

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

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



This is an abridged version; the full version is on [bmj.com](http://bmj.com)

### 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. 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).

Central venous cannulation can be unsafe: death is possible but rare.<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 and thrombosed veins may cause failure.

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

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 control-

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](mailto:d.hind@shef.ac.uk)

BMJ 2003;327:361-4



Additional references appear on [bmj.com](http://bmj.com)

led trials for evidence of the effectiveness of two dimensional ultrasound guidance and Doppler ultrasound guidance in patients undergoing central venous catheterisation.

## Methods

We searched 15 electronic bibliographic databases from inception to October 2001. The search strategy is available on [bmj.com](http://bmj.com) and elsewhere.<sup>4</sup> 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.

Allocation concealment and the method of generation of the allocation sequence were recorded, to assess the potential for selection bias. We also recorded whether an intention to treat analysis was performed.

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.

## 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.

The trials 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

Two dimensional ultrasound guidance was more effective for all five outcomes for internal jugular vein procedures in adults (table 1). Limited evidence suggested

**Table 1** 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			
<b>Adults</b>												
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
<b>Infants</b>												
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 2** 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		
<b>Adults</b>												
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
<b>Infants</b>												
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 <1 favour Doppler ultrasound guidance.

\*Outcome favours landmark method.

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.

For internal jugular vein procedures, Doppler ultrasound guidance significantly improved the chance of successful cannulation overall and on the first attempt (table 2). 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. 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. 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>5</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.

Potential benefits to health care providers 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>6</sup> Financial and logistical implications for the NHS are provision of sufficient ultrasound machines and staff training.

Economic modelling 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

**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

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.

Contributors: See [bmj.com](http://bmj.com)

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 Trottier 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 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.
- 6 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)

ELPS

This is an abridged version; the full version is on [bmj.com](http://bmj.com)

Finnish Institute of Occupational Health,  
Topeliuksenkatu 41 aA, FIN-00250 Helsinki, Finland  
Mika Kivimäki  
professor  
Jussi Vahtera  
senior researcher

International Centre for Health and Society,  
Department of Epidemiology and Public Health,  
University College London Medical School, London WC1E 6BT

Jenny Head  
senior lecturer  
Jane E Ferrie  
senior research fellow  
Martin J Shipley  
senior lecturer  
Michael G Marmot  
professor

Correspondence to: M Kivimäki  
[mika.kivimaki@ttl.fi](mailto:mika.kivimaki@ttl.fi)

*BMJ* 2003;327:364-8

## Sickness absence as a global measure of health: evidence from mortality in the Whitehall II prospective cohort study

Mika Kivimäki, Jenny Head, Jane E Ferrie, Martin J Shipley, Jussi Vahtera, Michael G Marmot

### Abstract

**Objective** To examine the association between sickness absence and mortality compared with associations between established health indicators and mortality.

**Design** Prospective cohort study. Medical examination and questionnaire survey conducted in 1985-8; sickness absence records covered the period 1985-98.

**Setting** 20 civil service departments in London.

**Participants** 6895 male and 3413 female civil servants aged 35-55 years.

**Main outcome measure** All cause mortality until the end of 1999.

**Results** After adjustment for age and grade, men and women who had more than five medically certified absences (spells >7 days) per 10 years had a mortality 4.8 (95% confidence interval 3.3 to 6.9) and 2.7 (1.5 to 4.9) times greater than those with no such absence. Poor self rated health, presence of longstanding illness, and a measure of common clinical conditions comprising diabetes, diagnosed heart disease, abnormalities on electrocardiogram, hypertension, and respiratory illness were all associated with mortality—relative rates between 1.3 and 1.9. In a multivariate model including all the above health indicators and additional health risk factors, medically certified sickness absence remained a significant predictor of mortality. No linear

association existed between self certified absence (spells 1-7 days) and mortality, but the findings suggest that a small amount of self certified absence is protective.

**Conclusion** Evidence linking sickness absence to mortality indicates that routinely collected sickness absence data could be used as a global measure of health differentials between employees. However, such approaches should focus on medically certified (or long term) absences rather than self certified absences.

### Introduction

Controversy exists about the status of sickness absence as a global measure of health; one way to increase understanding of this is to analyse mortality data. A major limitation in available evidence is a lack of studies examining the predictive validity of sickness absence for mortality compared with the predictive validity of more established measures of health.

The Whitehall II study of British civil servants has shown a strong association between indicators of ill health and sickness absence, particularly for longer spells of absence.<sup>1</sup> Factors that have predicted health, such as low socioeconomic status, heavy alcohol intake, widowhood and being single, and poor job control, have also been associated with increased absence rates in this cohort.<sup>1 2-6</sup> This report from the Whitehall II study examines associations of sickness absence with