig 6 (online only). Meta-analysis of revised veins comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*) or digital subtraction angiography (*DSA*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.



Supplementary Fig 7 (online only). Meta-analysis of leg salvage comparing duplex ultrasound (*DUS*) surveillance vs surveillance with ankle-brachial index (*ABI*). *CI,* Confidence interval; *ID,* identifier; *OR,* odds ratio.

Supplementary Table I (online only). The baseline characteristics of participants of included studies

Study ID	Vein graft, No.	Follow-up, months	Age, years, mean	Indication for surgery	Surveillance time protocol	Type of vein used in graft (No.)
Buth,[16] 1991	155	36	—	• CLI (76 patients) • IC (39 patients) • Aneurysmal disease (1 patient)	First year: every 3 months Second year: every 6 months	In situ (78)
Dalsing,[17] 1995	112	17.6	—	—	First year: every 3 months Second year: every 6 months	In situ (74) Reversed (20) Nonreversed (2)
Davies,[5] 2005	—	18	70	• IC (182 patients) • CLI (392 patients)	At 1 day, 5 days, then 3, 6, 9, 12, and 18 months	In situ (555)
Ferris,[19] 2003	224	24	86.5	• Ischemic tissue loss (47%) • Ischemic rest pain (32%) • Disabling claudication (18%) • Popliteal aneurysm (3%)	First year: every 3 months Second and third years: every 6 months Fourth-end years: once annually	In situ (175)
Golledge,[20] 1996	50	12	70	–	1.5, 3, 6, 9, and 12 months	In situ (4) Reversed (46)
Idu,[21] 1993	201	21	—	• Limb threatening (68.44%) • Tissue necrosis (28.3%) • Rest pain (40.1%)	First year: every 3 months Second year: every 6 months	In situ (40) Reversed (79)
Ihlberg,[22] 1999	362	12	73	• IC (19%) • Rest pain (28.5%) • Ischemic ulcer (38.7%) • Gangrene (14.2%) • Popliteal aneurysm (1.3%)	First year: every 3 months	In situ (110)
Ihlberg,[23] 1998	185	12	73	• CLI (128 patients)	First year: every 3 months	In situ (118) Ex situ (34)
Laborde,[24] 1992	124	16	–	• IC (96%)	First year: every 3 months Second year: every 6 months	In situ (124)
Lewis,[25] 1998	148	1.5	69	—	—	In situ (103) Reversed (40)
Lundell,[6] 1995	106	36	75	• IC (2%) • Rest pain (39.2%) • Ischemic ulcer (34.1%) • Gangrene (19.4%) • Popliteal aneurysm (3%)	First and second years: every 3 months Third year: once annually	In situ (88) Reversed (15)
Moody,[26] 1990	63	11.2	—	—	First year: every 3 months	—
Polak,[27] 1990	15	2	—	—	—	In situ (13) Reversed (1)
Stierli,[28] 1992	43	15	72	—	—	In situ (25) Reversed (4) Nonreversed (14)
Visser,[29] 2001	293	12	70.1	• CLI (37.2%) • Rest pain (36.2%) • IC (26.6%)	First year: every 3 months	—

CLI, Critical limb ischemia; *IC*, intermittent claudication; *ID*, identifier.

Supplementary Table II, A (online only). Quality assessment of the included randomized or quasi-randomized studies

Study ID	Random sequence generation	Allocation concealment	Blinding of participants, personnel, and outcome assessor	Attrition bias	Selective outcome reporting
Davies, 2005	Yes	Yes	Not reported	Low risk	No
Ihlberg, 1999	According to date of birth	Not reported	Not applicable	High risk	No
Ihlberg, 1998	According to date of birth	Not reported	Not reported	Low risk	No
Lundell, 1995	Not reported	Not reported	Not applicable	Low risk	No
Lewis, 1998[a]	No randomized	No	No	Not reported	No

ID, Identifier.
[a]Open or quasi-randomized studies.

Supplementary Table II, B (online only). Quality assessment of the included case series studies

Study ID	Case series collected in more than one center	The objective of the study clearly described	The inclusion and exclusion criteria clearly reported	The data collected prospectively	Patients recruited consecutively	The main findings of the study clearly described	Stratified outcomes
Dalsing, 1995	No	Yes	No	No	No	Yes	No
Ferris, 2003	No	Yes	No	Yes	No	Yes	Yes
Golledge, 1996	No	Yes	No	No	—	Yes	Yes
Laborde, 1992	No	Yes	No	Yes	Yes	Yes	Yes
Moody, 1990[a]	No	Yes	No	Yes (one group)	No	Yes	No
Polak, 1990	No	Yes	No	Yes	No	Yes	Yes
Stierli, 1992	No	Yes	No	Yes	No	Yes	No
Visser, 2001	Yes	Yes	Yes	Yes	No	Yes	No

ID, Identifier.
[a]Case series with historical controls.

Supplementary Table II, C (online only). Quality assessment of the included cohort and case-control studies

Study ID	Representativeness of the exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Outcome of interest was not present at the start of the study	Comparability of cohorts	Assessment of outcome
Golledge, 1996	Truly representative	Drawn from the same community	Secure records	Yes	Study controls for most important factor	Clinical assessment, record linkage
Idu, 1993	Truly representative	Drawn from the same community	Secure records	Yes	Study controls for most important factor	Clinical assessment, record linkage

ID, Identifier.