

## Ultrasonic locating devices for central venous cannulation: meta-analysis

Daniel Hind, Neill Calvert, Richard McWilliams, Andrew Davidson, Suzy Paisley, Catherine Beverley, Steven Thomas

### Abstract

**Objectives** To assess the evidence for the clinical effectiveness of ultrasound guided central venous cannulation.

**Data sources** 15 electronic bibliographic databases, covering biomedical, science, social science, health economics, and grey literature.

**Design** Systematic review and meta-analysis of randomised controlled trials.

**Populations** Patients scheduled for central venous access.

**Intervention reviewed** Guidance using real time two dimensional ultrasonography or Doppler needles and probes compared with the anatomical landmark method of cannulation.

**Data extraction** Risk of failed catheter placement (primary outcome), risk of complications from placement, risk of failure on first attempt at placement, number of attempts to successful catheterisation, and time (seconds) to successful catheterisation.

**Data synthesis** 18 trials (1646 participants) were identified. Compared with the landmark method, real time two dimensional ultrasound guidance for cannulating the internal jugular vein in adults was associated with a significantly lower failure rate both overall (relative risk 0.14, 95% confidence interval 0.06 to 0.33) and on the first attempt (0.59, 0.39 to 0.88). Limited evidence favoured two dimensional ultrasound guidance for subclavian vein and femoral vein procedures in adults (0.14, 0.04 to 0.57 and 0.29, 0.07 to 1.21, respectively). Three studies in infants confirmed a higher success rate with two dimensional ultrasonography for internal jugular procedures (0.15, 0.03 to 0.64). Doppler guided cannulation of the internal jugular vein in adults was more successful than the landmark method (0.39, 0.17 to 0.92), but the landmark method was more successful for subclavian vein procedures (1.48, 1.03 to 2.14). No significant difference was found between these techniques for cannulation of the internal jugular vein in infants. An indirect comparison of relative risks suggested that two dimensional ultrasonography would be more successful than Doppler guidance for subclavian vein procedures in adults (0.09, 0.02 to 0.38).

**Conclusions** Evidence supports the use of two dimensional ultrasonography for central venous cannulation.

### Introduction

Around 200 000 procedures for central venous access are performed in the NHS each year.<sup>1</sup> Catheters are inserted for several reasons, including haemodynamic monitoring, delivery of blood products and drugs (for example, chemotherapy and antibiotics), haemodialysis, total parenteral nutrition, and management of perioperative fluids. These procedures are performed in a wide range of locations within the hospital and at various insertion sites on the body by medical and, increasingly, nursing staff.

Central venous access is commonly attempted at the internal jugular vein, subclavian vein, femoral vein, or arm veins, using peripherally inserted central catheters. Safe puncture of a central vein (venepuncture) is traditionally achieved by passing the needle along the anticipated line of the vein using anatomical landmarks on the skin's surface (the landmark method). Surgical cut-down is a more invasive and alternative method for gaining central venous access, although it is now less commonly used.

Central venous cannulation can be unsafe: the National Confidential Enquiry into Perioperative Deaths has reported one death resulting from a procedure induced pneumothorax.<sup>2</sup> Less serious, but still costly for patient discomfort, clinician time, and NHS resources are the varying rates for failure and complications from central venous cannulation. Anomalies in anatomy may cause the operator to pass the needle in an inappropriate direction. The landmark method fails, irrespective of anatomy, if the vein has thrombosed. Each pass of a needle carries the risk of complications, so a successful first attempt is ideal.

The rates, risks, and consequences of complications arising from central venous cannulation vary across patient groups. Infants, obese patients, and those with short necks are more difficult to access. Patients with clotting problems, ventilated patients, and those undergoing emergency pacing procedures may have more serious consequences from a complication associated with venepuncture.<sup>2</sup> Repeated catheterisation (as in patients requiring chemotherapy or haemodialysis)

School of Health and Related Research (ScHARR), Regent Court, Sheffield S1 4DA

Daniel Hind  
*research associate*

Suzy Paisley  
*managing director, ScHARR Rapid Reviews Group*  
Catherine Beverley  
*information officer*

Fourth Hurdle Consulting, London WC1R 4QA  
Neill Calvert  
*consultant*

Royal Liverpool University Hospital, Liverpool L7 8XP

Richard McWilliams  
*consultant radiologist*

Sheffield Teaching Hospitals NHS Trust, Royal Hallamshire Hospital, Sheffield S10 2JF

Andrew Davidson  
*consultant anaesthetist*

Department of Academic Radiology, University of Sheffield, Northern General Hospital, Sheffield S5 7AU  
Steven Thomas  
*senior lecturer*

Correspondence to: D Hind  
d.hind@shef.ac.uk

bmj.com 2003;327:361



Additional references appear on bmj.com

sis) is a significant risk factor for the formation of thrombus.<sup>3</sup>

Medical ultrasound devices may be used to locate a vein in two ways. Real time ultrasonography generates a two dimensional grey scale image of the vein and surrounding tissues. Continuous wave Doppler ultrasonography generates an audible sound from flowing venous blood, with no information on depth of the vessel. We systematically reviewed randomised controlled trials for evidence of the effectiveness of two dimensional ultrasound guidance and Doppler ultrasound guidance in patients undergoing central venous catheterisation.

## Methods

Our study was commissioned by the National Institute for Clinical Excellence as part of the technology appraisal process. This institute is part of the UK NHS and its role is to provide patients, health professionals, and the public with authoritative, robust, and reliable guidance on current best practice. A monograph published in the Health Technology Assessment series provides further details on methods.<sup>4</sup>

We searched 15 electronic bibliographic databases from inception to October 2001. The bibliographies of relevant articles and submissions for sponsorship to the National Institute for Clinical Excellence were hand searched. Health services research resources were consulted through the internet. The search combined free text and thesaurus terms relating to central venous lines and ultrasonography. In smaller databases, searches were not restricted by publication type or study design. Filters used in Medline were aimed at identifying guidelines, systematic reviews, clinical trials, economic evaluations, and quality of life studies. Date and language restrictions were not applied. The full search strategy is available elsewhere.<sup>4</sup>

## Selection and validity

Inclusion criteria were: clinical effectiveness of two dimensional ultrasound guidance or Doppler ultrasound guidance for the placement of central venous lines; comparison of ultrasonography with the landmark method or the surgical cut-down procedure; inclusion of one or more of several outcomes—number of failed catheter placements, number of complications from catheter placement, risk of failure at first attempt, number of attempts to successful catheterisation, and time (seconds) to successful catheterisation. Only English language papers were selected, this being a rapid review to support decision making.

The abstracts of relevant citations were reviewed for potential randomised controlled trials. Trials were included unless the generation of allocation sequence was inadequate.<sup>5</sup>

Study quality was assessed by a component approach.<sup>6</sup> When reported, allocation concealment and the method of generation of the allocation sequence were recorded, to assess the potential for selection bias. To assess the potential for attrition bias, we recorded whether an intention to treat analysis was performed.

## Data

### Abstraction

Data abstraction was based on reported summary statistics for the intention to treat population. Two coworkers extracted data independently, and discrepancies were resolved by consensus. The numbers of catheters and patients were abstracted as reported, as were data on mechanical complications. The numbers of patients with complications were pooled for meta-analysis. The numbers of catheter placements, rather than the numbers of patients, were pooled for analysis. Data for adults and children were pooled separately, as were alternative insertion sites.

### Analysis

Treatment effect sizes and 95% confidence intervals were calculated for each randomised comparison for each outcome. Relative risks were calculated for dichotomous outcomes, and weighted mean differences were calculated for continuous outcomes. Statistical heterogeneity was analysed to assess whether the observed variance in effect size between studies was greater than that expected by chance.

## Results

We identified 27 trials. None reported allocation concealment. Three were excluded because the method of allocation was unclear and the trials were not described as randomised, and two were excluded because they had inadequate methods for generation of allocation sequence. Two prospective trials were rejected because vessels were located by Doppler ultrasound guidance followed by blind venepuncture. Two trials were rejected because they were reported in abstract form only. We therefore included 18 studies in our review (fig 1).

Table 1 lists participants' characteristics, interventions, operator experience, outcome measures, and quality of components for each trial. The trials

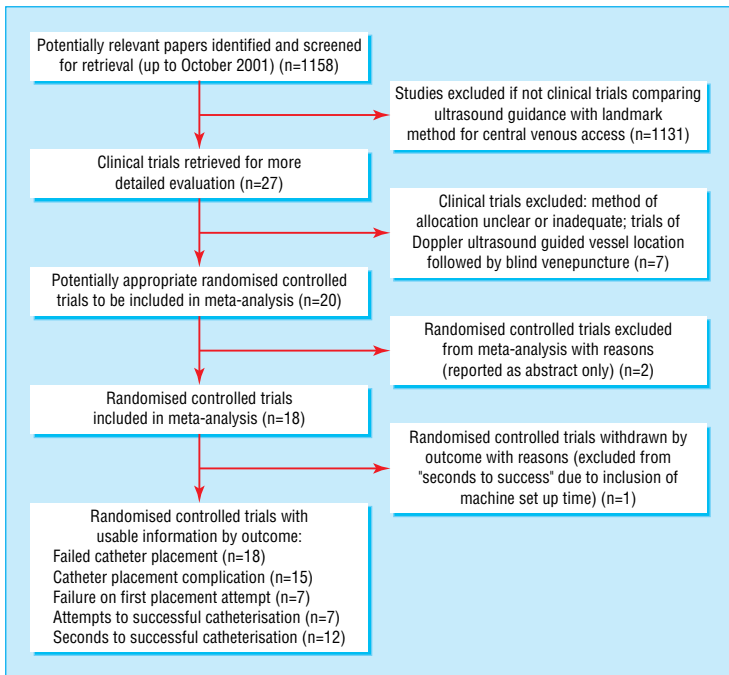


Fig 1 Study flow chart

**Table 1** Participants, interventions, outcomes, and quality components of 18 randomised controlled trials of ultrasound guidance for central venous catheterisation

Study	Setting	Participants	Comparison (entry site)	Outcomes measured	Operator experience	Randomisation method	Exclusions after randomisation
Alderson et al 1993 <sup>w1</sup>	Canadian urban children's hospital	Infants (<2 years) undergoing cardiac surgery; disease and risk not reported	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications	Experienced cardiac anaesthetist	Not reported	None
Bold et al 1998 <sup>w2</sup>	US tertiary care, outpatient oncology centre	Adult chemotherapy patients (cancer types not reported); high risk for failure or complications	Doppler ultrasound guidance v landmark method (subclavian vein)	Number of failed catheter placements	18 surgical oncology fellows (postgraduate year 6-10). Instruction in use of smart needle and "demonstrated competence" in use of Doppler probe	Computer generated block randomisation	None
Branger et al 1994 <sup>w3</sup>	French teaching hospital	Patients needing central venous catheterisation for haemodialysis, apheresis, or parenteral nutrition (disease not reported), low risk of complications (high risk patients excluded)	Doppler ultrasound guidance v landmark method (internal jugular vein and subclavian vein)	Number of failed catheter placements, number of attempts to successful catheterisation, time to successful catheterisation	14 junior postgraduate students with fewer than 5 years' clinical experience, and 8 senior staff with more than 5 years' experience, from nephrology, emergency, and intensive care. Taught the Doppler technique over two weeks, achieved at least one venous catheterisation before entering study	Random tables	None
Gilbert et al 1995 <sup>w4</sup>	US tertiary care, teaching hospital	Adult patients (disease not reported) at high risk from complications (obesity or coagulopathy)	Doppler ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, failure on first attempt, time to successful catheterisation	Number not reported. Junior housestaff "relatively inexperienced in using either technique"	Not reported	None
Gratz et al 1994 <sup>w5</sup>	US tertiary care, teaching hospital	Patients for cardiothoracic or vascular surgery (age and disease not reported)	Doppler ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, failure on first attempt, number of attempts to successful catheterisation, time to successful catheterisation	Number not reported; "experienced anesthesiologists"	Not reported	1 of 41
Gualtieri et al 1995 <sup>w6</sup>	US urban teaching hospital	Critical care patients undergoing non-emergency procedures (age, disease, and risk not reported)	Two dimensional ultrasound guidance v landmark method (subclavian vein)	Number of failed catheter placements; number of complications	18 physicians with <30 procedures	Random number	1 of 53
Hilty et al 1997 <sup>w7</sup>	US urban teaching hospital	Patients undergoing cardiopulmonary resuscitation (age, disease, and risk not reported)	Two dimensional ultrasound guidance v landmark method (femoral vein)	Number of failed catheter placements, failure on first attempt, number of attempts to successful catheterisation, time to successful catheterisation	2 emergency medicine residents in postgraduate years 3 and 4. 15-20 procedures using landmark method; 6-10 procedures using ultrasonography	Computer generated randomisation chart	None
Lefrant et al 1998 <sup>w8</sup>	French teaching hospital	Critically ill adults undergoing non-emergency procedures (disease and risk not reported)	Doppler ultrasound guidance v landmark method (subclavian vein)	Number of failed catheter placements, number of complications, failure on first attempt	1 staff anaesthesiologist, untrained in Doppler guidance before study	Random number	None
Mallory et al 1990 <sup>w9</sup>	US tertiary care, teaching hospital	Critically ill adult patients in intensive care; high and low risk (disease not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, failure on first attempt	Senior intensive care unit staff and critical care fellows. Mean not reported. Mean 6 years' experience	Not reported	None
Nadig et al 1998 <sup>w10</sup>	German teaching hospital	Dialysis patients (age, disease, and risk level not reported)	Two dimensional ultrasound guidance v two dimensional ultrasound guidance for vessel location followed by blind venepuncture (internal jugular vein)	Number of failed catheter placements, number of complications, failure on first attempt, time to successful catheterisation	Physicians; clinical experience 1-7 years	By lot	None
Slama et al 1997 <sup>w11</sup>	French university hospital	Adults in intensive care requiring cannulation of internal jugular vein (disease and risk assessment not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, failure on first attempt; time to successful catheterisation	Junior house staff (interns or residents) under the direct supervision of senior physician after at least three demonstrations by experienced operator and three attempts of right internal jugular vein using landmark method	Not reported	None

Continued on next page

**Table 1** Participants, interventions, outcomes, and quality components of 18 randomised controlled trials of ultrasound guidance for central venous catheterisation—*continued from previous page*

Study	Setting	Participants	Comparison (entry site)	Outcomes measured	Operator experience	Randomisation method	Exclusions after randomisation
Soyer et al 1993 <sup>w12</sup>	French hospital	Adult patients with liver dysfunction requiring transjugular liver biopsy (risk assessment not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, number of attempts to successful catheterisation, time to successful catheterisation	2 radiologists with same experience (not quantified)	Not reported	None
Sulek et al 2000 <sup>w13</sup>	US university affiliated hospital; operating room	Adult patients scheduled for elective abdominal, vascular, or cardiothoracic procedures with general anaesthesia and mechanical ventilation in whom central venous cannulation was clinically indicated (disease and risk assessment not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, number of attempts to successful catheterisation, time to successful catheterisation	Anaesthetist. All operators experienced in cannulation of internal jugular vein (at least 60 catheter placements) with known expertise in use of ultrasound guided internal jugular vein technique	Computer generated randomisation table	None
Teichgräber et al 1997 <sup>w14</sup>	German university teaching hospital	Patients undergoing routine catheterisation of internal jugular vein (age, disease, and risk-assessment not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications	Physicians. Number and experience not reported	Not reported	None
Troianos et al 1991 <sup>w15</sup>	US tertiary care, teaching hospital	Cardiothoracic surgical patients (age, disease, and risk factor not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, failure on first attempt, number of attempts to successful catheterisation, time to successful catheterisation	Not reported	Not reported	None
Verghese et al 1999 <sup>w16</sup>	US university teaching hospital	Infants scheduled for cardiovascular surgery, <12 months, weight <10 kg (disease and risk assessment not reported)	Two dimensional ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, number of attempts to successful catheterisation, time to successful catheterisation	Number not reported. Board eligible anaesthesia fellows who had completed residency training in anaesthesia	Computer generated randomisation table	None
Verghese et al 2000 <sup>w17</sup>	US university teaching hospital	45 infants scheduled to undergo internal jugular cannulation during cardiac surgery (disease and risk assessment not reported)	Two dimensional ultrasound guidance v Doppler ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, time to successful catheterisation	Number not reported. Fellows in paediatric anaesthesia	Computer generated randomisation table	None
Vucevic et al 1994 <sup>w18</sup>	British hospital	Cardiac surgery and intensive care unit patients (age, disease, and risk-assessment not reported)	Doppler ultrasound guidance v landmark method (internal jugular vein)	Number of failed catheter placements, number of complications, time to successful catheterisation	2 consultant anaesthetists; 10 procedures	Not reported	None

included a total of 1646 people scheduled for central venous catheterisation. Ten studies investigated two dimensional ultrasound guidance compared with the landmark method and six investigated Doppler ultrasound guidance compared with the landmark method. One trial investigated two dimensional ultrasound guidance compared with blind venepuncture preceded by ultrasound guidance. One trial, with three arms, investigated two dimensional ultrasound guidance compared with Doppler ultrasound guidance and the landmark method. No studies compared two dimensional ultrasound guidance as a single procedure against surgical cut-down. Nine trials described adequate methods for generation of allocation sequence within the randomisation process. Two trials did not indicate an intention to treat analysis.

#### Quantitative data synthesis

Table 2 summarises the pooled results from the meta-analyses comparing two dimensional ultrasonography with the landmark method for both adults and infants in all five outcomes. Figure 2 shows graphical data for

the primary outcome. Two dimensional ultrasound guidance was more effective for all five outcomes for internal jugular vein procedures in adults (relative risk reductions: 86% for failed catheter placements, 57% for complications with catheter placement, and 41% for failure on first attempt; all  $P < 0.05$ ). Fewer attempts were required to successfully cannulate patients and significantly less time was needed. Limited evidence suggested two dimensional ultrasound guidance reduced the relative risk of failed catheter placements by 86% in the subclavian vein and 71% in the femoral vein. Three studies of this comparison for procedures on internal jugular veins in infants had relatively small sample sizes but suggested that ultrasonography was significantly more effective (relative risk reductions: 85% for failed catheter placements and 73% for complications with catheter placement).

Table 3 summarises the results of the meta-analyses comparing Doppler ultrasound guidance with the landmark method. For internal jugular vein procedures, Doppler ultrasound guidance significantly improved the chance of successful cannulation overall

and on the first attempt. However, for cannulation of the subclavian vein, results significantly favoured the landmark method for relative risk of failed catheter placements and the mean number of seconds to successful catheterisation. Only one study of this comparison in infants was found (for internal jugular vein procedures), and this was too small to achieve statistical significance. No studies of this comparison in femoral vein procedures were identified for adults or infants.

In the absence of studies comparing two dimensional ultrasonography with Doppler ultrasonography in adults, we made an indirect comparison of the two estimated relative risks (table 4).<sup>7</sup> The ratio of relative risks for the primary outcome, failed catheter placements, was 0.36 (0.11 to 1.19) in favour of two dimensional ultrasonography for internal jugular vein procedures and 0.09 (0.02 to 0.38) for subclavian vein procedures.

## Discussion

Our systematic review shows a clear benefit from two dimensional ultrasound guidance for central venous access compared with the landmark method. This is manifest in a lower technical failure rate (overall and on first attempt), a reduction in complications, and faster access. One explanation for these benefits is that ultrasonography clarifies the relative position of the needle, the vein, and its surrounding structures. The image offered by two dimensional ultrasonography allows the user to predict variant anatomy and to assess the patency of a target vein. The clinical effect of using ultrasound guidance was more significant when the

internal jugular vein rather than the subclavian or femoral veins was cannulated, for which evidence was sparse. These results are similar to a previously published meta-analysis: however, that study inappropriately pooled the results from trials of both Doppler ultrasound guidance and two dimensional ultrasound guidance.<sup>8</sup> The evidence presented here favours the use of two dimensional ultrasound guidance for cannulation of the subclavian vein, with Doppler ultrasound guidance less successful and more time consuming than even the landmark method. It also proved more successful than Doppler ultrasound guidance or the landmark method when the internal jugular vein of infants was cannulated, the image aiding the navigation of diminutive anatomy; although this evidence came from only one study.

Ultrasound guidance is therefore likely to have benefits to patients with a reduction in the risks of the procedure, and they are less likely to undergo a prolonged, sometimes uncomfortable and possibly fruitless attempt at central venous cannulation. Potential benefits to NHS trusts are improvements in efficiency and reductions in costs of dealing with complications. To be weighed against this are the implications of advocating ultrasound guidance for central venous cannulation, such as a potential for deskilling in the landmark method that may be required in some emergency situations. Guidance from the National Institute for Clinical Excellence in this area states that it is important that “operators maintain their ability to use the landmark method and that the method continues to be taught alongside the 2-D ultrasound guided technique.”<sup>9</sup> Financial and logistical

**Table 2** Summary of significance of outcome measures for two dimensional (2-D) ultrasound guidance compared with landmark method for catheterisation

Variable	Internal jugular vein				Subclavian vein				Femoral vein			
	No of placements		Effect size (95% CI)	P value	No of placements		Effect size (95% CI)	P value	No of placements		Effect size (95% CI)	P value
	2-D ultrasound guidance	Landmark method			2-D ultrasound guidance	Landmark method			Doppler ultrasound guidance	Landmark method		
Adults												
Relative risk:												
Failed catheter placement	296	312	0.14 (0.06 to 0.33)	<0.0001	25	27	0.14 (0.04 to 0.57)	0.006	20	20	0.29 (0.07 to 1.21)	0.09
Complication with placement	284	295	0.43 (0.22 to 0.87)	0.02	25	27	0.10 (0.01 to 0.71)	0.02	—	—	NA	NA
Failure on first attempt	162	179	0.59 (0.39 to 0.88)	0.009	—	—	NA	NA	—	—	NA	NA
Mean No:												
Attempts to successful catheterisation	131	136	−1.50 (−2.53 to −0.47)	0.004	—	—	NA	NA	20	20	−2.70 (−5.26 to −0.14)	0.04
Seconds to successful catheterisation	180	192	−69.33 (−92.36 to −46.31)	<0.0001	—	—	NA	NA	20	20	−3.20 (−43.27 to 36.87)	0.9
Infants												
Relative risk:												
Failed placement	79	88	0.15 (0.03 to 0.64)	0.01	—	—	NA	NA	—	—	NA	NA
Complication with placement	79	88	0.27 (0.08 to 0.91)	0.03	—	—	NA	NA	—	—	NA	NA
Failure on first attempt	—	—	NA	NA	—	—	NA	NA	—	—	NA	NA
Mean No:												
Attempts to successful catheterisation	43	52	−2.00 (−2.78 to −1.22)	<0.0001	—	—	NA	NA	—	—	NA	NA
Seconds to successful catheterisation	59	68	−349.38 (−801.89 to 103.13)	0.13	—	—	NA	NA	—	—	NA	NA

NA=not available. All outcomes favoured ultrasound guidance (relative risk <1).



**Table 3** Summary of significance of outcome measures for Doppler ultrasound guidance compared with landmark method for catheterisation

Variable	Internal jugular vein				Subclavian vein				Femoral vein			
	No of placements		Effect size (95% CI)	P value	No of placements		Effect size (95% CI)	P value	No of placements		Effect size (95% CI)	P value
	Doppler ultrasound guidance	Landmark method			Doppler ultrasound guidance	Landmark method			Doppler ultrasound guidance	Landmark method		
Adults												
Relative risk:												
Failed catheter placement	86	99	0.39 (0.17 to 0.92)	0.03	310	314	1.48 (1.03 to 2.14)*	0.03*	—	—	NA	NA
Complication with placement	89	89	0.43 (0.17 to 1.05)	0.06	262	264	0.57 (0.11 to 2.88)	0.5	—	—	NA	NA
Failure on first attempt	52	64	0.57 (0.37 to 0.88)	0.01	143	143	1.04 (0.76 to 1.43)*	0.8*	—	—	NA	NA
Mean No:												
Attempts to successful catheterisation	34	35	−0.59 (−1.82 to 0.65)	0.4	48	50	−0.4 (−0.61 to −0.19)	0.0002	—	—	NA	NA
Seconds to successful catheterisation	86	99	34.86 (−54.49 to 124.21)*	0.4*	48	50	209.00 (175.48 to 242.52)*	<0.0001*	—	—	NA	NA
Infants												
No of failed catheter placements	13	16	1.23 (0.30 to 5.11)*	0.8*	—	—	NA	NA	—	—	NA	NA
No of complications from placement	13	16	0.82 (0.16 to 4.20)	0.8	—	—	NA	NA	—	—	NA	NA
Risk of failure on first attempt	—	—	NA	NA	—	—	NA	NA	—	—	NA	NA
Mean No of attempts to successful catheterisation	—	—	NA	NA	—	—	NA	NA	—	—	NA	NA
Mean No of seconds to successful catheterisation	13	16	138.00 (−114.72 to 390.72)*	0.3*	—	—	NA	NA	—	—	NA	NA

NA=not available. Relative risks &lt;1 favour Doppler ultrasound guidance.

\*Outcome favours landmark method.

implications for the NHS are provision of sufficient ultrasound machines and staff training.

Economic modelling, undertaken for the Health Technology Assessment programme, indicated that using ultrasound guidance for venepuncture in central venous access was likely to save £2000 (\$3249; €2840) of NHS resources for every 1000 procedures.<sup>4</sup> The model incorporated the inevitable costs of purchasing machines and training staff. The net resource saving was

attributable to savings from the need to treat fewer complications and notional savings from less time spent by clinicians and nurses achieving successful cannulation and dealing with complications, with all the implications for reduced use of expensive time in theatres and intensive care units. Although wider use of two dimensional ultrasound guidance for central venous access is unlikely to achieve hard cash savings for the NHS, the opportunity cost savings are genuine and relevant.

**Table 4** Summary of ratio of relative risks for two dimensional ultrasound guidance indirectly compared with Doppler ultrasound guidance

Variable	Internal jugular vein		Subclavian vein		Femoral vein	
	Effect size (95% CI)	P value	Effect size (95% CI)	P value	Effect size (95% CI)	P value
<b>Adults</b>						
Relative risk:						
Failed catheter placement	0.36 (0.11 to 1.19)	0.09	0.09 (0.02 to 0.38)	0.0008	NA	NA
Complication with placement	1.00 (0.32 to 3.13)	1.00	0.18 (0.01 to 2.57)	0.2	NA	NA
Failure on first attempt	1.04 (0.57 to 1.88)	0.9	NA	NA	NA	NA
Mean No:						
Attempts to successful catheterisation	−0.91 (−2.52 to 0.70)	0.3	NA	NA	NA	NA
Seconds to successful catheterisation	−104 (−196 to −12)	0.03	NA	NA	NA	NA
<b>Infants</b>						
Relative risk:						
Failed catheter placement	0.12 (0.02 to 0.98)	0.048	NA	NA	NA	NA
Complication from placement	0.33 (0.04 to 2.52)	0.3	NA	NA	NA	NA
Failure on first attempt	NA	NA	NA	NA	NA	NA
Mean (No):						
Attempts to successful catheterisation	NA	NA	NA	NA	NA	NA
Seconds to successful catheterisation	−487.38 (−1006.00 to 31.00)	0.06	NA	NA	NA	NA

NA=not available. All outcomes favoured two dimensional ultrasound guidance (relative risk &lt;1).

## What is already known on this topic

Hundreds of thousands of central venous lines are placed in patients every year in NHS hospitals

Complication and failure rates vary, and deaths have been reported

## What this study adds

Catheterisation under two dimensional ultrasound guidance is quicker and safer than the landmark method in both adults and children

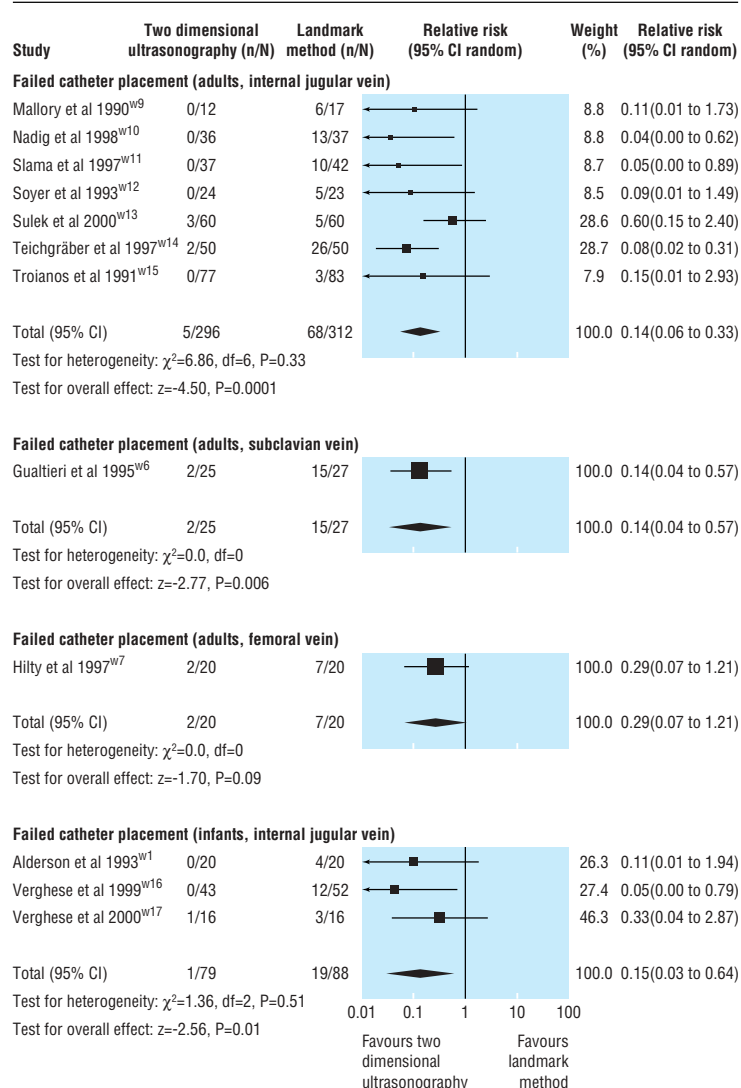
Two dimensional ultrasound guidance is more effective than Doppler ultrasound guidance for more difficult procedures

Contributors: DH and NC designed the review, screened search results, screened retrieved papers against inclusion criteria, appraised quality of papers, abstracted data from papers, analysed data, provided a methodological perspective in the interpretation of data, and wrote the review. RMcW and AD obtained and screened data on unpublished studies, provided a clinical perspective in the interpretation of data, provided general advice on the review, and wrote the review. SP coordinated the review, provided general advice on the review, and secured funding. CB designed the review, developed the search strategy, undertook searches, organised retrieval of papers, and wrote the review. ST provided a clinical perspective in the interpretation of data, provided general advice on the review, and wrote the review. KB, nurse consultant in critical care medicine (Sheffield Teaching Hospitals NHS Trust), provided a clinical perspective in the interpretation of data and provided general advice on the review.

Funding: The UK National Coordinating Centre for Health Technology Assessment programme funded the study.

Competing interests: RMcW has received honorariums from Sonosite for lecturing at training days.

- 1 Elliot TSJ, Faroqui MH, Armstrong RF, Hanson GC. Guidelines for good practice in central venous catheterization. *J Hosp Infect* 1994;28:163-76.
- 2 Callum KG, Whimster F. *Interventional vascular radiology and interventional neurovascular radiology: a report of the National Confidential Enquiry into Perioperative Deaths*. Data collection period 1 Apr 1998 to 31 Mar 1999. London, NCEPOD, 2000.
- 3 Trotter SJ, Veremakis C, O'Brien J, Auer AI. Femoral deep vein thrombosis associated with central venous catheterization: results from a prospective, randomized trial. *Crit Care Med* 1995;23:52-9.
- 4 Calvert N, Hind D, McWilliams RG, Thomas SM, Beverley C, Davidson A. The effectiveness and cost-effectiveness of ultrasound locating devices for central venous access: a systematic review. *Health Technol Assess* 2003;7(12).
- 5 Schulz KF, Chalmers I, Hayes RJ, Altman DG. Empirical evidence of bias: dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA* 2003;273:408-12.
- 6 Khan KS, ter Riet G, Glanville J, Sowden AJ, Kleijnen J. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: NHS Centre for Reviews and Dissemination, University of York, 2001.



**Fig 2** Risk of failure of catheter placement in studies of two dimensional ultrasound guidance compared with landmark method

- 7 Altman DG, Bland JM. Interaction revisited: the difference between two estimates. *BMJ* 2003;326:219.
- 8 Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med* 1996;24:2053-8.
- 9 National Institute for Clinical Excellence. *Guidance on the use of ultrasound locating devices for placing central venous catheters*. London: NICE, 2002. [NICE Technology Appraisal No 49.]

(Accepted 18 June 2003)