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Dressings and securement devices for central venous catheters (CVC) (Review)

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[Intervention Review]

Dressings and securement devices for central venous catheters (CVC)

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ABSTRACT

Background

Central venous catheters (CVCs) play a vital role in the management of acute and chronic illness. Dressings and securement devices must ensure CVCs do not dislodge or fall out, provide a barrier protection from microbial colonisation and infection, and be comfortable for the patient. There is a large range of dressing and securement products available for clinicians to use.

Objectives

To compare the available dressing and securement devices for CVCs, in terms of catheter-related bloodstream infection (BSI), catheter colonisation, entry- and exit-site infection, skin colonisation, skin irritation, failed catheter securement, dressing condition and mortality.

Search methods

In June 2015 we searched: The Cochrane Wounds Group Specialised Register; The Cochrane Central Register of Controlled Trials (CENTRAL); The Database of Abstracts of Reviews of Effects (DARE); NHS Economic Evaluation Database (NHSEED); Ovid MEDLINE; Ovid MEDLINE (In-Process & Other Non-Indexed Citations); Ovid EMBASE; EBSCO CINAHL; six clinical trial registries and reference lists of identified trials. There were no restrictions based on language or date of publication or study setting.

Selection criteria

We included randomised controlled trials that evaluated the effects of dressing and securement devices for CVCs. All types of CVCs were included, i.e. short- and long-term CVCs, tunnelled and non-tunnelled, port-a-caths, haemodialysis catheters, and peripherally-inserted central catheters (PICCs).

Data collection and analysis

We used standard Cochrane Collaboration methods including independent review of titles and abstracts for relevance, data extraction, and risk of bias assessment of the included studies by two review authors. Results are expressed using risk ratio (RR) for categorical data with 95% confidence intervals (CIs). For outcomes best presented as a rate-per-time-period, rate ratios and standard errors have been used. We performed multiple treatment meta-analyses to rank the effectiveness of each intervention for each outcome.

Main results

We included 22 studies involving 7436 participants comparing nine different types of securement device or dressing. All included studies were at unclear or high risk of performance bias due to the different appearances of the dressings and securement devices. The extent of blinding of outcome assessment was unclear in most studies. The quality of evidence varied between different comparisons and outcomes. We mainly downgraded the quality of evidence for imprecision, indirectness, risk of bias and inconsistency.

It is unclear whether there is a difference in the rate of catheter-related BSI between securement with gauze and tape and standard polyurethane (SPU) (RR 0.64, 95% CI 0.26 to 1.63, *low quality evidence*), or between chlorhexidine gluconate-impregnated (CGI) dressings and SPU (RR 0.65, 95% CI 0.40 to 1.05, *moderate quality evidence*). There is *high quality evidence* that medication-impregnated dressings reduce the incidence of catheter-related BSI relative to all other dressing types (RR 0.60, 95% CI 0.39 to 0.93).

There is *moderate quality evidence* that CGI dressings reduce the frequency of catheter-related BSI per 1000 patient days compared with SPU dressings (RR 0.51, 95% CI 0.33 to 0.78).

There is *moderate quality evidence* that catheter tip colonisation is reduced with CGI dressings compared with SPU dressings (RR 0.58, 95% CI 0.47 to 0.73), but the relative effects of gauze and tape and SPU are unclear (RR 0.95, 95% CI 0.51 to 1.77, *very low quality evidence*). It is unclear if there is a difference in rates of skin irritation or damage when CGI dressings are compared with SPU dressings (*moderate quality evidence)* (RR 11.17, 95% CI 0.84 to 149.48).

A multiple treatment meta-analysis found sutureless securement devices as likely to be the most effective at reducing the incidence of catheter-related BSI (*low quality evidence*), with CGI dressings ranked second (*low quality evidence*).

Authors' conclusions

Medication-impregnated dressing products reduce the incidence of catheter-related BSI relative to all other dressing types. There is some evidence that CGI dressings, relative to SPU dressings, reduce catheter-related BSI for the outcomes of frequency of infection per 1000 patient days, risk of catheter tip colonisation and possibly risk of catheter-related BSI. A multiple treatment meta-analysis found that sutureless securement devices are likely to be the most effective at reducing catheter-related BSI though this is low quality evidence. Most studies were conducted in intensive care unit (ICU) settings. More, high quality research is needed regarding the relative effects of dressing and securement products for CVCs. Future research may adjust the estimates of effect for the products included in this review and is needed to assess the effectiveness of new products.

PLAIN LANGUAGE SUMMARY

Dressings and securement for central venous catheters (CVCs)

Background

A central venous catheter (CVC) is a tube that is inserted into a blood vessel to enable the delivery of liquid nutrition, blood, medicine or fluids (or a combination of these) to a person who is ill. If a CVC is in place the patient does not need to suffer repeated needle insertions when treatments are due, as tubes can be attached to the CVC, the required fluid pumped in, and then the tubes detached when appropriate.

CVCs need to be secured adequately, usually with a dressing of some kind, in order to prevent them from becoming dislodged and to avoid infection (for example, catheter-related bloodstream infections (BSI)), and need to be comfortable for the patient. Many different types of products are available to secure CVCs, but it is not known which works best.

Review question

The objective of this research was to compare the available dressings and securement devices for CVCs to identify which works best.

What we found

The researchers searched medical databases up to September 2014, and identified 22 studies with a total of 7436 participants that were relevant to the research question. The studies investigated the following comparisons:

- nine studies compared sterile gauze with standard polyurethane dressings;
- six studies compared standard polyurethane dressings with chlorhexidine gluconate-impregnated dressings (chlorhexidine gluconate is an antibacterial disinfectant);
- one study compared standard polyurethane dressings with silver-impregnated dressings (silver compounds may have antibacterial properties);
- one study compared standard polyurethane dressings with hydrocolloid dressings;
- one study compared 'modern' gas permeable standard polyurethane dressings with 'old' (original) standard polyurethane dressings;
- one study compared highly adhesive transparent standard polyurethane dressings with chlorhexidine gluconate dressings;
- one study compared standard polyurethane dressings with sutureless (stitchless) securement devices;

- one study compared sterile gauze with no dressing; and
- one study compared chlorhexidine gluconate dressings with no dressings.

The included studies sometimes did not clearly report the methods they had used to minimise accidental or statistical error, but overall the methods were adequate.

Analysis of the study results showed that there is high quality evidence that securing a CVC with a dressing impregnated with a medication (chlorhexidine gluconate-impregnated or silver) reduces catheter-related blood stream infection compared with a dressing without medication. The results indicated moderate quality evidence for a reduction in the frequency of catheter-related BSI per 1000 patient days (this is a unit used in research that represents patient use; in this case 1000 patient days is equal to 1000 patients using CVCs for one day, or 500 patients using CVCs for two days, or 250 patients using CVCs for four days, etc.) when a chlorhexidine gluconate-impregnated dressing was used rather than a standard polyurethane dressing. When the risk of infection with chlorhexidine gluconate-impregnated dressings was compared with the risk with standard polyurethane dressings in another way (by calculating the ratio of the risk of infection with one versus the other without taking account to patient days of use) this difference was less clear. A less direct measure of infection, that is the extent of bacterial colonisation of the tip of the catheter after removal, showed more bacteria with the standard polyurethane dressing (moderate quality evidence).

The studies that contributed to this research were mainly carried out in intensive care unit settings, where a large number of CVCs are used for short durations. Other types of dressings and securement products for CVCs that were investigated by the studies analysed here did not show any observable effects on catheter-related BSI, catheter tip colonisation or any of the other outcomes assessed, such as skin irritation, failed catheter securement, condition of the dressing and patient death.

More, high quality research is needed to investigate the relative effects of the wide range of dressing and securement products that are available for CVCs.

This plain language summary is up-to-date as of 5th June, 2015.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Gauze and tape compared to standard polyurethane (SPU) for CVC dressing and securement

Gauze and tape compared to SPU for CVC dressing and securement

Patient or population: patients with CVC
Setting: all settings
Intervention: gauze and tape
Comparison: standard polyurethane (SPU)

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with standard polyurethane (SPU)	Risk with Gauze and tape				
Catheter-related blood stream infection assessed with: as defined by criteria specified by Maki 2006; Mermel 2009 and O'Grady 2002	Study population		RR 0.64 (0.26 to 1.63)	506 (8 RCTs)	⊕⊕◯◯ LOW [1 2]	
	75 per 1000	48 per 1000 (19 to 122)				
	Moderate					
	113 per 1000	72 per 1000 (29 to 184)				
Catheter tip colonisation assessed with: positive semi-quantitative (>15 cfu/catheter segment" or quantitative (>10 3 cfu/catheter segment" culture from a proximal or distal catheter segment (O'Grady 2002)	Study population		RR 0.95 (0.51 to 1.77)	342 (5 RCTs)	⊕◯◯◯ VERY LOW [2 3 4]	
	413 per 1000	392 per 1000 (211 to 731)				
	Moderate					
	619 per 1000	588 per 1000 (316 to 1000)				

*__The risk in the intervention group__ (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; **OR:** Odds ratio;

GRADE Working Group grades of evidence

High quality: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[1] Downgraded due to wide 95% confidence intervals (0.26 to 1.63)
[2] Downgraded due to variability in results between studies
[3] Downgraded due to outcome being a surrogate measure of catheter-related bloodstream infection
[4] Downgraded due to wide 95% confidence intervals (0.51 to 1.77)

Summary of findings 2. Chlorhexidine gluconate-impregnated (CGI) dressing compared to SPU dressings for CVC dressing and securement

Chlorhexidine gluconate-impregnated (CGI) impregnated dressings compared to SPU dressing for central venous catheter (CVC) securement and dressing

Patient or population: patients with CVCs
Setting: all settings
Intervention: CGI dressing
Comparison: SPU dressings

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with SPU dressings	Risk with Chlorhexidine gluconate-impregnated (CGI) dressing				
Catheter-related blood stream infection assessed with: as defined by criteria specified by Maki 2006; Mermel 2009 and O'Grady 2002	Study population		RR 0.65 (0.40 to 1.05)	4876 (5 RCTs)	⊕⊕⊕○ MODERATE [1]	
	30 per 1000	19 per 1000 (12 to 31)				
	Moderate					
	18 per 1000	12 per 1000 (7 to 19)				
Catheter tip colonisation: assessed with: positive semi-quantitative (>15 cfu/catheter segment" or quantitative (>10 3 cfu/catheter segment" culture from a proximal or distal catheter segment (O'Grady 2002)	Study population		RR 0.58 (0.47 to 0.73)	4431 (6 RCTs)	⊕⊕⊕○ MODERATE [2]	
	147 per 1000	85 per 1000 (69 to 108)				
	Moderate					

	268 per 1000	155 per 1000 (126 to 196)

*__The risk in the intervention group__ (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; **OR:** Odds ratio;

GRADE Working Group grades of evidence
High quality: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[1] Downgraded due to low rate of events and wide 95% confidence intervals
[2] Downgraded due to outcome being a surrogate measure of catheter-related bloodstream infection

Summary of findings 3. Medication-impregnated dressings compared to all other dressing types for central venous catheter (CVC) dressing and securement

Medication-impregnated dressings compared with all other dressing types for CVC dressing and securement

Patient or population: patients with CVCs
Setting: all settings
Intervention: medication-impregnated dressings
Comparison: all other dressing types

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with all other dressing types	Risk with Medication-impregnated dressings				
Catheter-related blood stream infection assessed with: as defined by criteria specified by Maki 2006; Mermel 2009 and O'Grady 2002	Study population		RR 0.60 (0.39 to 0.93)	5687 (6 RCTs)	⊕⊕⊕⊕ HIGH	
	28 per 1000	17 per 1000 (11 to 26)				
	Moderate					
	64 per 1000	38 per 1000 (25 to 59)				

*__The risk in the intervention group__ (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; **OR:** Odds ratio;

GRADE Working Group grades of evidence
High quality: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

BACKGROUND

Description of the condition

Central venous catheters (CVCs) play an important role in the management of patients, providing reliable vascular access and a site for venous pressure monitoring. They are inserted when a patient requires venous access over an extended period of time, and allow the intravenous administration of complex drug treatments, blood products and nutritional support without the trauma associated with repeated needle insertions (Webster 2011). Although mostly used in intensive-care units and oncology settings, CVCs are increasingly being used in other wards and outpatient settings.

There are multiple types of CVCs in use throughout clinical practice. A CVC can be designated by: its intended life span (e.g. temporary or short-term versus permanent or long-term); the site of insertion (e.g. subclavian vein, femoral vein, internal jugular vein or peripherally inserted central catheter (PICC)); the pathway from skin to vessel (e.g. tunnelled versus non-tunnelled); the physical length (e.g. long versus short) or some other special characteristic(s) (e.g. impregnation with heparin or number of lumens (lines); O'Grady 2011). More information regarding the variety of catheters used in clinical practice is included in Appendix 1.

Owing to the invasive procedure necessary for inserting a CVC and the resulting break in the skin (integument), complications such as exit-site infections and bloodstream infections can develop (Han 2010). A serious complication of CVCs is catheter-related blood stream infections (BSI), also known as 'catheter sepsis'. Catheter-related BSI rates are influenced by patient-related factors, such as severity and type of illness (e.g. full-thickness burns versus post-cardiac surgery), by catheter-related factors (such as the condition under which the catheter was placed and catheter type), and by institutional factors (e.g. bed numbers, hospital affiliation with an academic institution; O'Grady 2011). Many studies have estimated the incidence of catheter-related BSI, generally reporting a range between 1 and 3.1 per 1000 patient days, primarily within the adult intensive care unit (ICU) setting (Pronovost 2006; Schwebel 2012), but rates have been shown to decrease to zero after the introduction of interventions involving handwashing and skin antisepsis (Han 2010). The attributable cost of catheter-related BSI has been estimated within the adult ICU population and varies between USD 3124 and USD 60,536 per event when considering hospital staffing and consumables (Raad 2007; Schwebel 2012), and is associated with an attributable mortality of 0% to 11.5% (Timsit 2011).

CVCs are foreign objects, and, as such, require their external component to be both protected adequately from microbial contamination from the surrounding environment and secured to the skin. Dressings and securements must ensure CVCs do not dislodge or fall out (or both), or move within or out of the great veins. This can occur via movement or pressure on the external component of the device, through forced removal, or 'drag' from infusion tubing or 'catching' on environmental structures (Naimer 2004). Movement of the CVC to a location outside the target placement can result in line failure or cardiovascular instability. In critical situations line failure (e.g. the interruption of inotropic support during cardiogenic shock) can have catastrophic consequences for the patient's morbidity and mortality.

Description of the intervention

There is a plethora of CVC dressings and securement devices from which clinicians may select. The earliest securement approach was simple tape or gauze-tape, with plastic film dressings becoming prominent in the 1980s. First-generation occlusive standard polyurethane (SPU) dressings were later developed to become semi-permeable to oxygen, carbon dioxide and water vapour (e.g. OpSite IV 3000®, Smith and Nephew; Tegaderm Plus®, 3M), as occlusive dressings trap moisture on the skin and so provide an ideal environment for quick growth of local microflora (Frasca 2010). Each dressing is transparent, permitting continuous visual inspection of the catheter site. A recent approach to CVC securement is the bordered polyurethane (BPU) dressing that retains the clear central polyurethane component of SPU dressings with an added external adhesive border of foam or cloth fabric to maximise catheter security (e.g. Tegaderm Advanced®, 3M).

The majority of catheter-related BSI are caused by micro-organisms found in the patient's own commensal skin flora, such as *Staphylococcus epidermidis* and *Staphylococcus aureus* (Timsit 2011); consequently, in recent years we have seen the arrival of medication-impregnated dressings. The most common of these are the chlorhexidine gluconate-impregnated (CGI) dressings. These CGI dressings release chlorhexidine gluconate on the underlying cutaneous surface when placed over the catheter insertion site (Arvaniti 2012). Chlorhexidine gluconate is a cationic biguanide that provides rapid antisepsis because of its broad spectrum of germicidal activity against most catheter-related BSI-causing pathogens (Garland 2001). Chlorhexidine gluconate impregnates the whole dressing, or is applied using an impregnated sponge (e.g. Biopatch®) and covered by a transparent polyurethane dressing. Other medication-impregnated dressings include silver-impregnated and iodine-impregnated dressings (Wille 1993). The iodine-impregnated dressings release free iodine when exposed to wound exudate, while the silver-impregnated dressings expose the entrance site to silver ions; both iodine and silver have antimicrobial properties. Some researchers recommend the use of hydrocolloid dressings for the dressing of CVCs. This type of dressing is traditionally used on open wound sites to promote moist healing as the hydrocolloid matrix absorbs excess moisture away from the skin surface, and so reduces the likelihood of microbial growth (Nikoletti 1999).

Securement of the CVC is also facilitated by mechanisms other than dressings. Traditionally, CVCs were routinely sutured in place, prior to a dressing being applied (O'Grady 2011). In addition to this option, clinicians frequently reinforced the device security using non-commercial options including sterile strips or non-sterile tape. Recently, sutureless securement devices (SSD) have become available commercially. These are used in addition to transparent dressings, and use a large adhesive footplate and an underlying pad with an device-locking clasp (e.g. StatLock®, Bard). These theoretically reduce movement, kinking and flow impedance, and maximise catheter stabilisation (Yamamoto 2002).

Each of these CVC dressing and securement types has different therapeutic goals and is readily available for clinicians and patients to purchase from numerous suppliers, depending upon the treatment setting (e.g. outpatients). The diversity of dressings and securement devices available to clinicians (including variation within each of the types discussed above) makes evidence-based decision-making difficult in this area. With the availability

of increasingly sophisticated and expensive CVC dressings and securements, practitioners need to know how effective these dressings are compared with more traditional dressings.

How the intervention might work

The ideal CVC dressing and securement device should:

- provide a barrier that protects from microbial colonisation and infection, preventing catheter related BSI;
- provide adequate securement to prevent accidental removal, partial dislodgement and micro-motion, thus preventing CVC failure;
- be comfortable and non-irritating for the patient;
- be easy to use; and
- be cost-effective.

Several studies have reported the effects of interventions to reduce catheter-related BSI rates, including maximal sterile precautions during insertion, skin antisepsis, securement devices and antimicrobial catheter coatings (Han 2010; Levy 2005; Timsit 2011). The role of the CVC dressing in preventing catheter-related BSI is to provide a protective barrier that prevents migration of skin organisms at the insertion site into the cutaneous catheter tract - and subsequent colonisation of the catheter tip - and preventing direct contamination of the catheter by contact with hands and other materials (O'Grady 2011).

Why it is important to do this review

Decreasing the incidence of catheter-related BSI and preventing CVC failure are important objectives with a significant impact on patient morbidity and mortality, yet there is no consensus on the optimal dressing or securement type to use with CVCs, despite more than two decades of research and debate. An earlier Cochrane review, 'Gauze and tape and polyurethane dressings for CVC', focused on only two product types (Webster 2011), and, therefore, does not address adequately the variety of products now available in the clinical environment. A large variety of dressings and types of securement is currently available for use with CVCs, including medication-impregnated dressings and sutureless securement devices.

OBJECTIVES

To compare the available dressings and securement devices for CVCs, in terms of catheter-related bloodstream infection (BSI), catheter colonisation, entry- and exit-site infection, skin colonisation, skin irritation, failed catheter securement, dressing condition and mortality.

METHODS

Criteria for considering studies for this review

Types of studies

We included all randomised controlled trials (RCTs) that evaluated the effects of CVC dressings and securement devices for their impact on catheter-related BSI, catheter colonisation, entry- and exit-site infection, skin colonisation, skin irritation, catheter security, dressing condition or mortality, irrespective of publication status or language. We would have included controlled clinical trials (CCTs) only in the absence of RCTs. CCTs are studies in which the trial involves testing an intervention and a control, with concurrent enrolment and follow-up of test and control-treated groups, but the method of allocation is not considered to be strictly random (Lefebvre 2011). We also excluded cross-over and cluster-randomised trials in order to minimise potential bias in accordance with Reeves 2011.

Types of participants

Any person of any age requiring a CVC in any healthcare or community setting. All CVCs were included, i.e. short- and long-term CVCs, tunnelled and non-tunnelled, port-a-caths, haemodialysis catheters, and peripherally-inserted central catheters (PICCs). For studies that included other types of vascular catheter, only data pertaining to CVCs were included.

Types of interventions

We included trials that compared any CVC dressings or securement device including, but not limited to, the following.

Dressings

- Gauze and tape.
- Standard polyurethane (SPU) dressings: semi-permeable and highly permeable.
- Highly adhesive polyurethane dressings.
- Bordered polyurethane (BPU) dressings.
- Chlorhexidine gluconate-impregnated (CGI) dressings.
- Other medication-impregnated dressings.
- Hydrocolloid dressings.
- No dressing.

Securement device

- Sutureless securement devices (SSD).
- Sutures.
- No securement.

Types of outcome measures

Primary outcomes

- Incidence of catheter-related blood stream infection (BSI): as defined by one of the following three criteria.
  - Primary bacteraemia/fungaemia with at least one positive blood culture from a peripheral vein with no other identifiable source for the BSI other than the CVC, plus, one of: a positive semiquantitative (> 15 colony-forming units (cfu)) or quantitative (> 10^3 cfu) device culture, with the same organism (species and antibiogram) isolated from the device and blood (Maki 2006; O'Grady 2002).
  - Two blood cultures (one from an CVC hub and one from a peripheral vein), that both meet the CVC related-BSI criteria for quantitative blood cultures (three-fold greater colony count of growth for the same organism as from the peripheral blood), or differential time to positivity (DTP; growth of the same microbe from hub drawn blood at least two hours before growth from the peripheral blood; Mermel 2009).
  - Two quantitative blood cultures of samples obtained through two catheter lumens in which the colony count for the blood sample drawn through one lumen is at least three-fold

greater than the colony count for the blood sample from the second lumen (Mermel 2009).

Secondary outcomes

- Frequency of catheter-related BSI per 1000 patient days: catheter-related BSI as previously defined.
- Incidence of catheter tip colonisation: positive semi-quantitative (> 15 cfu/catheter segment) or quantitative (> 10^3 cfu/catheter segment) culture from a proximal or distal catheter segment (O'Grady 2002).
- Incidence of entry- and exit-site infection: as described by the trial investigator.
- Incidence of skin/site colonisation: positive semi-quantitative (> 15 cfu) or quantitative (> 10^3 cfu) culture from the skin around the catheter site (O'Grady 2002).
- Incidence of skin irritation or damage: as described by the study investigator using a formal assessment tool (e.g. erythema and dryness scales; Kampf 2005).
- Incidence of failed catheter securement: frequency of accidental or forced removal or dislocation resulting in CVC failure.
- Dressing condition/durability: incidence or mean score using a formal assessment tool (e.g. Pedrolo 2011).
- Mortality from any cause.

Studies must have reported at least one pre-specified outcome, in accordance with these definitions, in order to be included in this systematic review.

Search methods for identification of studies

Electronic searches

We searched the following electronic databases to identify reports of relevant randomised clinical trials:

- The Cochrane Wounds Group Specialised Register (5 June 2015);
- The Cochrane Central Register of Controlled Trials (CENTRAL; *The Cochrane Library* 2015, Issue 6);
- The Database of Abstracts of Reviews of Effects (DARE; *The Cochrane Library* 2015, Issue 6);
- NHS Economic Evaluation Database (*The Cochrane Library* 2015, Issue 6);
- Ovid MEDLINE (1946 to June 04, 2015);
- Ovid MEDLINE (In-Process & Other Non-Indexed Citations, June 04, 2015);
- Ovid EMBASE (1974 to June 04, 2015);
- EBSCO CINAHL (1982 to June 04, 2015).

We used the following search strategy in CENTRAL:

#1MeSH descriptor: [Catheterization, Central Venous] explode all trees (779 citations)
#2(venous near/3 (catheter* or line*)):ti,ab,kw (1526 citations)
#3(central near/3 (catheter* or line*)):ti,ab,kw (1408 citations)
#4(hickman next catheter*):ti,ab,kw (33 citations)
#5(broviac next catheter*):ti,ab,kw (9 citations
#6(cook next catheter*):ti,ab,kw (4 citations)
#7MeSH descriptor: [Catheters, Indwelling] explode all trees (959 citations)
#8("implantable vascular access device" or IAVD or PortACath):ti,ab,kw (3 citations)
#9("peripherally inserted central catheter" or PICC):ti,ab,kw (68 citations)
#10(h*emodialysis next catheter*):ti,ab,kw (111 citations)
#11#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 (2414 citations)
#12MeSH descriptor: [Occlusive Dressings] explode all trees (451 citations)
#13MeSH descriptor: [Bandages, Hydrocolloid] explode all trees (162 citations)
#14MeSH descriptor: [Silver] explode all trees (177 citations)
#15MeSH descriptor: [Silver Sulfadiazine] explode all trees (145 citations)
#16MeSH descriptor: [Polyurethanes] explode all trees (373 citations)
#17MeSH descriptor: [Iodine] explode all trees (324 citations)
#18MeSH descriptor: [Chlorhexidine] explode all trees (1375 citations)
#19((occlusive* or hydrocolloid* or silver* or polyurethane* or permeable or nonpermeable or non-permeable or transparent or chlorhexidine or iodine* or gauze or tape) near/3 (dressing* or sponge*)):ti,ab,kw (1184 citations)
#20#12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 (3391 citations)
#21#11 and #20 (203 citations)

We adapted this strategy to search Ovid MEDLINE, Ovid EMBASE and EBSCO CINAHL, details of these searches can be found in Appendix 2. We combined the Ovid MEDLINE search with the Cochrane Highly Sensitive Search Strategy for identifying randomised trials in MEDLINE: sensitivity- and precision-maximising version (2008 revision; Lefebvre 2011). We combined the EMBASE search with the Ovid EMBASE filter developed by the UK Cochrane Centre (Lefebvre 2011). We combined the CINAHL searches with the trial filters developed by the Scottish Intercollegiate Guidelines Network (SIGN 2012). There were no restrictions on the basis of date, study setting, language or publication status.

We also searched the following clinical trial registers:

- ClinicalTrials.gov (http://www.clinicaltrials.gov/);
- Current Controlled Trials (http://www.controlled-trials.com/mrct);
- Hong Kong clinical trials register (http://www.hkclinicaltrials.com);
- Indian clinical trials registry (http://ctri.nic.in/Clinicaltrials/login.php);
- UK Clinical Trials Gateway (http://www.controlled-trials.com/ukctr/);
- the World Health Organization (WHO) International Clinical Trials Registry Platform (http://apps.who.int/trialsearch/Default.aspx); and
- EU Clinical Trials Register (https://www.clinicaltrialsregister.eu/ctr-search/search)

Searching other resources

We handsearched bibliographies of all retrieved and relevant publications identified by these strategies for further relevant studies. We contacted experts in the field to ask for information relevant to this review. We also contacted dressing and securement

device manufacturers for unpublished data in order to counteract publication bias.

Data collection and analysis

Selection of studies

Independently, two review authors (AU and MM) assessed titles and abstracts of retrieved studies for relevance. After this initial assessment, we retrieved full versions of all potentially eligible studies. Independently, the same two review authors checked the full papers for eligibility. We resolved discrepancies between review authors through discussion and, where required, consulted a third independent review author (CR). For transparency we have published a summary of the selection of studies, including excluded studies and reasons for exclusion, using the PRISMA flowchart (Liberati 2009).

Data extraction and management

We extracted details from eligible studies and summarised them using a data extraction sheet. Due to the large number of studies included in this review, teams of two review authors reviewed specific interventions including: CGI dressing studies, gauze studies, SSD studies, paediatric and neonatal studies, and the remaining studies. These teams extracted data independently, which were cross-checked for accuracy and agreed upon. We resolved any discrepancies though discussion and arbitration by a third review author, when necessary. For studies that were published in duplicate, we extracted maximal data from all relevant publications, but we did not duplicate data in analyses. When there were any data missing from the papers, we attempted to contact the trial authors to retrieve them.

We used a data extraction sheet to extract summary data from each trial. The data extraction sheet contained baseline characteristics of the study participants: their number; age; gender; disease; treatment; type of CVC; dressing or securement, or both; number of dressing changes during the dwell time of the CVC; and healthcare setting in which the intervention occurred. We listed each trial's criteria for participant inclusion and exclusion, a description of the intervention(s), the number of people randomised to each intervention, and primary and secondary outcome measures.

Assessment of risk of bias in included studies

Each eligible study was independently assessed for methodological quality and bias using the Cochrane Collaboration 'Risk of bias' assessment tool. This tool addresses six specific domains, namely, sequence generation, allocation and concealment, blinding of participants/care providers, blinding of outcome assessors, incomplete outcome data, selective outcome reporting, as well as other issues that potentially may bias the study (Higgins 2011a). In accordance with Higgins 2011a, assessment for 'other' bias concerned baseline balance between treatment groups, early cessation of the trials and commercial sponsorship. We have completed a 'Risk of bias' table for each eligible study and outcome using the categories of 'low', 'high' or 'unclear' risk of bias. The criteria for judging risk of bias assessments (i.e. categories of low, high or unclear) were made in accordance with recommendations in Higgins 2011a. Assessment of risk of bias is discussed within the text and the judgements are presented as a 'Risk of bias' summary graph, which summarises judgements by domain, and a 'Risk of bias' summary figure, which cross-tabulates judgements by study. Together these tools have been used to assess overall risk of bias, in combination with the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (Schunemann 2011). The GRADE approach assesses the quality of evidence per comparison and outcome throughout five factors: risk of bias, indirectness of the population, interventions and outcomes, inconsistency amongst studies, imprecision (including information size and confidence intervals) and publication bias.

We undertook data extraction for risk of bias from the included studies using the same approach explained above in Data extraction and management. We extracted and summarised data using a data extraction sheet. Teams of two review authors reviewed specific interventions, extracted data independently and cross-checked the data for accuracy and agreement. We resolved any discrepancies through discussion and arbitration by a third review author, when necessary. We contacted trial authors if data pertaining to risk of bias was missing, including protocol-based assessments of selective outcome reporting. The review authors searched trial registries, as previously described, to identify research protocols to enable assessment for selective outcome reporting.

Measures of treatment effect

Our primary analysis involves pair-wise comparisons of treatment effect between dressing and securement types, using all the described outcomes. For dichotomous outcomes, we have calculated the risk ratio (RR) plus 95% confidence intervals (CI). For the outcome best presented as a rate-per-time-period (i.e. catheter-related BSI per 1000 patient days), we have used rate ratios (RaR) and standard errors (SE) to inform inverse-variance analysis. This analysis required the provision of patient days per intervention group. As CVCs are inserted for variable durations, the rate of catheter-related BSI per 1000 patient days was used to describe the variable frequency of catheter-related BSI across the catheter duration between the CVC securement and dressing options.We undertook meta-analysis when more than one study used the same intervention and reported the same outcome.

In addition to the main pair-wise analysis described above, in order to inform clinical decision-making we planned to undertake pair-wise comparisons using the 'clustering' of interventions on the basis of patient treatment goals and outcomes. These clustering comparisons were done because of the heterogeneity of populations that use CVCs, and the way their goals for treatment differ. In order to minimise bias, these clustering comparisons were identified prior to undertaking the analyses. We planned to compare the following.

Catheter-related BSI

- Medication-impregnated dressings (CGI, povidone-iodine and silver-impregnated etc.) versus non-impregnated dressings (SPU, BPU, gauze and tape, hydrocolloid).
- CGI-impregnated dressings versus all other medication-impregnated dressings (povidone-iodine, silver etc.).
- Silver-impregnated dressings versus all other medication-impregnated dressings (povidone-iodine, CGI etc.).
- Povidine-iodine impregnated dressings versus all other medication-impregnated dressings.
- Gauze and tape versus SPU and BPU.

Incidence of skin irritation or damage

- Hydrocolloid dressing versus all others.
- Gauze and tape versus SPU and BPU.
- CGI-impregnated dressings versus SPU and BPU.

Failed catheter securement

- BPU versus all non-bordered dressings (SPU, hydrocolloid).
- SSD versus all other dressing types.
- No dressing versus all other dressing types.

Unit of analysis issues

The majority of the included RCTs randomised participants and not their CVCs. Two studies recruited participants multiple times for multiple CVCs: Carrer 2005 recruited 82 participants with 107 CVCs; Chambers 2005 recruited 95 participants with 114 CVCs. These studies falsely assumed independence of the CVCs, which provides a potential risk of bias. For the current review, attempts were made to contact the study authors in order to obtain the results for one CVC per participant, but these data were not available. For these studies, data involving CVCs as the unit of analysis were included. Future updates of this review will incorporate studies that used CVCs as the unit of analysis, rather than participants, in a sensitivity analysis to examine for potential risk of bias.

In accordance with Higgins 2011b, for included studies that involved the comparison of multiple interventions using a single control, we split the 'shared' control group to avoid additional unit of analysis issues. We did this to distribute the appropriate study weight and maintain independent comparisons fairly.

Dealing with missing data

When there was evidence of missing data, we attempted to contact the study authors to request the missing information. When after several attempts to contact the trial author the missing data were not provided, we analysed the available data only. We emailed the authors of ten included studies to ask for further information and clarification of key aspects of their study methods and results. Study authors from seven of the ten trials responded (de Barros 2009; Levy 2005; Nikoletti 1999; Olson 2004; Shivnan 1991; Timsit 2009; Timsit 2012), with four authors able to provide all information required (de Barros 2009; Levy 2005; Timsit 2009; Timsit 2012). We have also addressed the potential impact of the missing data on the findings of the review in the Discussion.

Loss to follow-up and attrition data were adequate and well described by ten studies (Arvaniti 2012; Brandt 1996; Chambers 2005; Garland 2001; Giles 2002; Pedrolo 2011; Ruschulte 2009; Shivnan 1991; Timsit 2009; Timsit 2012). Five studies had high levels of attrition and loss to follow-up (Carrer 2005; Conly 1989; le Corre 2003; Levy 2005; Nikoletti 1999). The remaining seven studies provided inadequate information regarding loss to follow-up and attrition for us to assess for bias (de Barros 2009; Hagerstrom 1994; Hill 2010; Olson 2004; Roberts 1998; Wille 1993; Yamamoto 2002).

Assessment of heterogeneity

A random-effects model was used for data synthesis because of predicted clinical heterogeneity. We considered clinical, methodological and statistical heterogeneity and undertook an assessment of comparability of the studies prior to meta-analysis. We investigated the degree of statistical heterogeneity, that is, variation between the true intervention effects underlying the different studies, by a combination of methods. This involved visual inspection of the meta-analytic model and interpretation of the Chi^2 and I^2 statistics that examine the total variance across studies due to heterogeneity rather than chance (Higgins 2003).

Assessment of reporting biases

We reported each outcome separately. We used funnel plots to assess reporting biases for the main analysis (Egger 1997; Analysis 1.1). Any asymmetry of the funnel plot may indicate possible publication bias.

Data synthesis

Initially we conducted a structured narrative summary of the studies included in the review to inform the development of meta-analysis. We entered quantitative data into Review Manager (RevMan) 5.3 and analysed them using the RevMan analysis software (RevMan 2014). We pooled data for meta-analysis using RevMan 5.3, and used a random-effects model because of the clinical heterogeneity.

Multiple treatments meta-analysis (MTM)

Due to the number of treatment options available for CVC securement and dressing, a 'multiple-treatments meta-analysis' has been undertaken in order to assist clinicians in making meaningful-decisions (Higgins 2011b; Salanti 2008). These analyses provide a 'ranking' of each intervention for example by the probability of each intervention being the best in terms of a particular outcome.

MTM data synthesis

Calculation of log risk ratios and their standard errors was repeated in Stata (StataCorp 2011). The log rate ratios and their standard errors were calculated in Stata (using the 'network setup' command; White 2012). Values of zero incidences were replaced with 0.1 for MTM.

MTM quality and inconsistency assessments

Risk of bias assessment within the MTM analyses was undertaken following the principles of the GRADE approach (Schunemann 2011) across the domains of risk of bias, indirectness, inconsistency and imprecision. Network diagrams were developed to display the network of interventions using nodes and edges. Nodes represented the competing treatments; the size of the shapes drawn over the nodes was proportionate to the number of studies where that intervention was evaluated. The edges represented the available direct comparisons between pairs of treatments; the thickness of the edges is weighted by the total number of devices/patients randomised in that comparison; colour indicated average level of study limitation due to bias (green=low, yellow=moderate, red=high) (Chaimani 2013). Contributions matrices (not presented) were used to identify the most influential comparisons for the network, and to evaluate the quality of evidence for the ranking of treatments. Based on the bias level (shown with coloured edges on the network plot) of the most influential comparisons, a decision was made to downgrade the overall confidence (in the overall ranking of interventions) for reasons of study limitations, or not to downgrade (Salanti 2014).

Indirectness due to differences between study populations, interventions and outcome measures resulting in a lack of

transitivity was also assessed, resulting in further downgrading of confidence where necessary (Salanti 2014). Inconsistency refers to a disagreement between direct and indirect evidence, and overall confidence in the ranking of interventions was downgraded if there was evidence of inconsistency and/or the overall (common) heterogeneity was moderate / high. Inconsistency was assessed with 'ifplot' in Stata, and was evident at $p<0.05$. If the mean RoR is large (e.g. >2), this indicated possible inconsistency even if $p>0.05$ (Chaimani 2013). A common heterogeneity was used for all comparisons within each loop. The level of common heterogeneity was considered low at $\tau^2<0.045$ and high at $\tau^2>1.14$ (Salanti 2014), except at networks without loops. In this case the I^2 statistic was calculated and assessed for intervention pairs (with direct evidence and more than one study) as low (<25%), moderate (25-75%) or high (>75%). Rankings (by probabilities of being the best intervention) were produced using 'network rank' in Stata after running the consistency model ('network meta c' in Stata; White 2012). Confidence in the overall ranking was considered initially as 'high', and then later downgraded to 'moderate', 'low' and 'very low' as required.

Subgroup analysis and investigation of heterogeneity

We planned the following subgroup analyses for the primary outcomes, but were unable to complete them due to insufficient data within each pair-wise comparison.

- Adult participants versus paediatric participants versus neonatal participants.
- Participants diagnosed with haematology/oncology conditions versus other participants.
- CVC type (tunnelled versus non-tunnelled, short-term versus long-term, dialysis versus non-dialysis, PICC versus centrally-inserted CVC).
- Participants receiving the intervention in an acute versus a community setting.
- Participants receiving lipid and parenteral nutrition (PN) versus patients not receiving lipid and PN.

Sensitivity analysis

We planned to perform a sensitivity analysis of primary outcomes to explore the effects of excluding those studies at high risk of bias from the final meta-analysis. We planned only to include studies that were assessed as having a low risk of bias in all key domains, namely, adequate generation of the randomisation sequence, adequate allocation concealment, and blinding of outcome assessor, for the estimates of treatment effect. However we were unable to perform this analysis for the outcome of catheter-related BSI due to poor reporting. There were insufficient studies in the other comparisons to permit a meaningful analysis on the remaining intervention comparisons.

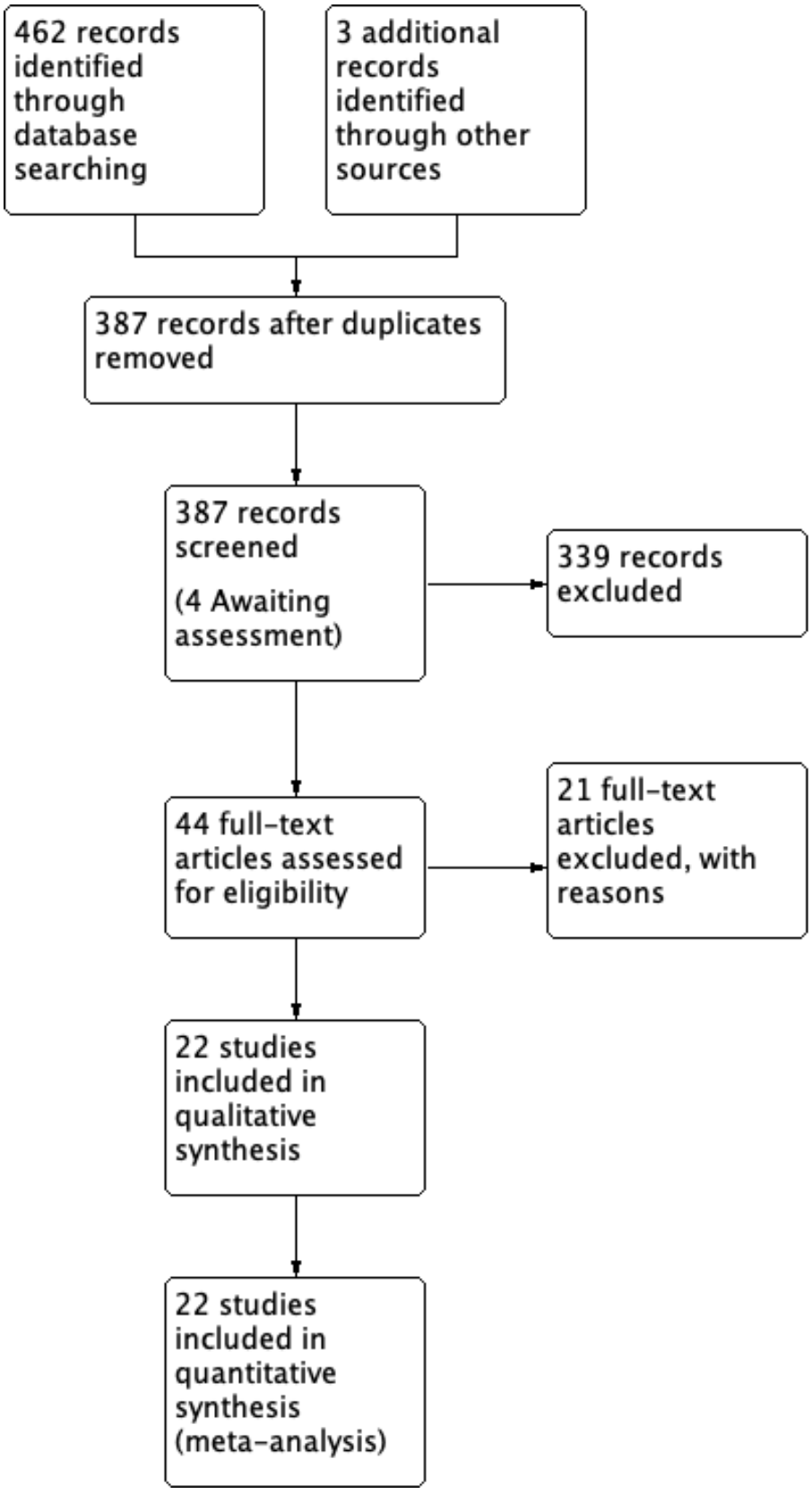
RESULTS

Description of studies

Results of the search

The results of the search and selection of studies are summarised in the PRISMA study flow diagram Figure 1. The search of electronic bibliographic databases identified 415 records, 69 of which were duplicates. Searches of clinical trial registries did not identify additional studies, but the handsearching of bibliographies identified three studies for potential inclusion. Of the 349 titles screened, 305 were excluded. We screened 44 full-text articles for potential inclusion, and excluded 21, listing the reasons for their exclusion in the Characteristics of excluded studies tables. We identified four studies which we have not yet retrieved in full text or are awaiting information from the trial authors (Broadhurst 2014; Calvino 2014; Gu 2014; Pedrolo 2014).

Figure 1. Study flow diagram.



Included studies

The 22 included studies, with a total of 7436 participants, are described in Characteristics of included studies. The studies were RCTs conducted in 25 countries, including the USA (five studies), Canada (three studies), France and Australia (two studies each), Greece, Italy, New Zealand, Spain, Turkey, Sweden, Israel, Brazil, Germany and the Netherlands (one study each).

Population and setting

Studies were undertaken in intensive care units (ICUs; Arvaniti 2012; Carrer 2005; Garland 2001; Hill 2010; Levy 2005; Nikoletti 1999; Pedrolo 2011; Roberts 1998; Timsit 2009; Timsit 2012), oncology and haematology units (Chambers 2005; Olson 2004; Ruschulte 2009; Shivnan 1991), including bone marrow transplantation units (Brandt 1996), haemodialysis centres (de Barros 2009; Hagerstrom 1994; le Corre 2003), general surgical units (Giles 2002; Wille 1993; Yamamoto 2002), and throughout the hospital (Conly 1989). One study continued to study participants after discharge from acute care (le Corre 2003).

Eleven studies restricted participation to adults (Arvaniti 2012; Brandt 1996; Chambers 2005; le Corre 2003; Nikoletti 1999; Olson 2004; Pedrolo 2011; Timsit 2009; Timsit 2012; Wille 1993; Yamamoto 2002); one study to paediatric participants (Levy 2005); two studies to neonates (Garland 2001; Hill 2010); while two studies had a combination of adults and children (Conly 1989; Shivnan 1991). The age of participants was not described in six studies (Carrer 2005; de Barros 2009; Giles 2002; Hagerstrom 1994; Roberts 1998; Ruschulte 2009).

The types of CVCs studied were restricted to tunnelled CVCs in four studies (Brandt 1996; Chambers 2005; Hagerstrom 1994; le Corre 2003), non-tunnelled, percutaneous CVCs in six studies (Carrer 2005; Levy 2005; Nikoletti 1999; Pedrolo 2011; Roberts 1998; Ruschulte 2009), peripherally inserted central catheters (PICCs) in two studies (Hill 2010; Yamamoto 2002), and a combination of CVC types in four studies (Conly 1989; Garland 2001; Timsit 2009; Timsit 2012). The type of CVC investigated was not described in six studies (Arvaniti 2012; de Barros 2009; Giles 2002; Olson 2004; Shivnan 1991; Wille 1993).

Interventions and comparisons

As expected, the studies included many different interventions and comparisons. Researchers compared:

- sterile gauze with standard polyurethane (SPU) in nine studies (Brandt 1996; Carrer 2005; Conly 1989; de Barros 2009; Giles 2002; Hagerstrom 1994; le Corre 2003; Pedrolo 2011; Shivnan 1991);
- SPU with chlorhexidine gluconate-impregnated (CGI) dressings in six studies (Arvaniti 2012; Garland 2001; Levy 2005; Roberts 1998; Ruschulte 2009; Timsit 2009);
- SPU with silver-impregnated dressings in one study (Hill 2010);
- SPU with hydrocolloidal dressing in one study (Nikoletti 1999);
- second generation gaseous permeability SPU with first generation SPU (old generation SPU) in one study (Wille 1993);
- SPU, highly adhesive transparent dressings with CGI dressings in one study (Timsit 2012)
- SPU with sutureless securement devices (SSD) in one study (Yamamoto 2002);
- sterile gauze with no dressing in one study (Olson 2004); and
- CGI dressings with no dressing in one study (Chambers 2005).

Outcomes

There was variability in the reporting of outcomes. The primary outcome of catheter-related BSI was reported by 17 studies (Arvaniti 2012; Brandt 1996; Chambers 2005; Conly 1989; de Barros 2009; Garland 2001; Giles 2002; Hagerstrom 1994; le Corre 2003; Olson 2004; Pedrolo 2011; Ruschulte 2009; Shivnan 1991; Timsit 2009; Timsit 2012; Wille 1993; Yamamoto 2002). Each of these studies defined the outcome of catheter-related BSI in accordance with the definition of our review. Several other studies reported catheter infection or sepsis, but did not meet the definition as described in our protocol, these studies are described in Characteristics of excluded studies.

Eight studies reported the patient day information required for our secondary outcome of 'frequency of catheter-related BSI per 1000 patient days' (Arvaniti 2012; Chambers 2005; le Corre 2003; Ruschulte 2009; Timsit 2009; Timsit 2012; Wille 1993; Yamamoto 2002). We attempted to contact the remaining eight study authors who had provided catheter-related BSI incidence in the pair wise comparisons, one provided patient day information (de Barros 2009), two were unable to locate the data (Olson 2004; Shivnan 1991), two did not respond (Garland 2001; Pedrolo 2011), and contact information could not be found for the remaining three (Brandt 1996; Giles 2002; Hagerstrom 1994).

The remaining secondary outcomes were reported inconsistently. Twelve studies reported the incidence of catheter tip colonisation according to our definitions (Arvaniti 2012; Carrer 2005; Conly 1989; de Barros 2009; Garland 2001; Giles 2002; Levy 2005; Nikoletti 1999; Pedrolo 2011; Roberts 1998; Timsit 2009; Timsit 2012). Two studies reported the incidence of skin or site colonisation according to our protocol definitions (Giles 2002; Shivnan 1991). The incidence of entry- and exit-site infection was reported by four studies (Brandt 1996; Chambers 2005; Roberts 1998; Shivnan 1991), skin irritation or damage was reported by five studies (Garland 2001; Hill 2010; Levy 2005; Pedrolo 2011; Yamamoto 2002), incidence of failed catheter security by four studies (Arvaniti 2012; Brandt 1996; de Barros 2009; Yamamoto 2002), and mortality from any cause by four studies (Arvaniti 2012; Chambers 2005; Hill 2010; Pedrolo 2011). The incidence of dressing durability or condition was assessed using an a priori definition by one study (Pedrolo 2011), however no studies reported a mean score for dressing condition or durability using a formal assessment tool.

Due to the small number of studies that reported each outcome, clustering comparisons were only undertaken for catheter-related BSI, and medication-impregnated dressings (CGI, povidone-iodine and silver-impregnated) versus non-impregnated dressings (SPU, BPU, gauze and tape, hydrocolloid).

Excluded studies

We excluded 21 studies for the following reasons.

- Study design: the studies were clinical controlled studies, with sequential assignment rather than randomised allocation (two studies).
- Population: arterial catheters and CVCs recruited to the studies, outcomes reported together. We contacted the study authors, but they were unable to provide separated results (two studies).

- Confounding interventions: the study involved the application of specific dosages of skin antiseptics and administration set changes at different intervals that may have had a significant impact on the outcome results (one study).
- Outcome definition: outcomes used in the study did not meet our outcome definitions (16 studies).
- Inadequate data for extraction: the data were not provided in a way that allowed meaningful extraction, and we were unable to contact study authors (one study).

A description of each study is available in the Characteristics of excluded studies table (Crawford 2004; Davidson 1986; Freiberger 1992; George 2011; Keenlyside 1991; Keenlyside 1993; Khattak 2010; Lawson 1986; Little 1998; Lucas 1996; Madeo 1998; Maki 1984; Maki 2000; Neufeld 1991; Olson 2008; Petrosino 1988; Powell 1982; Powell 1985; Reynolds 1997; Schwebel 2012; Timsit 2010).

Risk of bias in included studies

Figure 2 shows that there is no evidence of funnel plot asymmetry to indicate potential reporting bias in the included studies.We judged that the majority of the studies had an unclear risk of bias for most criteria; Figure 3 presents the overall risk of bias. The characteristics of individual studies are summarised in the Characteristics of included studies tables. We did not downgrade the quality of the evidence for unclear risk of bias.

Figure 2. Funnel plot of comparison: 1 Primary analysis, outcome: 1.1 Catheter-related blood stream infection.

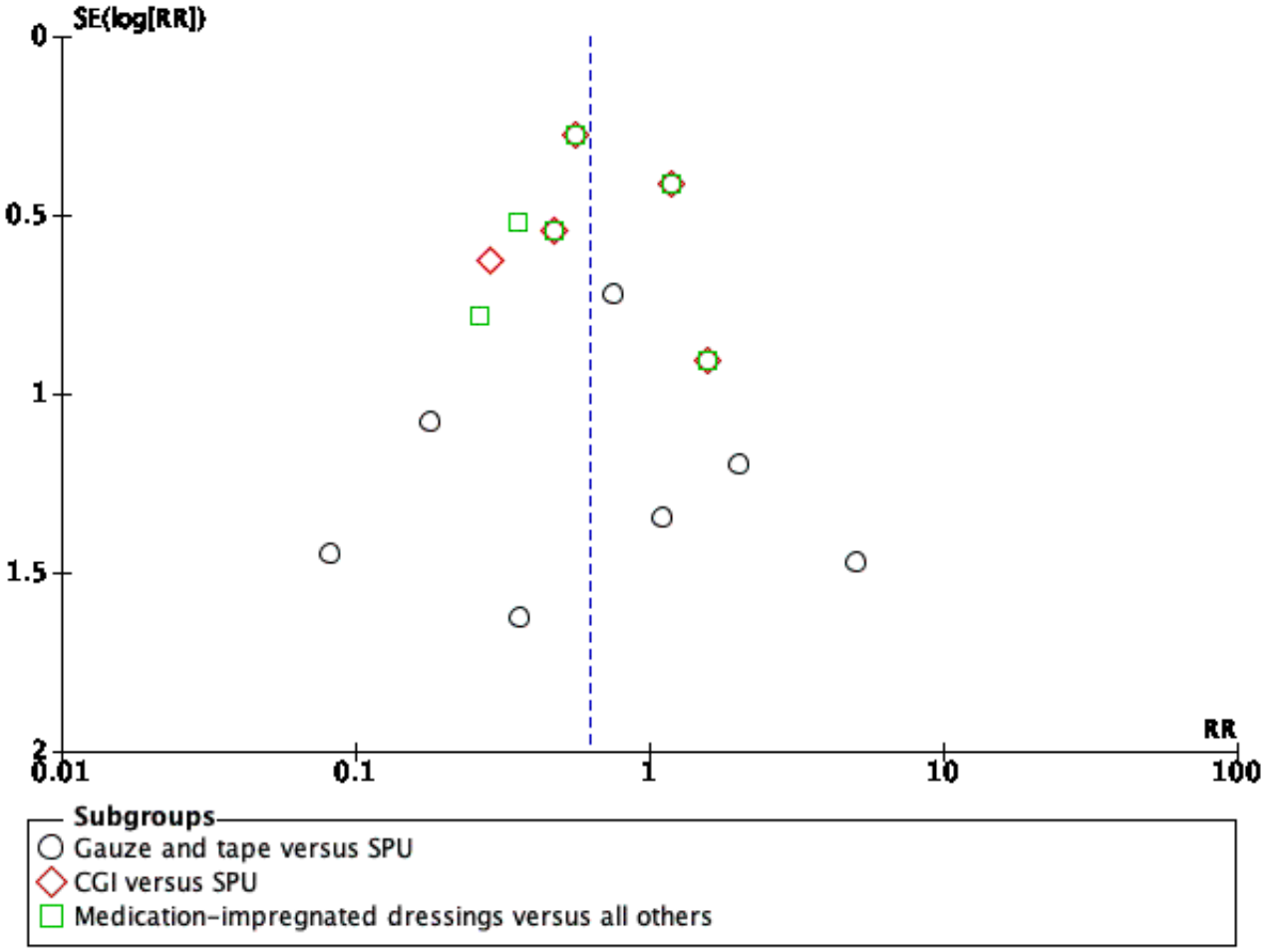


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

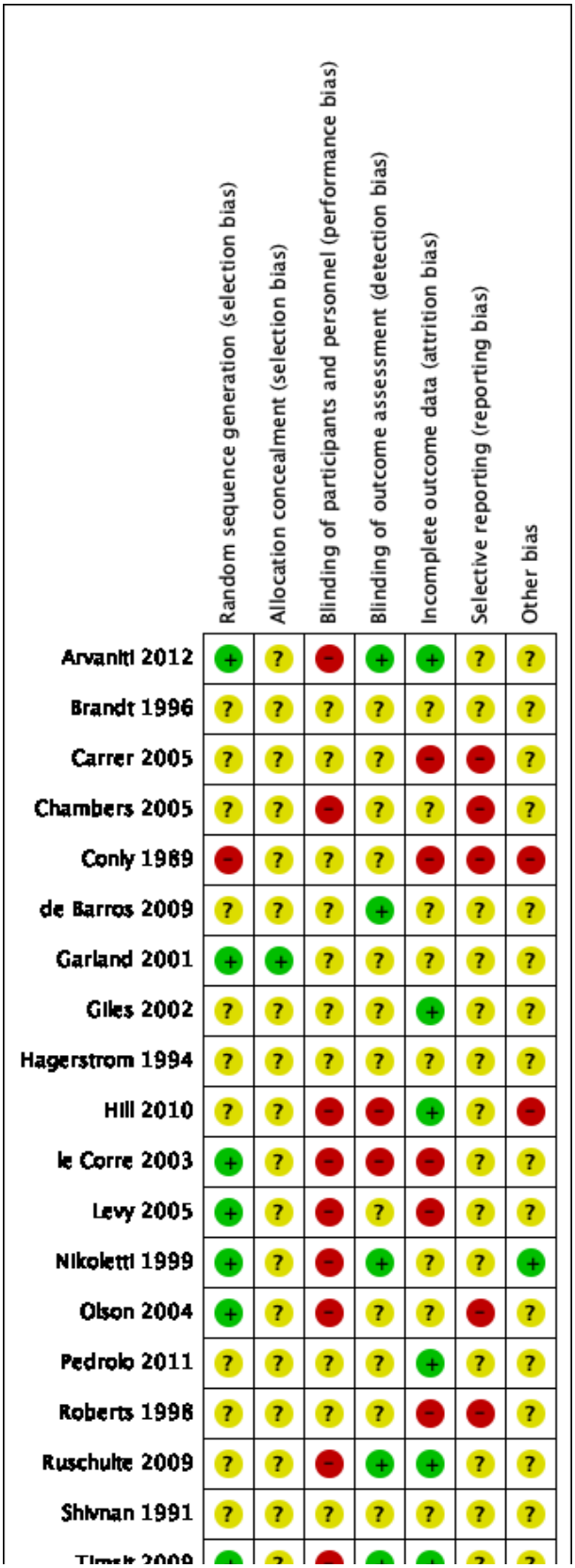
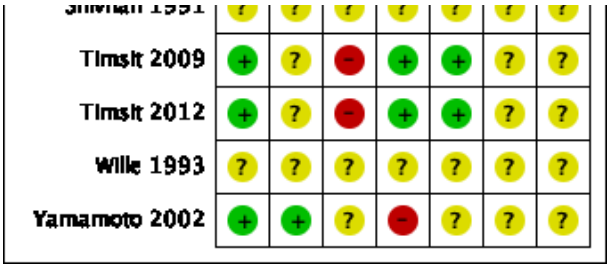


Figure 3. (Continued)



Allocation

Nine of the 22 included studies described an adequate method of sequence generation (Arvaniti 2012; Garland 2001; le Corre 2003; Levy 2005; Nikoletti 1999; Olson 2004; Timsit 2009; Timsit 2012; Yamamoto 2002). An adequate method of allocation concealment was reported in only two of the studies (Garland 2001; Yamamoto 2002).

Blinding

No study blinded personnel or participants, as this was not achievable due to the visibility of the intervention. Only six studies reported blinding the outcome assessor (Arvaniti 2012; de Barros 2009; Nikoletti 1999; Ruschulte 2009; Timsit 2009; Timsit 2012).

Incomplete outcome data

Five studies provided incomplete outcome data with high percentages of undescribed attrition and loss-to-follow up (Carrer 2005; Conly 1989; le Corre 2003; Levy 2005; Roberts 1998). Seven studies reported complete outcome data (Arvaniti 2012; Giles 2002; Hill 2010; Pedrolo 2011; Ruschulte 2009; Timsit 2009; Timsit 2012). The remaining studies provided inadequate information to ascertain attrition bias.

Selective reporting

Protocols were available for two studies that had been registered in clinical trial registries (Timsit 2009; Timsit 2012). Five studies did not provide some of their outcomes per interventional group (Carrer 2005; Chambers 2005; Conly 1989; Olson 2004; Roberts 1998)

Other potential sources of bias

Five of the studies were sponsored by product manufacturers (Garland 2001; Shivnan 1991; Timsit 2012; Wille 1993; Yamamoto 2002). Three studies described systematic differences between the intervention and control groups at baseline (Arvaniti 2012; Conly 1989; Hill 2010), while three studies provided no participant baseline data, only CVC information (Hagerstrom 1994; Pedrolo 2011; Wille 1993). The majority of the included RCTs randomised participants and not their CVCs. Two studies recruited participants multiple times for multiple CVCs (Carrer 2005; Chambers 2005). One study stopped early for unknown reasons (Olson 2004).

Effects of interventions

See: **Summary of findings for the main comparison** Gauze and tape compared to standard polyurethane (SPU) for CVC dressing and securement; **Summary of findings 2** Chlorhexidine gluconate-impregnated (CGI) dressing compared to SPU dressings for CVC dressing and securement; **Summary of findings 3** Medication-impregnated dressings compared to all other dressing types for central venous catheter (CVC) dressing and securement

The main results are displayed in Summary of findings for the main comparison(gauze and tape compared with SPU), Summary of findings 2 (CGI compared with SPU) and Summary of findings 3(medication impregnated dressings compared with all other dressing types).

1.1 Incidence of catheter-related bloodstream infection (BSI)

Analysis 1.1 displays the results of the meta-analysis for catheter-related BSI for the pair-wise comparisons.

1.1.1 Gauze and tape compared with standard polyurethane (SPU) dressings (eight trials, 506 participants)

Eight studies in adult bone marrow transplantation units (101), haemodialysis (138), gastroenterological (72), adult ICU (21), paediatric and adult oncology (98) and general ward (76) settings reported this intervention and outcome, with 28 participants out of a total of 506 developing a catheter-related BSI (Brandt 1996; Conly 1989; de Barros 2009; Giles 2002; Hagerstrom 1994; le Corre 2003; Pedrolo 2011; Shivnan 1991). There was no clear difference between gauze and tape and SPU dressings on the incidence of catheter-related BSI (RR 0.64, 95% CI 0.26 to 1.63; Analysis 1.1). *Low quality evidence* (downgraded for inconsistency and imprecision). Statistical heterogeneity was low but point estimates cross the line (Chi^2 6.82; P value 0.34; I^2 12%).See Summary of findings for the main comparison.

1.1.2 Gauze and tape compared with no dressings (one trial, 78 participants)

One small study in an adult oncology setting (Olson 2004) reported on the effect of gauze and tape compared with no dressings and found no clear difference in the incidence of catheter-related BSI (RR 1.47, 95% CI 0.72 to 3.00) however this study was too small to detect a difference should it exist. *Low quality evidence* (downgraded for risk of bias and imprecision)

1.1.3 SPU dressings compared with old generation SPU dressings (one trial, 101 participants)

One small study in an adult surgical setting (Wille 1993) found clear difference in the incidence of catheter-related BSI between SPU dressings and "old generation" SPU dressings (RR 0.33, 95% CI 0.04 to 3.04) however because this study was so small we cannot be confident that a difference does not exist. *Low quality evidence* (downgraded for imprecision)

1.1.4 Highly adhesive transparent dressing compared with SPU dressings (one trial, 982 participants)

One study in an adult ICU setting (Timsit 2012) found no clear difference in catheter-related BSI between a highly adhesive transparent dressing and SPU dressings (RR 0.60, 95% CI 0.20 to 1.77). *Moderate quality evidence* (downgraded for imprecision)

1.1.5 Chlorhexidine gluconate-impregnated (CGI) dressings compared with SPU dressing (five trials, 4876 participants)

We pooled five trials (Arvaniti 2012; Garland 2001; Ruschulte 2009; Timsit 2009; Timsit 2012) comparing CGI with SPU dressings. It is unclear whether CGI dressings reduce the risk of catheter-related BSI compared with SPU dressings as although there was a reduction in risk of catheter-related BSI this did not reach traditional levels of statistical significance (P=0.08) (RR 0.65, 95%, CI 0.40 to 1.05; Analysis 1.1.2) (*moderate quality evidence,* downgraded for imprecision). Five studies in adult ICU (3620), neonatal ICU (705) and adult haematology/oncology (601) units/wards reported this intervention and outcome, with 106 participants out of 4876 developing a catheter-related BSI . Statistical heterogeneity was low (Chi^2 5.38; P value 0.25; I^2 26%). See Summary of findings 2.

1.1.6 CGI dressing compared with highly adhesive transparent dressing (one trial, 1453 participants)

One study (adult ICU) found no clear difference in the incidence of catheter-related BSI (Timsit 2012) between CGI dressings and a highly adhesive transparent dressing (RR 0.48, 95% CI 0.14 to 1.66). *Moderate quality evidence* (downgraded for imprecision)

1.1.7 SPU dressings compared with hydrocolloid dressings (one trial, 128 participants)

There were fewer cases of catheter-related BSI with SPU dressings than hydrocolloid dressings in a single study in adult ICU (Nikoletti 1999) (RR 0.53, 95% CI 0.29 to 0.97). *Moderate quality evidence* (downgraded for imprecision)

1.1.8 SPU dressings compared with sutureless securement devices (one trial, 170 participants)

There were fewer cases of catheter-related BSI with sutureless securement devices than SPU in a single study in adult general acute and home care settings (Yamamoto 2002) (RR 8.00, 95% CI 1.02 to 62.58, P value 0.05). *Low quality evidence* (downgraded for risk of bias and imprecision).

1.1.9 CGI dressing compared with no dressing (one trial, 112 participants)

There was no clear difference in the incidence of catheter-related BSI between CGI dressings and no dressing in one small study (RR 0.27, 95% CI 0.06 to 1.22). This study was based in an adult haematology setting (Chambers 2005). *Moderate quality evidence* (downgraded for imprecision)

1.1.10 Medication-impregnated dressings compared with all others (six trials, 5687 participants)

Six studies from adult ICU (4269), neonatal ICU (705) and adult haematology/oncology (713) settings reported this intervention and outcome; 124 participants out of a total of 5687 developed a catheter-related BSI (Arvaniti 2012; Chambers 2005; Garland 2001; Ruschulte 2009; Timsit 2009; Timsit 2012). There was *high quality evidence* that medication-impregnated dressings reduce the risk of catheter-related BSI compared with all other dressings (RR 0.60, 95% CI 0.39 to 0.93; P value 0.02) (Analysis 1.1). Statistical heterogeneity was low (Chi^2 6.21; P value 0.29; I^2 19%). See Summary of findings 3.

1.2 Frequency of catheter-related bloodstream infection per 1000 patient days

Analysis 1.2 presents the results of the meta-analysis for catheter-related BSI per 1000 patient days for the pair-wise comparisons.

1.2.1 Gauze and tape compared with SPU dressings (two trials, 8538 patient days)

Two studies in haemodialysis settings reported this intervention and outcome, with 10 participants out of a total of 8538 patient days developing a catheter-related BSI (de Barros 2009; le Corre 2003). There was no clear evidence of a difference in the frequency of catheter -related BSI per 1000 patient days when gauze and tape was compared with SPU dressing (RR 0.71, 95% CI 0.20 to 2.52; Analysis 1.2). . Statistical heterogeneity was low (Chi^2 0.37; P value 0.54; I^2 0%). *Moderate quality evidence* (downgraded for imprecision)

1.2.2 SPU compared with old generation SPU (one trial, 780 patient days)

There was no clear difference in the frequency of catheter-related BSI per 1000 patient days in a single study in an adult surgical setting (Wille 1993) when SPU was compared with old generation SPU (RR 0.35, 95% CI 0.01 to 18.61). *Moderate quality evidence* (downgraded for imprecision)

1.2.3 SPU compared with sutureless securement devices (one trial, 5730 patient days)

One study in general adult acute and home settings (Yamamoto 2002) found no difference between SPU and sutureless securement devices in the frequency of catheter-related BSI per 1000 patient days (RR 0.13, 95% CI 0.00 to 5.82). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.2.4 CGI dressings compared with SPU (four trials, 42,689 patient days)

The pooled results of four studies (in adult ICU; 32,958 patient days) and haematology/oncology; 9731 patient days) (Arvaniti 2012; Ruschulte 2009; Timsit 2009; Timsit 2012) show that CGI dressings reduce the frequency of catheter-related BSI per 1000 patient days compared with SPU (RR 0.51, 95% CI 0.33 to 0.78, P value 0.002; Analysis 1.2). There was no statistical heterogeneity detected (Chi^2 2.52; P value 0.47; I^2 0%). *Moderate quality evidence* (downgraded for imprecision)

1.2.5 Highly adhesive transparent dressing compared with SPU (one trial, 8831 patient days)

One study in adult ICU (Timsit 2012) found no difference in the frequency of catheter-related BSI per 1000 patient days between highly adhesive transparent dressings and SPU (RR 0.67, 95% CI 0.14 to 3.11). *Moderate quality evidence* (downgraded for imprecision)

1.2.6 CGI dressings compared with no dressing (one trial, 12,351 patient days)

One study in adult haematology (Chambers 2005) found no difference in the frequency of catheter-related BSI per 1000 patient days between CGI dressings and no dressing (RR 3.98, 95% CI 0.76 to 20.91). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.3 Incidence of catheter tip colonisation

Analysis 1.3 displays the results of the meta-analysis for catheter tip colonisation for the pair-wise comparisons.

1.3.1 Gauze and tape compared with SPU dressings (five trials, 341 participants)

Five studies in haemodialysis (66), gastroenterological (72), adult ICU (127), and general ward (76) settings reported this intervention and outcome, with 99 participants out of a total of 341 having their CVC tip colonised (Carrer 2005; Conly 1989; de Barros 2009; Giles 2002; Pedrolo 2011). There was no clear difference in the risk of catheter tip colonisation between gauze and tape and SPU dressings (RR 0.95, 95% CI 0.51 to 1.77; Analysis 1.3). . See Summary of findings for the main comparison. Statistical heterogeneity was high (Chi^2 12.06; P value 0.02; I^2 67%). *Very low quality evidence* (downgraded for inconsistency, indirectness and imprecision)

1.3.2 CGI compared with SPU dressings (six trials, 4431 participants)

Pooling the results of six trials (Chi^2 6.41; P value 0.27; I^2 22%) showed that the risk of catheter tip colonisation is reduced with CGI compared with SPU dressings (RR 0.58, 95% CI 0.47 to 0.73; Analysis 1.3). Six studies reported this intervention and outcome, with 457 participants out of a total of 4431 having their CVC tip colonised (Arvaniti 2012; Garland 2001; Levy 2005; Roberts 1998; Timsit 2009; Timsit 2012). These results are also presented in Summary of findings 2. This analysis is based upon participants from adult ICU (3581), neonatal ICU (705) and paediatric ICU (145) settings. *Moderate quality evidence* (downgraded for indirectness)

1.3.3 Highly adhesive transparent dressing compared with SPU (one trial, 982 participants)

There was no difference in the incidence of catheter tip colonisation between highly adhesive transparent dressings and SPU (RR 1.32, 95% CI 0.88 to 1.98). This single study (Timsit 2012) was in an adult ICU setting. *Low quality evidence* (downgraded for imprecision and indirectness)

1.3.4 SPU compared with hydrocolloidal dressings (one trial, 128 participants)

One small study in adult ICU (Nikoletti 1999) found no difference in the incidence of catheter tip colonisation between SPU and hydrocolloid dressings (RR 1.88, 95% CI 1.03 to 3.42). *Low quality evidence* (downgraded for imprecision and indirectness)

1.4 Incidence of entry- and exit-site infections

1.4.1 Gauze and tape compared with SPU dressings (two trials, 199 participants)

The pooled results of two studies (Brandt 1996; Shivnan 1991) comparing the use of gauze and tape with SPU dressings found no clear difference in the incidence of entry- and exit-site infections (RR 0.84, 95% CI 0.34 to 2.07; Analysis 1.4; (Chi^2 0.15; P value 0.69; I^2 0%). These studies took place in adult bone marrow transplant unit (101) and paediatric and adult oncology (98) settings. *Moderate quality evidence* (downgraded for imprecision)

1.4.2 SPU compared with CGI dressings (one trial, 33 participants)

A single small study in adult ICU (Roberts 1998) found no clear difference in the incidence of entry- and exit-site infections between SPU and CGI dressings (RR 0.80, 95% CI 0.21 to 3.02). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.4.3 CGI dressings compared with no dressing (one trial, 112 participants)

A single small study in an adult haematology setting (Chambers 2005) found fewer entry- and exit-site infections with CGI than with no dressing (RR 0.20, 95% CI 0.06 to 0.66). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.5 Incidence of skin or site colonisation

1.5.1 Gauze and tape compared with SPU dressings (two trials, 170 participants)

Two studies (Giles 2002; Shivnan 1991).compared gauze and tape with SPU in gastroenterology (72) and paediatric and adult oncology (98) settings. These studies were pooled (I^2 0%). There was no difference In the incidence of skin or site colonisation between gauze and tape and SPU dressing (RR 0.86, 95% CI 0.30 to 2.51; Analysis 1.5). *Moderate quality evidence* (downgraded for imprecision)

1.6 Incidence of skin irritation or damage

1.6.1 Gauze and tape compared with SPU dressings (one trial, 21 participants)

There was no clear evidence of difference in skin irritation or damage between gauze and tape and SPU in a single study (adult ICU) (Pedrolo 2011) (RR 6.60, 95% CI 0.95 to 45.75). *Moderate quality evidence* (downgraded for imprecision)

1.6.2 CGI compared with SPU (two trials, 850 participants)

There was no clear evidence of a difference in the incidence of skin irritation or damage between CGI dressings and SPU when two studies were pooled (Chi^2 2.17; P value 0.14; I^2 54%) (Garland 2001; Levy 2005) (RR 11.17, 95% CI 0.84 to 149.48; Analysis 1.6). These studies took place in neonatal ICU (705) and paediatric ICU (145) settings. Higher rates of skin irritation or damage were evidence in the neonatal than the paediatric population. *Moderate quality evidence* (downgraded for imprecision)

1.6.3 SPU compared with other medication-impregnated dressings (one trial, 118 participants)

A single small study (Hill 2010) compared the effects of SPU and other medication-impregnated dressings, in this case silver, on the rate of skin irritation or damage in neonatal ICU and found no difference (there was no irritation or skin damage in either group). *Low quality evidence* (downgraded for imprecision)

1.6.4 SPU compared with sutureless securement devices (SSD; one trial, 170 participants)

A single small study (Yamamoto 2002) found no difference in the incidence of skin irritation or damage between SPU and SSDs in general adult acute and home-care settings. (RR 0.61, 95% CI 0.06 to 5.78). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.7 Incidence of failed catheter securement

1.7.1 Gauze and tape compared with SPU dressing (two trials, 167 participants)

The pooled results of two studies (Brandt 1996; de Barros 2009) found no difference between gauze and tape and SPU dressings in the incidence of failed catheter securement (RR 0.90, 95% CI 0.33 to 2.49; Analysis 1.7). This analysis is based upon participants from adult BMT (101) and haemodialysis (66) settings. Statistical heterogeneity was absent (Chi^2 0.54; P value 0.46; I^2 0%). *Moderate quality evidence* (downgraded for imprecision)

1.7.2 SPU compared with CGI dressings (one trial, 306 participants)

One study in adult ICU (Arvaniti 2012) compared SPU with CGI dressings and found no difference in the incidence of failed catheter securement (RR 2.40, 95% CI 0.47 to 12.20). *Moderate quality evidence* (downgraded for imprecision)

1.7.3 SPU compared with SSD (one trial, 170 participants)

One study in adult acute and home care settings compared (Yamamoto 2002) SPU with SSD and found no difference in the incidence of failed catheter securement (RR 1.20, 95% CI 0.55 to 2.63). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.8 Dressing condition or durability

1.8.1 Gauze and tape compared with SPU dressing (one trial, 21 participants)

One very small study in adult ICU (Pedrolo 2011) compared gauze and tape with SPU and found no difference in dressing condition or durability (RR 0.57, 95% CI 0.10 to 3.27). *Moderate quality evidence* (downgraded for imprecision)

1.9 Mortality

1.9.1 Gauze and tape compared with SPU dressing (one trial, 21 participants)

One very small study in adult ICU (Pedrolo 2011) compared mortality in people receiving either gauze and tape or SPU and found no clear difference (RR 1.10, 95% CI 0.19 to 6.41). *Moderate quality evidence* (downgraded for imprecision)

1.9.2 SPU compared with CGI dressing (one trial, 606 participants)

One study in adult ICU (Arvaniti 2012) an increase in mortality with SPU compared with CGI dressing (RR 3.71, 95% CI 2.48 to 5.55). This study had a high mortality rate, with a total of 80 out of 606 participants dying. *Moderate quality evidence* (downgraded for imprecision)

1.9.3 SPU dressing compared with other medication-impregnated dressing (one trial, 118 participants)

One study in neonatal ICU (Hill 2010) found no clear difference in mortality between SPU and other medication-impregnated dressings (impregnated with silver) (RR 1.53, 95% CI 0.14 to 16.31). *Low quality evidence* (downgraded for risk of bias and imprecision)

1.9.4 CGI compared with no dressing (one trial, 112 participants)

One study in adult haematology (Chambers 2005) found no clear difference in mortality between CGI and no dressing (RR 1.33, 95% CI 0.55 to 3.25). *Low quality evidence* (downgraded for risk of bias and imprecision)

Sensitivity analyses

We planned sensitivity analyses for two major outcomes, catheter-related BSI and catheter tip colonisation, to evaluate the impact of excluding studies based on the risks of selection and attrition bias. We were unable to perform the analyses on catheter-related BSI, as poor reporting meant we were not able to identify those studies at high risk bias. We performed sensitivity analyses on catheter tip colonisation, for the comparison of CGI dressings versus SPU. There were insufficient studies for the other comparisons to permit a meaningful analysis to be performed.

2.1 Catheter tip colonisation

As described in Analysis 2.1, the exclusion of two studies (Levy 2005; Roberts 1998) with a high risk of attrition bias did not alter the pooled estimates substantially when we compared CGI dressings with SPU ('without' attrition bias: RR 0.59, 95% CI 0.46 to 0.77, compared to 'with' attrition bias: RR 0.58 95% CI 0.47 to 0.73).

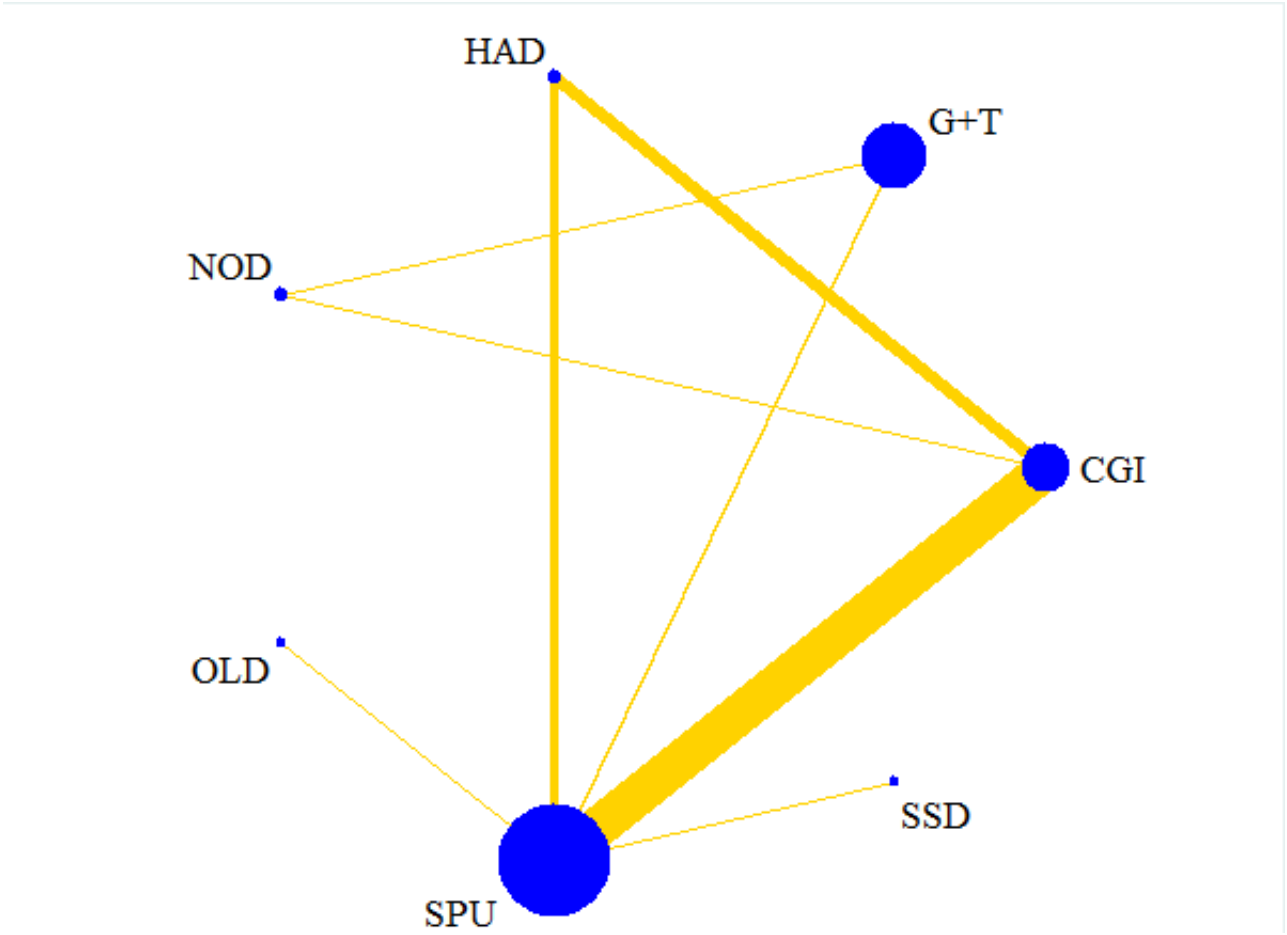
Multiple treatments meta-analysis

We undertook a multiple treatments meta-analysis for each outcome for which more than two interventions were compared. These results are summarised graphically in the figures section.

3.1 Incidence of catheter-related BSI

SSD had the highest probability of being the most effective intervention to reduce the incidence of catheter-related BSI, followed by CGI (Figure 4). *Low quality of evidence* (downgraded due to moderate risk of bias, likely inconsistency and moderate common heterogeneity).

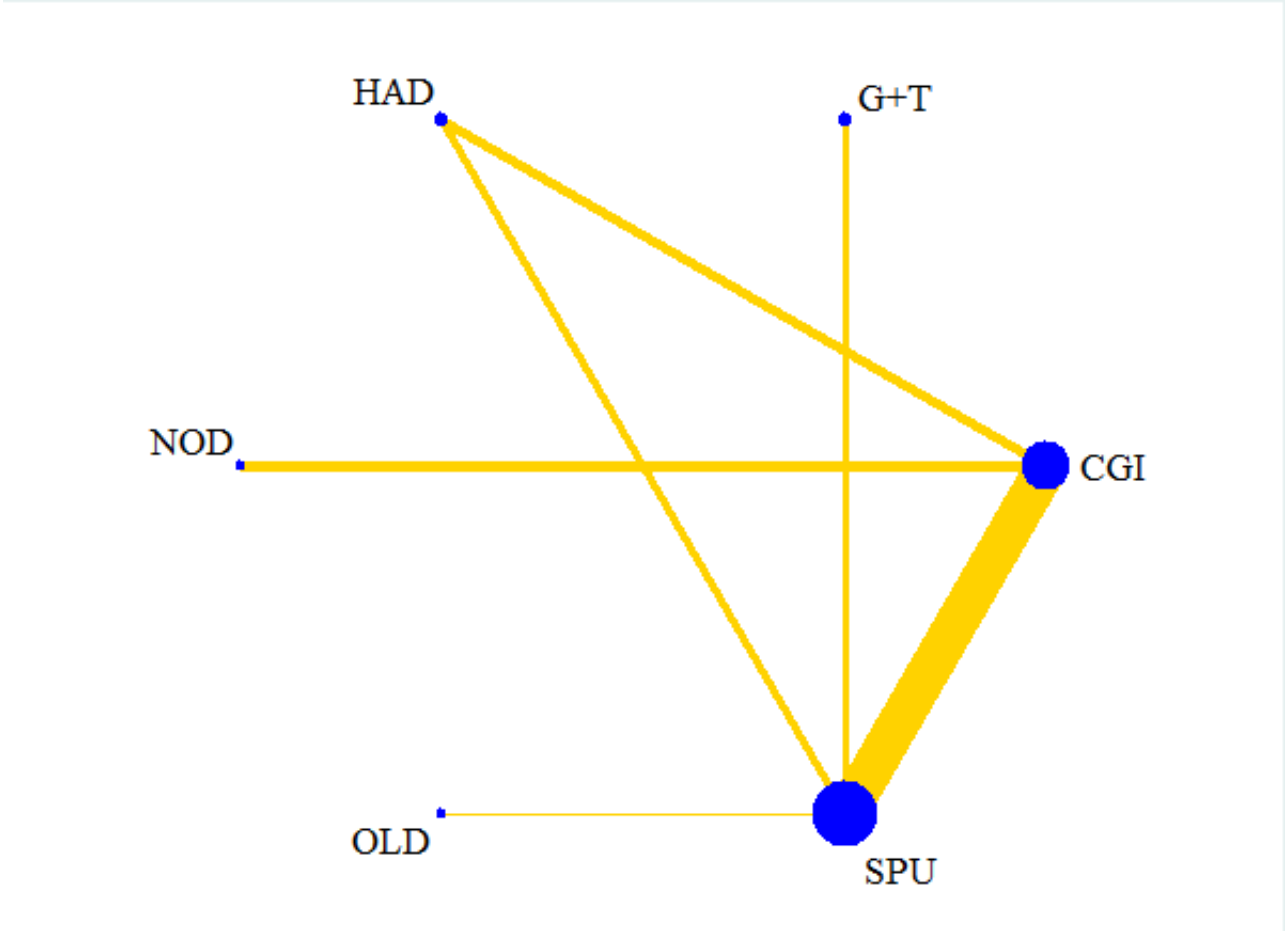
Figure 4. .1 MTM Network plot: Incidence of catheter related bloodstream infection SPU standard polyurethane, G +T gauze and tape, BPU bordered polyurethane, CGI chlorhexidine gluconate impregnated, NOD no dressing, SSD sutureless securement device, OLD old standard polyurethane, HAD highly adhesive dressing.



3.2 Frequency of catheter-related BSI per 1000 patient days

"Old" SPU had the highest probability of being the most effective intervention to reduce the frequency of catheter-related BSI per 1000 patient days, followed by CGI (Figure 5). *Moderate quality of evidence* (downgraded due to moderate risk of bias).

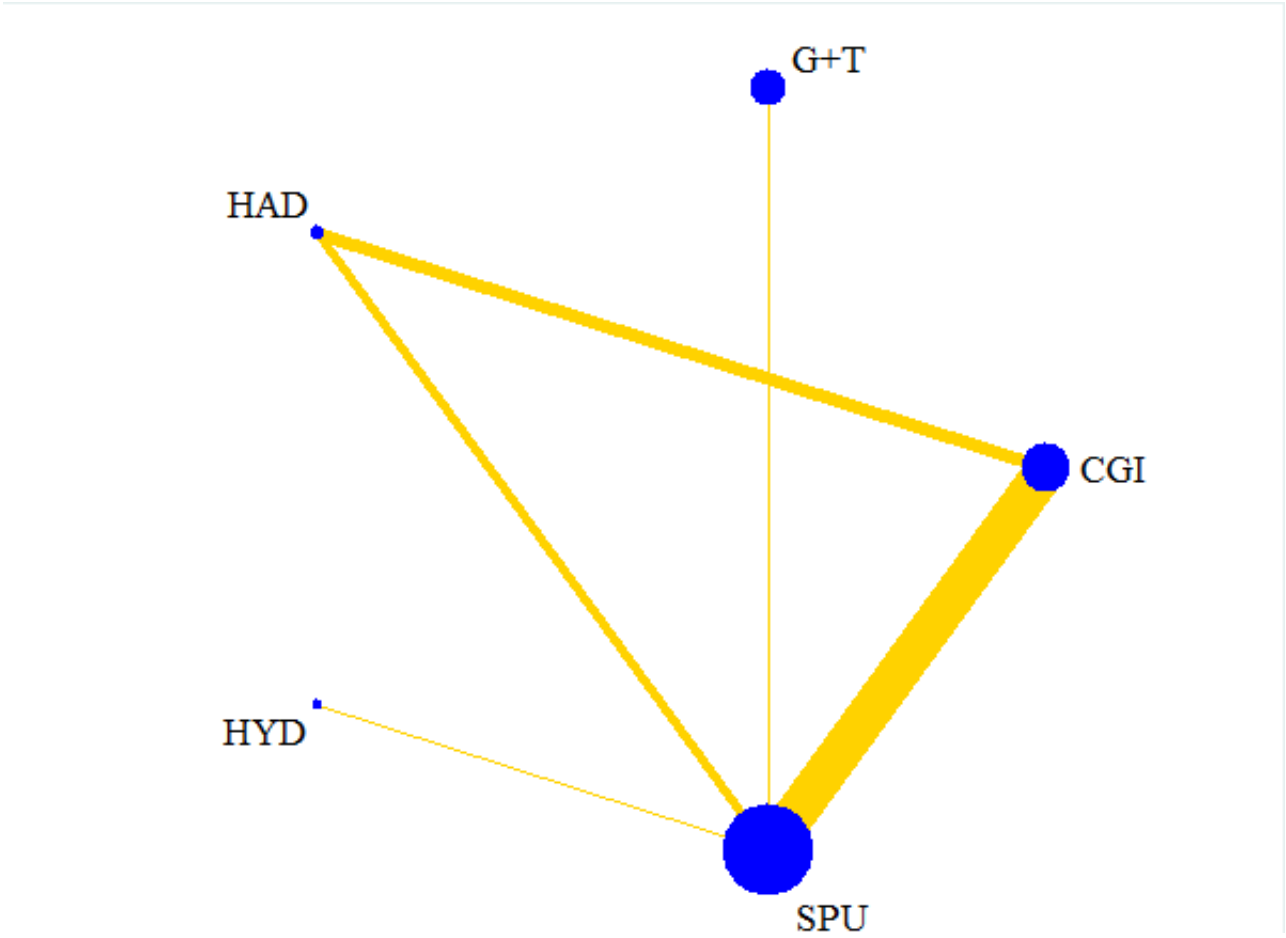
Figure 5. 3.2 MTM Network plot: Frequency of catheter-related bloodstream infection per 1000 patient days SPU standard polyurethane, G+T gauze and tape, CGI chlorhexidine gluconate impregnated, NOD no dressing, OLD old standard polyurethane, HAD highly adhesive dressing.



3.3 Incidence of catheter tip colonisation

CGI had the highest probability of being the most effective intervention to reduce the incidence of catheter tip colonisation, followed by gauze and tape (Figure 6). *Moderate quality of evidence* (downgraded due to moderate risk of bias).

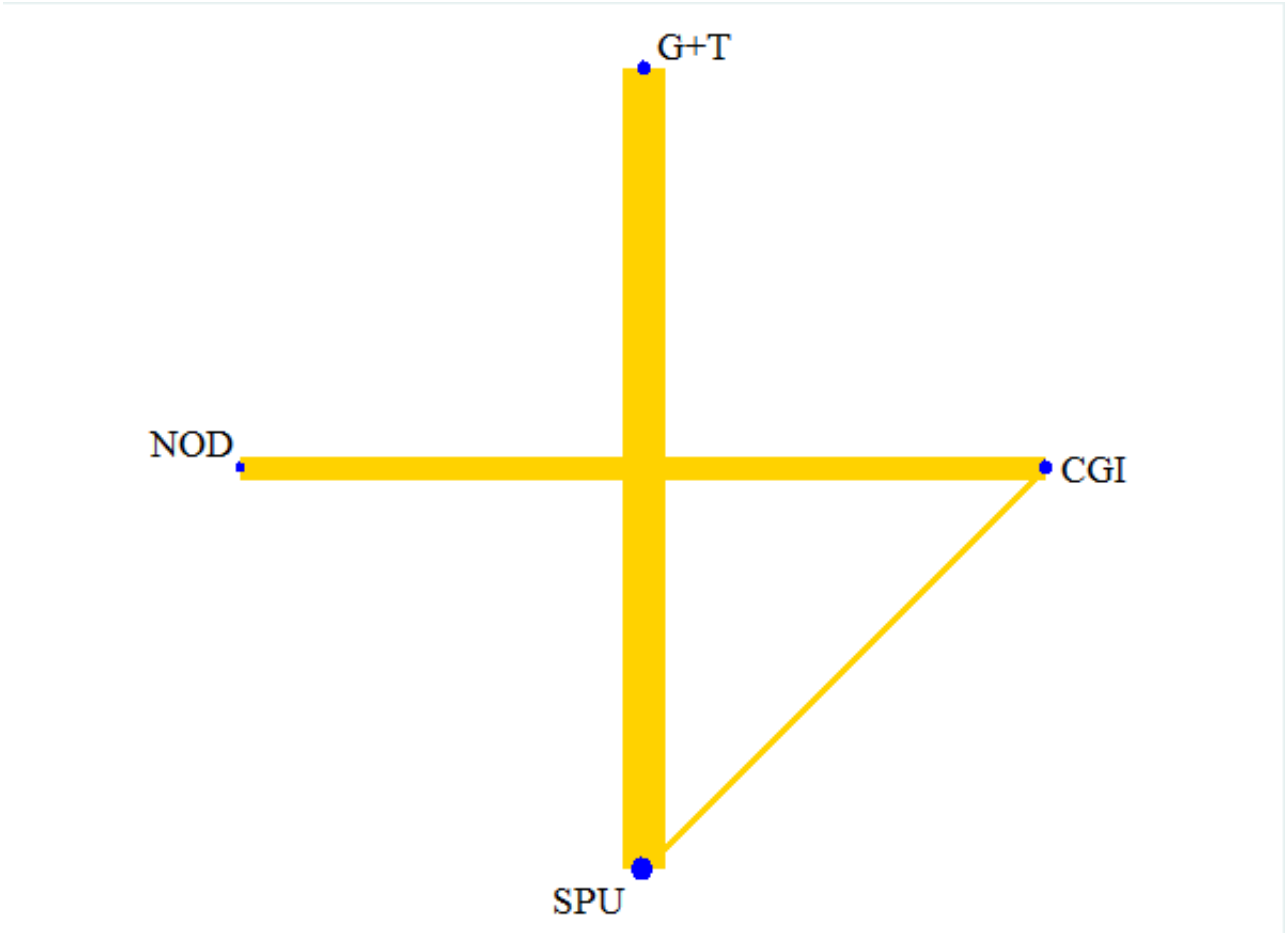
Figure 6. 3.3 MTM Network plot: Incidence of catheter tip colonisation SPU standard polyurethane, G+T gauze and tape, CGI chlorhexidine gluconate impregnated, HYD hydrocolloid, HAD highly adhesive dressing.



3.4 Incidence of entry- or exit-site infection

Gauze and tape had the highest probability of being the most effective intervention to reduce the incidence of entry or exit site infection. No dressing had the lowest probability (Figure 7). *Low quality of evidence* (downgraded due to moderate risk of bias and low levels of transitivity (indirectness)).

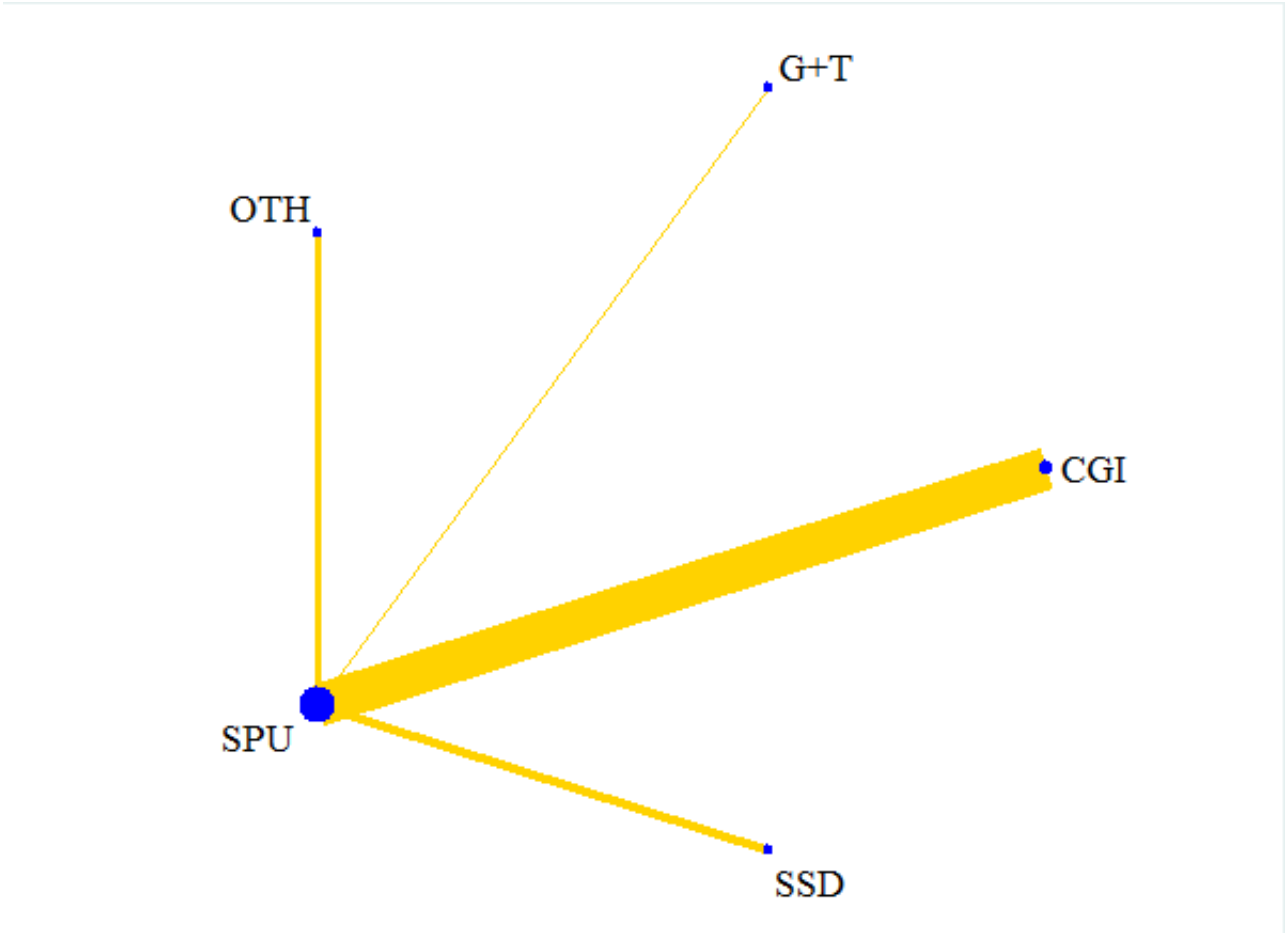
Figure 7. 3.4 MTM Network plot: Incidence of entry- and exit- site infections SPU standard polyurethane, G+T gauze and tape, CGI chlorhexidine gluconate impregnated, NOD no dressing.



3.5 Incidence of skin irritation or damage

SSD had the highest probability of being the most effective intervention to reduce the incidence of skin irritation or damage, followed by SPU (Figure 8). *Low quality of evidence* (downgraded due to moderate risk of bias, moderate heterogeneity (inconsistency)).

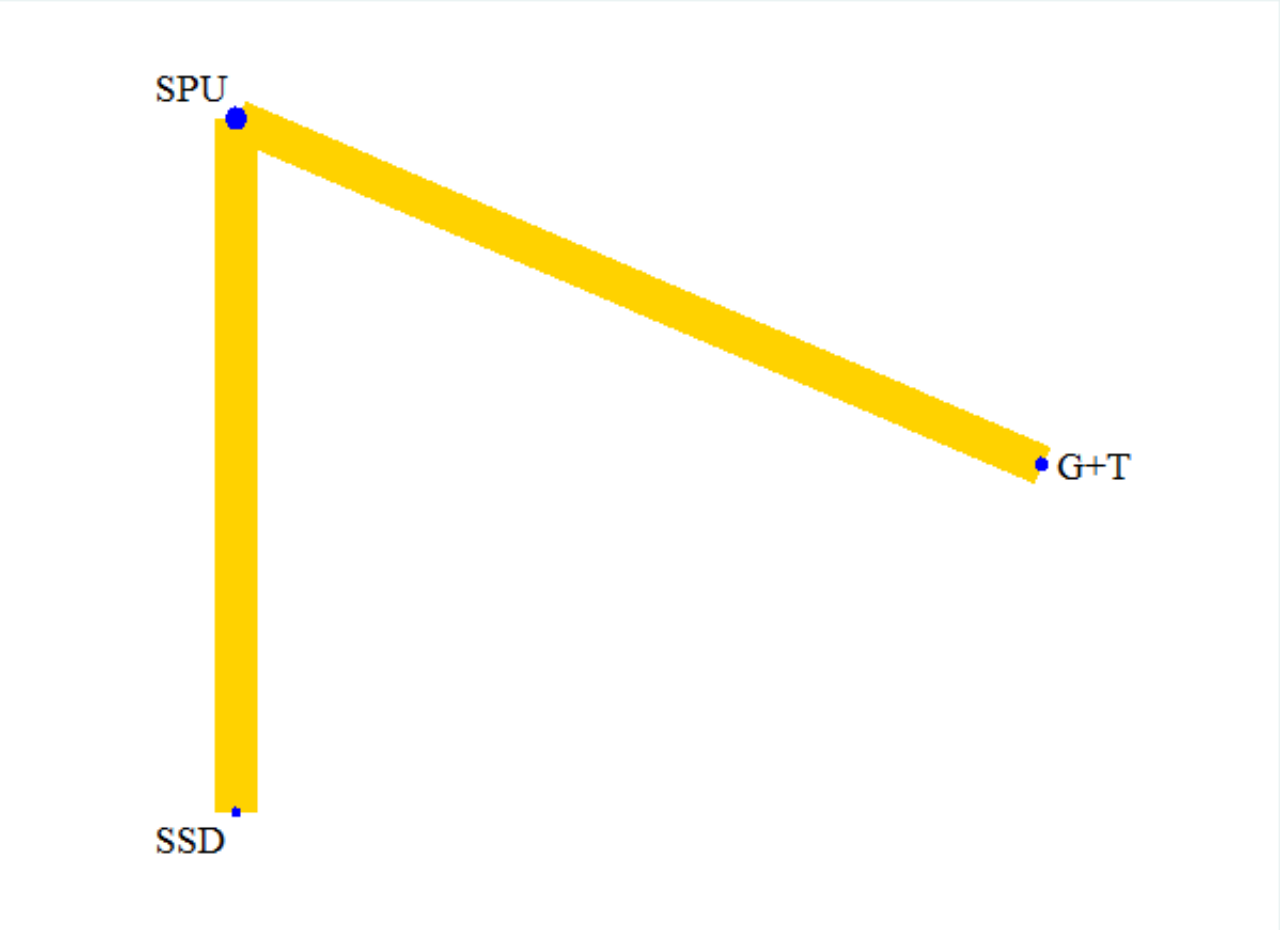
Figure 8. 3.5 MTM Network plot: Incidence of skin irritation or damage SPU standard polyurethane, G+T gauze and tape, CGI chlorhexidine gluconate impregnated, SSD sutureless securement device, OTH other medication impregnated dressing



3.6 Incidence of failed catheter securement

Gauze and tape had the highest probability of being the best intervention to reduce the incidence of failed catheter securement, followed by SPU (Figure 9). *Moderate quality of evidence* (downgraded for moderate risk of bias).

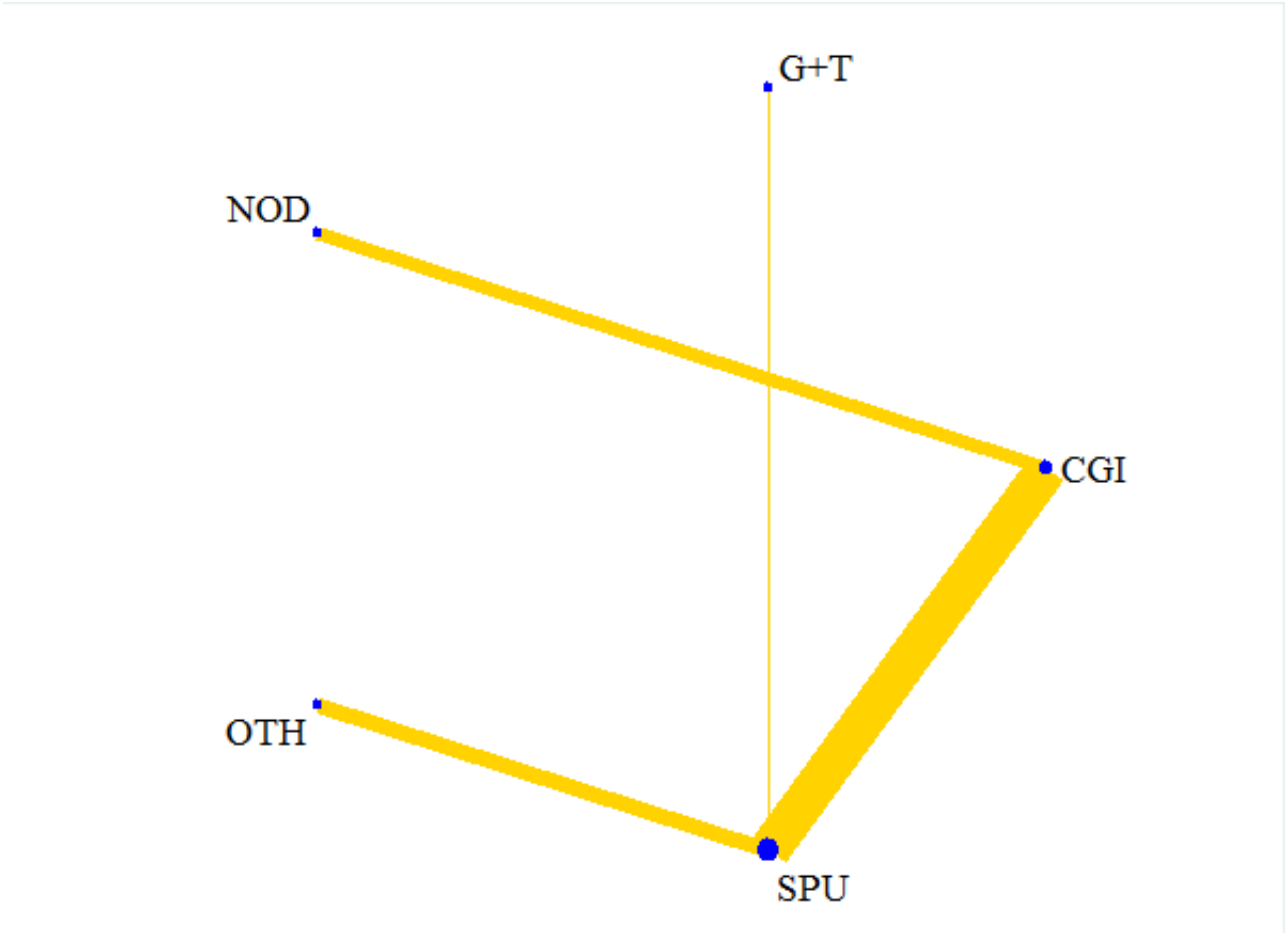
Figure 9. 3.6 MTM Network plot: Incidence of failed catheter securement SPU standard polyurethane, CGI chlorhexidine gluconate impregnated, SSD sutureless securement device,



3.7 Incidence of mortality

No dressing was associated with the highest probability of being the most effective intervention to reduce mortality, followed by CGI (Figure 10). *Low quality of evidence* (downgraded for moderate risk of bias, low levels of transitivity (indirectness)).

Figure 10. 3.7 MTM Netowrk plot: Mortality SPU standard polyurethane, G+T gauze and tape, CGI chlorhexidine gluconate impregnated, NOD no dressing, OTH other medication impregnated dressing



DISCUSSION

Summary of main results

CGI dressings may reduce catheter-related blood stream infection relative to SPU and other dressings (moderate quality of evidence). This direction of effect is consistent for the outcomes of relative risk of catheter-related blood stream infection, rates of blood stream infection per 1000 patient days and catheter tip colonisation however there is uncertainty around the result for the primary outcome of relative risk and no difference cannot be excluded. There is high quality evidence that the use of medication-impregnated dressing products reduce the incidence of catheter-related BSI in comparison with all other dressing types. The class of interventions termed 'medication-impregnated dressings' included only CGI dressings in various forms (e.g. patch or whole dressing), whilst the 'all other dressing types' group involved SPU, highly adhesive transparent dressings and no dressing. There was moderate quality evidence for a reduction in the frequency of catheter-related BSI per 1000 patient days with the use of CGI dressings, compared to SPU. There was also moderate quality evidence in the reduction in the risk of colonisation of the CVC tip with CGI dressings compared to SPU. Colonisation of the CVC tip is considered an indirect measure of catheter-related BSI. Most studies were conducted in ICU settings (Analysis 1.1.2: 89% participants; Analysis 1.2.2: 77% catheter days; Analysis 1.3.2: 100% participants). The evidence for the effectiveness of CGI dressings is probably not generalisable beyond these settings.

The results of the multiple-treatment meta-analysis (MTM) are generally in agreement with the pair-wise comparisons. CGI dressings were ranked as having the highest probability of reducing the incidence of catheter tip colonisation and second to SSD for reducing the incidence of catheter-related BSI and frequency of catheter-related BSI per 1000 patient days. The level of evidence reported in the MTM was of low to moderate quality, and further research may alter these results.

One large RCT comparing CGI and SPU dressings was excluded from this review (Maki 2000; 1401 participants); this RCT compared the effectiveness of CGI dressings with SPU for the securement and dressing of arterial catheters, pulmonary artery catheters and CVC. The trial found a significant reduction in the incidence of catheter-related BSI for participants receiving CGI dressings (P value < 0.05). This study was excluded because the outcome data were not provided separately for catheter type. We contacted the study authors, but they were not able to provide us with the CVC outcomes. Exclusion of these results may have had a significant impact on the results of the meta-analyses included in this review. If we had been able to include these data, it is highly likely that our estimates of effect for the incidence of catheter-related BSI would

have become significant and favoured CGI dressings compared to SPU.

There is some concern in the current literature regarding the increased risk of skin irritation or damage for CGI dressings. Our current analysis results were heavily influenced by a single study that examined 705 neonatal ICU participants (59.2% of participants in the meta-analysis; Garland 2001). The majority of reactions occurred in neonates up to 28 weeks gestational age and up to 1000 g in weight. Local contact dermatitis from the CGI dressing may limit its use in acutely ill low-birthweight neonates or others with impaired skin integrity (Garland 2001).

Overall completeness and applicability of evidence

We identified a large number of studies in which the population, intervention, comparison and outcomes matched our prespecified selection criteria. The studies were conducted in 25 different countries, in a range of settings and age-related populations, with different CVC types. Despite this, the majority of dressing and securement products have not been adequately compared, due to the large variety that are currently available. This means that there is ongoing uncertainty regarding the effectiveness of several of the commercially and clinically available products. Additionally, several of our outcomes, that reported on skin or site colonisation and dressing durability, were poorly reported. CVC catheter security was not adequately addressed by the included studies. Considering the serious consequences associated with accidental CVC removal due to poor security, this is an outcome that needs to be investigated.

Quality of the evidence

Risk of bias was difficult to assess in most studies because of poor reporting. Since it was not possible to blind personnel or participants to the CVC dressing and securement product, there was a potential source of performance bias and staff or patients may have behaved differently given knowledge of the intervention; this seems unlikely however. Blinding of outcome assessors was feasible for the primary outcome, but was achieved and reported adequately by only six of the studies (Arvaniti 2012; de Barros 2009; Nikoletti 1999; Ruschulte 2009; Timsit 2009; Timsit 2012). Only two studies achieved and reported the minimisation of selection bias adequately via both random sequence generation and allocation concealment (Garland 2001; Yamamoto 2002). Several of the trials reported receiving partial or full manufacturer sponsorship (Garland 2001; Shivnan 1991; Timsit 2012; Wille 1993; Yamamoto 2002), however it is unclear whether this had an impact on the reported results. It is common within the field of intravascular device research for investigators to receive partial or full sponsorship for the completion of research. The funnel plot did not reveal any underlying positive or negative publication bias.

Potential biases in the review process

We followed clearly described procedures to prevent potential bias in the review process. The comprehensive search of multiple sources and the methods we used are transparent and reproducible. Claire Rickard and Amanda Ullman have received research funding from Centurion Medical Products (Williamston, MI) that is unrelated to this review; products manufactured by Centurion Medical Products are not included within this review. The other review authors have not reported any conflict of interest.

Agreements and disagreements with other studies or reviews

The previous version of this review 'Gauze and tape and polyurethane dressings for CVC' identified a four-fold increase in the rate of catheter-related BSI when a polyurethane dressing was used, compared with gauze and tape (Webster 2011). However, with the widening of the inclusion criteria to include recently published research and participants in community settings, this difference has ceased to be significant.

The Centres for Disease Control and Prevention (CDC) recommend the use of either a sterile gauze or SPU dressing to cover the CVC site (O'Grady 2011). By comparison, 'epic3', the English national evidence-based guidelines (Loveday 2014), recommend the use of SPU, unless the insertion site is perspiring profusely or the insertion site is bleeding or leaking. Both the CDC and epic3 guidelines advocate the use of a CGI dressing as a strategy to reduce catheter-related BSI, but CDC recommend CGI dressings only for temporary short-term catheters in patients over two months of age and then only if the central line-associated BSI rate is not decreasing despite adherence to basic prevention methods.

Our review suggests that catheter-related BSI may be reduced with CGI compared with SPU, and that the risk of catheter-related BSI is reduced with medication-impregnated dressings compared with all others. Additionally, we identified a reduction in the incidence of catheter tip colonisation when using a CGI dressing compared to SPU. A previous meta-analyses, Ho 2006, that compared the effectiveness of CGI dressings to SPU for intravascular and epidural catheters had similar results. That meta-analysis identified a significant reduction in intravascular catheter or exit-site bacterial colonisation for CGI dressings compared to SPU (14.8% versus 26.9%; odds ratio (OR) 0.47, 95% CI 0.34 to 0.65; P value < 0.00001) and a trend towards a reduction in intravascular catheter-related BSI or central nervous system infection (2.2% versus 3.8%; OR 0.58, 95% CI 0.29 to 1.14; P value 0.11). Participants who had their intravascular and epidural catheters dressed with a CGI dressing had a significantly increased rate of local cutaneous reactions in comparison to those dressed with SPU (OR 8.17, 95% CI 1.19 to 56.14, P value 0.04), and the majority of these reactions occurred in neonatal patients.

A recent meta-analysis, Safdar 2014, evaluated the efficacy of CGI dressing compared to 'conventional' dressings for CVC, pulmonary artery or peripheral arterial catheters. This analysis identified that the use of a CGI dressing compared to a 'conventional' dressing reduced the risk of catheter-related BSI (RR 0.60, 95% CI 0.41 to 0.88; P value 0.009) and catheter colonisation (RR 0.52, 95% CI 0.43 to 0.64; P value < 0.001). These results agree with this review, even with the inclusion of pulmonary artery and arterial catheters, in addition to CVC.

AUTHORS' CONCLUSIONS

Implications for practice

There is some evidence that chlorhexidine-impregnated (CGI) dressings used for securing central venous catheters may reduce the risk of catheter-related BSI, compared with standard polyurethane (SPU) dressings and other (non-impregnated) dressing types. This evidence mainly comes from intensive care unit settings.

The evidence for the relative effects of different dressing and securement comparisons, including gauze and tape versus SPU, on catheter tip colonisation and catheter-related BSI is unclear.

There was inadequate research to permit us to make recommendations about CVC security using the different dressing and securement products.

Implications for research

More, high quality research is needed regarding the relative effects of dressing and securement products for CVCs. New products are continually becoming commercially available, and researchers need to provide the evidence to inform clinical decision making in this area. Clinically important outcomes including CVC security, have not been adequately addressed by current research.

Future research may adjust the estimates of effect for the products included in this review. Researchers should plan their protocols so that the risk of bias in each domain is minimised and should report trials clearly in accordance with the CONSORT guidelines (Schulz 2010).

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Arvaniti 2012

Methods	RCT in 5 ICUs in Greece
Participants	306 participants admitted to ICUs requiring a multilumen CVC Inclusion criteria: • CVC predicted to stay in ICU patient for ≥ 3 days • first CVC in ICU Exclusion criteria: • < 18 years • neutropenic patients • pregnant women • patients with an expected ICU stay of < 3 days • known allergy to silver or chlorhexidine
Interventions	Group I: SPU changed every 3 days or sooner if spoiled or contaminated Group II: SPU and a chlorhexidine-impregnated sponge (Biopatch™) changed every 7 days Both groups had sterile gauze over the entry site for the first 24 hours
Outcomes	• Catheter-related BSI • Catheter-tip colonisation • Catheter security • Mortality
Notes	Group III: Additional 159 participants not included in the review: silver-impregnated CVC (Oligon™) due to co-intervention.

Arvaniti 2012 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "patients were randomly allocated to one of the three groups, separately for each participating ICU, and according to computer-generated randomization sequences" (p 421)
Allocation concealment (selection bias)	Unclear risk	Quotation: "The randomization number and the corresponding study group were sealed in envelopes in numeric order. Envelopes were posted to the ICUs with accompanying instructions to be opened by respecting their numerical order" (p 421) Not stated if envelopes were opaque
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quotation: "Double-blind design was not possible as a result of apparent differences between the compared products" (p 421)
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quotation: "Two ICU infectious diseases experts scrutinized all data blinded to the randomization group to identify concomitant infections and avoid erroneous attribution of the recorded events to the study catheters" (p 422)
Incomplete outcome data (attrition bias) All outcomes	Low risk	Well described attrition data; loss to follow up for catheter tip colonisation outcome 19.1% (figure 1; p 422) Intention-to-treat analysis undertaken. Quotation: "data were also analyzed as per protocol analysis in which all uncultured catheters were considered missing" (p 422)
Selective reporting (reporting bias)	Unclear risk	No clinical trial registration or published protocol All outcomes reported as described in publication
Other bias	Unclear risk	Significant difference between groups for patient age (p 423)

Brandt 1996

Methods	RCTl in the USA
Participants	101 participants undergoing autologous BMT with newly inserted long-term triple-lumen, tunnelled Hickman™ CVCs Inclusion criteria: • > 18 years old • alert, orientated, able to give informed consent • admitted to the BMT unit for autologous BMT • surgical insertion of a long-term CVC in the operating room Exclusion criteria: • pre-existing bacteraemia or fungaemia within 14 days of study entry • CVC placement was intended to be short-term

Brandt 1996 *(Continued)*

Interventions	Group I: SPU (Opsite 3000™; Smith and Nephew) moisture vapour permeable dressing changed every 7 days Group II: sterile gauze with tape changed daily
Outcomes	• Catheter-related BSI • Entry- and exit-site infection • Failed catheter security
Notes	Dressing condition/durability reported: did not use a tool with established validity and reliability

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "subjects were randomly assigned" (p 830)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up reported. Less than 10% attrition. Not stated whether intention-to-treat analysis was used
Selective reporting (reporting bias)	Unclear risk	No clinical trial registration or published protocol
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (p 832)

Carrer 2005

Methods	Randomised, factorial controlled trial in a single Italian ICU
Participants	82 participants admitted to a medical-surgical ICU Inclusion criteria: • non-tunnelled CVC • predicted dwell time of > 72 hours Exclusion criteria: not reported
Interventions	Group I: gauze and tape with low sterile barrier Group II: transparent simple polyurethane (SPU) with low sterile barrier Group III: gauze and tape with maximum sterile barrier

Carrer 2005 *(Continued)*

	Group IV: SPU with maximum sterile barrier For the purposes of the review: Groups I and III (gauze) were combined and Groups II and IV (SPU) were combined
Outcomes	Skin/site colonisation
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not reported Quotation: "patients were randomly subdivided in four groups" (p 198)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	Large attrition rate in some groups, which are not accounted for in analysis. Intention-to-treat analysis not used
Selective reporting (reporting bias)	High risk	Catheter-related BSI: information collected, but not presented by intervention group
Other bias	Unclear risk	Baseline balance of groups: Quotation: "Groups were homogenous" (p 199) Multiple CVCs per participant recruited, analysis per CVC

Chambers 2005

Methods	RCT in a single site in New Zealand
Participants	95 participants admitted to a haematology unit Inclusion criteria: • admitted to a haematology unit and undergoing chemotherapy • tunnelled, cuffed CVC • adult Exclusion criteria: • unable to give informed consent • known allergy to chlorhexidine

Chambers 2005 *(Continued)*

Interventions	Group I: no dressing Group II: CGI dressings consisting of a 2.5 cm hydrophilic polyurethane foam disk containing chlorhexidine gluconate in a sustained-release formulation, with a SPU (Opsite IV3000^{TM}), changed weekly or as needed until catheter removal Both groups had sterile gauze and SPU applied until the exit site was dry and free from exudate
Outcomes	• Catheter-related BSI • Entry- and exit-site infection • Mortality
Notes	Patients recruited more than once: CVC unit of analysis

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not reported
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quotation: "the clinical team was not blinded to treatment" (p 59)
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported Quotation: "all cases of infection were initially classified by three investigators (STC, RLS and JS) and were later reviewed independently by another investigator (PG)" (p 56)
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Well described attrition data: complete data were not available on 2 participants, 1 from each group, who left the hospital and continued treatment elsewhere (p 57). Intention-to-treat analysis described
Selective reporting (reporting bias)	High risk	No clinical trial registration or published protocol Catheter tip colonisation not fully described per study group
Other bias	Unclear risk	Minimal information of patient characteristics described, not clear whether groups balanced at baseline

Conly 1989

Methods	RCT in a single site in Canada
Participants	79 participants admitted to medical, surgical, paediatric or ICU Inclusion criteria: • admitted to any medical, surgical or paediatric ward or ICU • CVC inserted for a duration ≥ 3 days

Conly 1989 *(Continued)*

	Exclusion criteria: • CVCs for short term haemodynamic monitoring
Interventions	Group I: dry gauze and tape Group II: SPU (Opsite™) A pressure dressing was allowed for the first 24-48 hours for both groups
Outcomes	• Catheter-related BSI • Catheter tip colonisation
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Quotation: "were prospectively randomized"; "patients were randomly assigned by hospital number" (p 310)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	Large amounts of attrition and missing data not adequately described by the manuscript; including outcome data
Selective reporting (reporting bias)	High risk	No clinical trial registration or published protocol Skin/site colonisation not described by study group - outcome could not be included in the review
Other bias	High risk	Groups not balanced at baseline including higher ICU admission, steroid usage and jugular vein insertion in the gauze group. This may have resulted in a higher risk of catheter-related BSI and catheter tip colonisation in this group Patients recruited once, but multiple CVCs included. CVC unit of analysis

de Barros 2009

Methods	RCT in Spain
Participants	66 participants with long-term CVCs for haemodialysis Inclusion criteria: • internal jugular CVC for haemodialysis treatment inserted by nephrologists

de Barros 2009 *(Continued)*

	• end-stage renal disease Exclusion criteria: • acute renal failure undergoing dialysis via a femoral CVC
Interventions	Group I: SPU (Tegaderm™; 3M) changed every 7 days or as needed Group II: sterile gauze with tape changed at each dialysis session
Outcomes	• Catheter-related BSI • Catheter tip colonisation • Failed catheter security
Notes	One CVC per participant only

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "a random list of dressings was used to divide 66 patients in two groups (33 in group 1 and 33 in group 2" (p 482)
Allocation concealment (selection bias)	Unclear risk	Quotation: "the sequences of dressings were kept in a locked envelope. If the patient was eligible... the envelope containing dressing sequences was opened and the following indicated intervention was performed" (p 482) Not reported whether the envelope was opaque
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quotation: "the microbiologists processed the samples without knowing how patients were allocated in the study" (p 483)
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up reported. Not stated whether intention-to-treat analysis was used
Selective reporting (reporting bias)	Unclear risk	No clinical trial registration or published protocol
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (p 484)

Garland 2001

Methods	RCT in 6 neonatal ICUs in the USA
Participants	705 participants admitted to a neonatal ICUs Inclusion criteria: • neonates who would likely require a CVC for at least 48 hours • percutaneous and surgically inserted

Garland 2001 *(Continued)*

	Exclusion criteria: not clearly reported. Changed after 15 months of study recruitment related to adverse reactions; infants < 26 weeks who required a CVC before 1 week of age were excluded
Interventions	Group I: SPU cleansed with 10% povidone iodine. Percutaneous CVC dressings were changed every 7 days, surgically inserted CVC dressings were changed twice weekly Group II: CGI dressing (Biopatch™) with 250 µg/mg of chlorhexidine gluconate and SPU. Cleansed with 70% isopropyl. Both percutaneous and surgically inserted CVC dressings were changed weekly
Outcomes	• Catheter-related BSI • Catheter-tip colonisation • Skin irritation or damage: severe contact dermatitis
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "neonates were block randomized" (p 1431) Quotation: "computer generated randomization codes developed by the study statistician were maintained by center pharmacists" (p 1432)
Allocation concealment (selection bias)	Low risk	Quotation: "maintained by the pharmacy at hospital" (p 1432)
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not stated
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Similar attrition rates for loss to follow-up in both groups; microbial analysis of catheter colonisation not performed 8% of SPU group, 6% of CGI group
Selective reporting (reporting bias)	Unclear risk	Not registered as a clinical trial, no published protocol Reported all outcomes described in publication
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (table 1) Confounding differences in interventions: 10% povidone-iodine for skin antisepsis in Group I; 70% isopropyl for skin antisepsis in Group II. Funded by product company (Johnson and Johnson™) who manufacture the products used in both intervention and control arms

Giles 2002

Methods	RCT in a general surgery department in Turkey
Participants	72 participants with single-lumen polyurethane CVCs inserted pre-operatively

Giles 2002 *(Continued)*

	Inclusion criteria: not clearly outlined Quotation: "patients undergoing surgical procedures for various benign or malignant gastrointestinal disorders" (p 256) Quotation: "the aims of CVC insertion were either for monitoring or TPN administration" (p 256) Exclusion criteria: not reported
Interventions	Group I: transparent occlusive dressing changed every 7 days unless signs of local inflammation Group II: sterile gauze changed daily and insertion site cleaned by 10% povidone-iodine solution
Outcomes	• Catheter-related BSI • Catheter tip colonisation • Skin/site colonisation
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not reported Quotation: "according to the number patient on the random table" (p 256)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing data. No loss to follow-up
Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol. All reported outcomes described
Other bias	Unclear risk	Groups are balanced at baseline; no statistically significant difference between groups

Hagerstrom 1994

Methods	RCT in Sweden in 2 dialysis units
Participants	14 participants with long-term CVCs for haemodialysis Inclusion criteria: • requiring haemodialysis treatment for renal insufficiency

Hagerstrom 1994 *(Continued)*

	Exclusion criteria: not reported
Interventions	Group I: SPU (OpSite IV3000™) changed after haemodialysis procedure (approximately twice/week) Group II: sterile gauze with tape changed after haemodialysis procedure (approximately twice/week)
Outcomes	Catheter-related BSI
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "were randomised to one of the two dressing treatment groups" (study design section)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Attrition and loss to follow-up were not reported
Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol. All reported outcomes described
Other bias	Unclear risk	No description of baseline participant comparison

Hill 2010

Methods	RCT in a neonatal ICU in the USA
Participants	100 participants admitted to a neonatal ICU Inclusion criteria: • admitted to neonatal ICU for at least 72 hours • requiring a PICC to be placed Exclusion criteria: • CVC in situ, pre-existing skin condition or discolouration
Interventions	Group I: SPU (Tegaderm™; 3M). Dressings changed every 3 weeks, unless otherwise indicated

Hill 2010 *(Continued)*

	Group II: silver-impregnated dressing (Algidex Ag IV PATCH™) secured with a steri strip. The patch, extraluminal catheter and exit site were then covered with a SPU dressing (Tegaderm™; 3M™). Dressings changed every 2 weeks, unless otherwise indicated
Outcomes	• Skin irritation or damage: signs of redness, swelling or discolouration • Mortality
Notes	Catheter-related BSI was a secondary outcome of study, but was not defined

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "computer randomization" (p 471)
Allocation concealment (selection bias)	Unclear risk	Quotation: "envelopes containing the status were assembled unknown to the principal investigator and study nurse. After each patient was enrolled, the envelope with the number corresponding to order of enrolment was opened and the patient was placed in their assigned group" (p 470) Not stated if the envelopes were opaque
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not blinded. Quotation: "To assess skin safety, the bedside nurse evaluated the skin under the transparent dressing at least twice daily and documented any signs of redness, swelling or discoloration" (p 471)
Blinding of outcome assessment (detection bias) All outcomes	High risk	Not blinded. Quotation: "To assess skin safety, the bedside nurse evaluated the skin under the transparent dressing at least twice daily and documented any signs of redness, swelling or discoloration" (p 471)
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcome data adequately described. No reported loss to follow-up
Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol. All reported outcomes described
Other bias	High risk	Baseline imbalances on several variables including gender, age and birthweight

le Corre 2003

Methods	RCT in Canada
Participants	58 participants with long-term CVCs for haemodialysis Inclusion criteria: • > 18 years old • requiring haemodialysis treatment for chronic terminal renal insufficiency • tunnelled jugular CVC inserted by vascular radiologist • competent to provide informed consent Exclusion criteria:

le Corre 2003 *(Continued)*

	• receiving systemic antibiotic therapy • history of bacteraemia within previous 3 months without change of CVC
Interventions	Group I: SPU (Tegaderm™; 3M) changed every 7 days Group II: sterile gauze with tape changed every 2-3 days
Outcomes	Catheter-related BSI
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "computer generated 1:1 ratio" (p 57)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quotation: "open-label" (p 57)
Blinding of outcome assessment (detection bias) All outcomes	High risk	Quotation: "open-label" (p 57)
Incomplete outcome data (attrition bias) All outcomes	High risk	Large amount of attrition. Only 58/62 were included in final analysis; intention-to-treat not used. 17 not followed up to removal at 6 months
Selective reporting (reporting bias)	Unclear risk	Not registered as a clinical trial, no published protocol
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (table 1)

Levy 2005

Methods	RCT in a single paediatric cardiac ICU in Israel
Participants	145 participants admitted to the paediatric cardiac ICU Inclusion criteria: • 0-18 years age • Require a CVC for > 48 hours • Inserted in an operating theatre by an anaesthetic specialist Exclusion criteria: not reported
Interventions	Group I: SPU (Tegaderm™; 3M) only changed when required (e.g. mechanical complication, bleeding, oozing, signs of exit-site infection)

Levy 2005 *(Continued)*

	Group II: CGI (Biopatch™) and SPU only changed when required (e.g. mechanical complication, bleeding, oozing, signs of exit-site infection)
Outcomes	• Catheter tip colonisation • Skin irritation or damage: contact dermatitis
Notes	Catheter-related BSI: data collected as a secondary outcome, but study definition did not match review definition

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "Random number generator" (p 677)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not blinded. Quotation: "The CVC insertion site was inspected daily by the nursing staff and by the study investigators (O.D.) for adverse events" (p 677)
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Quotation: "the microbiology laboratory personnel were blinded and could not identify which group the CVC had been randomized" (p 677) Skin irritation outcome assessor not blinded
Incomplete outcome data (attrition bias) All outcomes	High risk	Significant attrition and loss to follow-up. Post-randomization attrition information not provided by group
Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol Exit-site infection rates were not reported in results section
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (p 678)

Nikoletti 1999

Methods	RCT in an adult ICU in Australia
Participants	150 participants with CVCs inserted in ICU Inclusion criteria: • ≥ 18 years old • insertion of a multilumen CVC in ICU Exclusion criteria: • CVC inserted for < 24 hours • inserted outside ICU • inserted via guidewire exchange • tunnelled or implanted CVCs

Nikoletti 1999 *(Continued)*

Interventions	Group I: SPU (Tegaderm™; 3M) changed every 5 days or earlier if soiled or nonadherent Group II: hydrocolloid dressing (Comfeel™) changed every 5 days or earlier if soiled or nonadherent
Outcomes	Catheter-tip colonisation
Notes	Catheter-related BSI and skin colonisation outcomes were described, but did not meet the review's outcome definition

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Not described in publication Correspondence with authors: "computer generated random numbers"
Allocation concealment (selection bias)	Unclear risk	Not reported in publication or correspondence with authors
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not described in publication Correspondence with authors: "participants and clinicians were not blinded"
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Not described in publication Correspondence with authors: "blinded microbiological outcome assessment"
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Large amounts of missing data and attrition. The majority was well described in the publication
Selective reporting (reporting bias)	Unclear risk	Protocol well described, but not published. Not registered as a clinical trial
Other bias	Low risk	Baseline balance of groups: no statistically or clinically significant differences in age, critical illness severity, length of hospital stay (Table 2, p 491)

Olson 2004

Methods	RCT in an inpatient and outpatient oncology setting in Canada
Participants	78 participants undergoing treatment for cancer Inclusion criteria: • 18-75 years old • life expectancies of 6 months or more • receiving their first CVC • double or triple lumen CVC • available for follow-up • visually and cognitively competent • able to read and write English

Olson 2004 *(Continued)*

	Exclusion criteria:not stated
Interventions	Group I: sterile gauze dressing, changed daily if neutropenic or every second day if not neutropenic; cleansed with 4% chlorhexidine in 70% alcohol Group II: no dressing Both groups were treated as if in Group I until day 21 post CVC insertion, when they were randomised
Outcomes	Catheter-related BSI
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Not stated in publication Private correspondence with authors: "computer generated sequence"
Allocation concealment (selection bias)	Unclear risk	Not stated in publication Private correspondence with authors: "envelopes", not stated if opaque
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants and family members cared for the CVC dressing and securement regimen throughout the study (p 38)
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No attrition or loss-to-follow up data provided
Selective reporting (reporting bias)	High risk	Outcomes of catheter-tip colonisation and skin/site colonisation were not reported No clinical trial registration or published protocol
Other bias	Unclear risk	Trial stopped recruitment early for unknown reasons

Pedrolo 2011

Methods	RCT in Brazil
Participants	21 participants admitted to ICU Inclusion criteria: • > 18 years • non-tunnelled CVCs • recruited within 24 hours of ICU admission or 8 hours of CVC insertion

Pedrolo 2011 *(Continued)*

	Exclusion criteria: not reported
Interventions	Group I: SPU (Tegaderm™; 3M) changed every 7 days or when exudate or displacement made it necessary Group II: sterile gauze with tape changed daily
Outcomes	• Catheter-related BSI • Catheter tip colonisation • Dressing condition durability defined: quotation: "fixation to the skin" (p 280) • Skin irritation or damage: quotation: "local reaction to dressing was verified through skin exfoliation, maceration and/or allergic reactions presented where the selected material was in contact with the skin" (p 280)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "a drawing was performed to allocate individuals in the control or study groups" (p 279)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quotation: "all catheters were observed until removed and there was no loss to follow up" (p 280)
Selective reporting (reporting bias)	Unclear risk	Not registered as a clinical trial, no published protocol
Other bias	Unclear risk	No description of participant population for baseline variability; catheter data only

Roberts 1998

Methods	RCT in a single ICU in Australia
Participants	33 participants admitted to ICU Inclusion criteria: • CVCs inserted in ICU Exclusion criteria: not reported

Roberts 1998 *(Continued)*

	Participants could be recruited more than once. Unit of analysis was the CVC not the participant
Interventions	Group I: SPU (Opsite IV3000™), changed and cleansed with 0.5% chlorhexidine in 70% alcohol every 5 days and as necessary Group II: CGI dressing (Biopatch™) with SPU (Opsite IV3000™), changed and cleansed with 0.5% chlorhexidine in 70% alcohol every 5 days and as necessary
Outcomes	• Catheter tip colonisation • Exit-site infection
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "Randomly assigned to either the experimental or the control group"
Allocation concealment (selection bias)	Unclear risk	Not stated
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not stated
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	High risk	Missing data on 7/40 participants, attrition not well described
Selective reporting (reporting bias)	High risk	Did not report catheter-related infection outcomes No registration of clinical trial or published protocol
Other bias	Unclear risk	Baseline balance of groups: no statistically or clinically significant differences in age, gender, CVC duration. Other clinical variables (e.g. critical illness severity) not stated (p 17)

Ruschulte 2009

Methods	RCT in Germany
Participants	601 participants with haematological and oncological conditions Inclusion criteria: • triple lumen, jugular or subclavian CVCs, inserted by anaesthetic consultants • undergoing chemotherapy for treatment of haematological and oncological conditions Exclusion criteria:

Ruschulte 2009 *(Continued)*

- expected admission for ≤ 5 days
- previous reaction to chlorhexidine

Interventions	Group I: SPU changed regularly after 7 days or if they had been lifted Group II: CGI dressing (Biopatch™) with SPU. Changed regularly after 7 days or if they had been lifted
Outcomes	Catheter-related BSI
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not stated
Allocation concealment (selection bias)	Unclear risk	Not stated
Blinding of participants and personnel (performance bias) All outcomes	High risk	Personnel and participants were not blinded. Quotation: "The insertion sites were inspected and palpated daily by the specialist oncology nurses" (p 268)
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "by having nurses who were not involved in the study assess the insertion sites and microbiologists unaware of the patients' group assignments" (p 271)
Incomplete outcome data (attrition bias) All outcomes	Low risk	No attrition or loss to follow-up
Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol
Other bias	Unclear risk	Baseline balance of groups: no statistically or clinically significant differences in age, gender, neutropenia, CVC duration (table 1, p 269)

Shivnan 1991

Methods	RCT in the USA
Participants	98 participants undergoing autologous or allogenic BMT with pre-existing or newly inserted right atrial CVCs Inclusion criteria: • 2-60 years old • haematologic malignancy or immune-deficiency disease • pre-existing or newly inserted right atrial CVC • admitted to the BMT unit for autologous or allogenic BMT Exclusion criteria: not described

Shivnan 1991 *(Continued)*

Interventions	Group I: SPU (Tegaderm™ 3M) changed every 4 days Group II: sterile gauze with tape changed daily Both groups received gauze for the first 24 hours
Outcomes	• Catheter-related BSI • Entry- and exit-site infection • Skin/site colonisation: day 8 of study
Notes	Many skin colonisation dates reported; short term (day 8) colonisation reported within the review.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quotation: "block randomisation within each stratum" (p 1350)
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	5/103 excluded post-randomisation 27.5% required modifications of the dressing Not stated whether intention-to-treat analysis was used
Selective reporting (reporting bias)	Unclear risk	No clinical trial registration or published protocol Main study aims were assessed and reported
Other bias	Unclear risk	Baseline balance of groups: no statistically significant differences (p 1352) Sponsored by product manufacturer (3M Company™, St. Paul, MN) manufacturer of the SPU intervention No data on topical vancomycin use and dressing modification for each group

Timsit 2009

Methods	RCT in France
Participants	2051 participants in ICUs Inclusion criteria: • CVCs or arterial catheters for > 48 hours

Timsit 2009 *(Continued)*

	• > 18 years Exclusion criteria: • PICC • pulmonary arterial catheters • haemodialysis catheters • allergy to study products
Interventions	Group I: SPU dressing (Tegaderm™; 3M) changed every 3 or 7 days Group II: CGI sponge dressing (BioPatch™; Ethicon Inc) with SPU changed every 3 or 7 days
Outcomes	• Catheter-related BSI • Catheter-related BSI per 1000 catheter days • Catheter tip colonisation
Notes	Published manuscript includes arterial lines; additional information provided to report CVC-only results

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "The randomization schedule, stratified by ICU, was developed using a web-based random-number generator to select permuted blocks of 8 patients each" (p 1232)
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quotation: "The study was not blinded for the investigators or ICU staff" (p 1232) Not described for participants
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Was blinded for the microbiologists processing the skin and catheter cultures and for the assessors" (p 1232)
Incomplete outcome data (attrition bias) All outcomes	Low risk	Moderate attrition, well described in CONSORT diagram (Figure 1; p 1235)
Selective reporting (reporting bias)	Unclear risk	Difficult to obtain separated CVC outcomes, not originally reported Clinical trial registered via clinicaltrials.gov
Other bias	Unclear risk	Baseline variables not reported for CVC outcomes. Balanced critical illness severity, length of ICU stay, mechanical ventilation, age for overall study as per Table 1 (p 1236)

Timsit 2012

Methods	RCT in France

Timsit 2012 *(Continued)*

Participants	1879 participants in ICUs Inclusion criteria: • CVCs or arterial catheters for > 48 hours • > 18 years Exclusion criteria: • PICC • pulmonary arterial catheters • haemodialysis catheters • allergy to study products • catheters inserted before ICU admission
Interventions	Group I: SPU dressing (Tegaderm™; 3M) Group II: CGI dressing (Tegaderm CHG IV Securement Dressing™; 3M) Group III: highly adhesive transparent dressing (Tegaderm HP Transparent™; 3M)
Outcomes	• Catheter-related BSI • Catheter-related BSI per 1000 catheter days • Catheter tip colonisation
Notes	Published manuscript includes arterial lines; additional information provided to report CVC-only results

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quotation: "Randomization was by a web-based random-number generator producing permuted blocks of eight, with stratification on ICUs. Each block contained four allocations to the chlorhexidine dressing, two to the highly adhesive dressing and two to the standard dressing. The investigators were unaware of the block size and of the permutation procedure" (p 1273)
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quotation: "The study was not blinded for the investigators or ICU staff" (p 1273) Not described for participants
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quotation: "was blinded for the microbiologists processing the skin and catheter cultures and for the adjudication committee" (p 1273)
Incomplete outcome data (attrition bias) All outcomes	Low risk	Moderate attrition, well described in CONSORT diagram (Figure 1; p 1275) Quotation: "Analyses were performed in the intent-to-treat population, which included all patients except those who withdrew their consent to study participation." (p 1274)
Selective reporting (reporting bias)	Unclear risk	Difficult to obtain separated CVC outcomes, not originally reported

Timsit 2012 *(Continued)*

		Clinical trial registered via clinicaltrials.gov
Other bias	Unclear risk	Baseline variables not reported for CVC outcomes – balanced for overall study Supported by 3M (St Paul, MN); the manufacturer of all of the study interventional products

Wille 1993

Methods	RCT in the Netherlands
Participants	101 adult participants requiring a subclavian or jugular CVC Inclusion criteria: • age > 16 years, • hospitalised for major elective surgery Exclusion criteria: not stated
Interventions	Group I: SPU (OpSite^{TM}; Smith and Nephew) with moisture vapour permeability of 800 g m^{-2}. Changed regularly every 3 days. Group II: new generation SPU (OpSite IV3000^{TM}; Smith and Nephew) with increased moisture vapour permeability (2000 g m^{-2}). Dressing changed every 3 days
Outcomes	Catheter-related BSI
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not described Quotation: "the patients were randomized to one of the two dressing groups" (p 114)
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Attrition poorly described. No information on missing data Quotation: "the 13 patients not included in the analysis were evenly distributed between the two dressing groups" (p 115)

Wille 1993 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol. All outcomes described in publication
Other bias	Unclear risk	No data on co morbidities or severity of illness Sponsored by Smith & Nephew™, Harlow, UK - product manufacturer of both intervention groups

Yamamoto 2002

Methods	RCT in the USA
Participants	170 adult participants requiring a peripherally inserted central catheter (PICC) Inclusion criteria: not stated Exclusion criteria: not stated
Interventions	Group I: securement via 2.0 prolene sutures and standard polyurethane dressing (SPU). Changed regularly every 3 days or more frequently if necessary Group II: securement via a SSD (StatLock™) and SPU. Dressing changed every 3 days, SSD every 6 days When participant discharged home, dressings changed weekly
Outcomes	• Catheter-related BSI • Skin irritation or damage: cellulitis; tenderness, erythema, oedema, purulent exudate (p 78) • Failed catheter securement: accidental removal or movement that resulted in the loss of function (p 78)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Not stated in publication Private correspondence: "using blinded envelopes"
Allocation concealment (selection bias)	Low risk	Quotation: "concealed envelopes distributed to research assistants" (p 78)
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not stated
Blinding of outcome assessment (detection bias) All outcomes	High risk	Outcome assessors for dislodgement and skin damage not blinded Not stated whether microbiology outcome assessors were blinded
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Loss to follow-up and attrition not stated

Yamamoto 2002 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	No registration of clinical trial or published protocol
Other bias	Unclear risk	Research sponsored by StatLock product manufacturer (Venetec International, San Diego, CA)

Abbreviations
BMT: bone marrow transplant
CGI: chlorhexidine-impregnated
CVC: central venous catheter
ICU: intensive care unit
PICC: peripherally-inserted central catheter
RCT: randomised controlled trial
SPU: standard polyurethane
SSD: sutureless securement device
TPN: total parenteral nutrition

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Crawford 2004	No outcomes that accorded with our review definitions: cost-related data only
Davidson 1986	No outcomes reported that accorded with our review definitions: no definitions of blood and skin cultures provided
Freiberger 1992	Results not reported by intervention group Skin/site swab with any bacterial growth included: not positive semi-quantitative (> 15 cfu) or quantitative (> 10^3 cfu) culture from the skin around the catheter site (O'Grady 2002)
George 2011	No outcomes reported that accorded with our review definitions: no definition or assessment tool to evaluate skin irritation or damage
Keenlyside 1991	No outcomes reported that accorded with our review definitions: no definition or assessment tool to evaluate dressing condition, skin irritation or damage
Keenlyside 1993	Duplicate publication from Keenlyside 1991: no outcomes that accorded with our review definitions
Khattak 2010	No outcomes that accorded with our review definitions: all blood cultures included, not catheter-related BSI
Lawson 1986	No outcomes that accorded with our review definitions: no definition or assessment tool to evaluate skin irritation, damage or infection
Little 1998	Inadequate data for extraction
Lucas 1996	No outcomes that accorded with our review definitions: no definition regarding microbiological criteria for skin/site colonisation
Madeo 1998	Arterial and CVC outcomes reported together; unable to extract CVC outcomes
Maki 1984	Not a RCT
Maki 2000	Arterial and CVC outcomes reported together; unable to extract CVC outcomes

Study	Reason for exclusion
Neufeld 1991	No outcomes that accorded with our review definitions: no definition regarding microbiological criteria for skin/site colonisation
Olson 2008	No outcomes as per our review definitions: outcome assessments used to describe skin irritation or damage did not have established reliability
Petrosino 1988	No outcomes that accorded with our review definitions: described skin/site colonisation without microbiological definition
Powell 1982	No outcomes that accorded with our review definitions. Catheter-related BSI not in accordance with review outcome definitions
Powell 1985	Extreme confounders involving the use of specific dosages of skin antisepsis and administration set change intervals within the interventions
Reynolds 1997	CCT not RCT (sequential assignment)
Schwebel 2012	No outcomes as per our review definitions: cost-related data only
Timsit 2010	No outcomes as per our review definitions: cost-related data only

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

Broadhurst 2014

Methods	
Participants	
Interventions	
Outcomes	
Notes	authors contacted for further information

Calvino 2014

Methods	
Participants	
Interventions	
Outcomes	
Notes	authors contacted for further information

Gu 2014	
Methods	
Participants	
Interventions	
Outcomes	
Notes	authors contacted for further information

Pedrolo 2014	
Methods	
Participants	
Interventions	
Outcomes	
Notes	authors contacted for further information

DATA AND ANALYSES

Comparison 1. Primary analysis

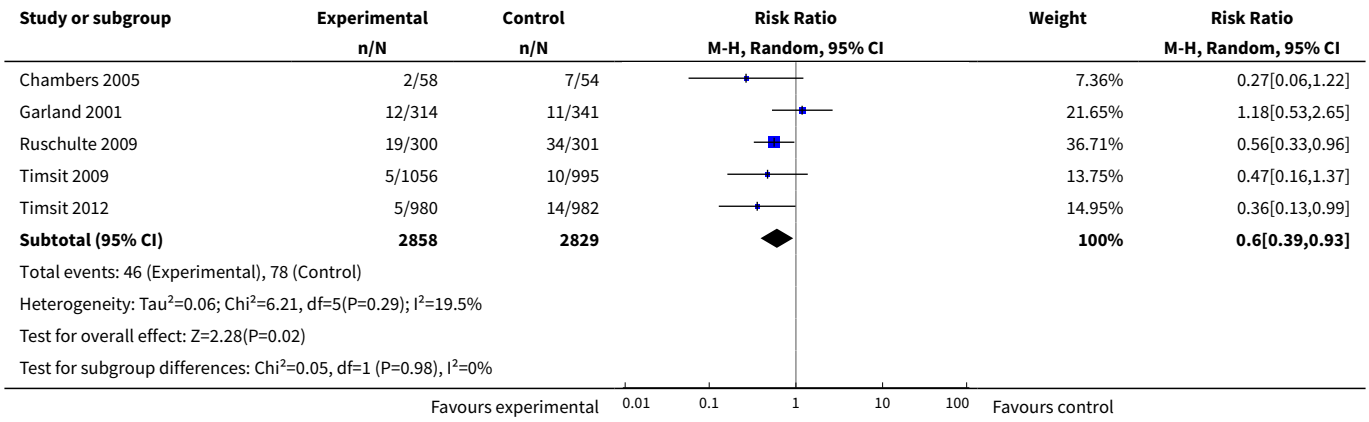
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Catheter-related blood stream infection	14		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
1.1 Gauze and tape versus SPU	8	506	Risk Ratio (M-H, Random, 95% CI)	0.64 [0.26, 1.63]
1.2 CGI versus SPU	5	4876	Risk Ratio (M-H, Random, 95% CI)	0.65 [0.40, 1.05]
1.3 Medication-impregnated dressings versus all others	6	5687	Risk Ratio (M-H, Random, 95% CI)	0.60 [0.39, 0.93]
2 Frequency of catheter-related BSI per 1000 patient days	6		Rate Ratio (Random, 95% CI)	Subtotals only
2.1 Gauze and tape versus SPU	2		Rate Ratio (Random, 95% CI)	0.71 [0.20, 2.52]
2.2 CGI versus SPU	4		Rate Ratio (Random, 95% CI)	0.51 [0.33, 0.78]
3 Catheter tip colonisation	11		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
3.1 Gauze and tape versus SPU	5	342	Risk Ratio (M-H, Random, 95% CI)	0.95 [0.51, 1.77]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
3.2 CGI versus SPU	6	4431	Risk Ratio (M-H, Random, 95% CI)	0.58 [0.47, 0.73]
4 Entry- and exit-site infection	2		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
4.1 Gauze and tape versus SPU	2	199	Risk Ratio (M-H, Random, 95% CI)	0.84 [0.34, 2.07]
5 Skin/site colonisation	2		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
5.1 Gauze and tape versus SPU	2	170	Risk Ratio (M-H, Random, 95% CI)	0.86 [0.30, 2.51]
6 Skin irritation or damage	2		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
6.1 CGI versus SPU	2	850	Risk Ratio (M-H, Random, 95% CI)	11.17 [0.84, 149.48]
7 Failed catheter securement	2		Risk Ratio (M-H, Random, 95% CI)	Subtotals only
7.1 Gauze and tape versus SPU	2	167	Risk Ratio (M-H, Random, 95% CI)	0.90 [0.33, 2.49]

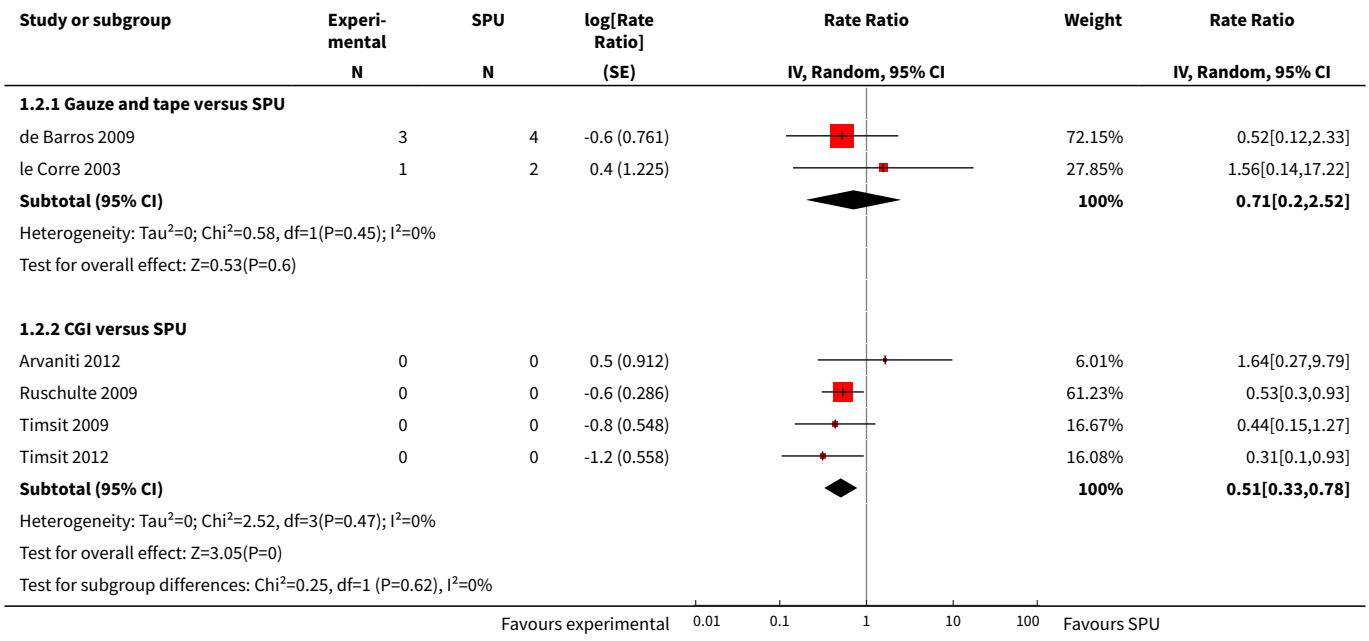
Analysis 1.1. Comparison 1 Primary analysis, Outcome 1 Catheter-related blood stream infection.

Study or subgroup	Experimental n/N	Control n/N	Risk Ratio M-H, Random, 95% CI	Weight	Risk Ratio M-H, Random, 95% CI
1.1.1 Gauze and tape versus SPU					
Brandt 1996	1/53	5/48		16.52%	0.18[0.02,1.5]
Conly 1989	0/34	7/42		9.82%	0.08[0,1.38]
de Barros 2009	3/33	4/33		31.27%	0.75[0.18,3.09]
Giles 2002	0/39	0/33			Not estimable
Hagerstrom 1994	2/7	0/7		9.54%	5[0.28,88.53]
le Corre 2003	2/29	1/29		13.76%	2[0.19,20.86]
Pedrolo 2011	1/10	1/11		11.16%	1.1[0.08,15.36]
Shivnan 1991	0/47	1/51		7.92%	0.36[0.02,8.65]
Subtotal (95% CI)	**252**	**254**		**100%**	**0.64[0.26,1.63]**
Total events: 9 (Experimental), 19 (Control)					
Heterogeneity: Tau^2=0.19; Chi^2=6.82, df=6(P=0.34); I^2=11.99%					
Test for overall effect: Z=0.93(P=0.35)					
1.1.2 CGI versus SPU					
Arvaniti 2012	3/150	2/156		6.77%	1.56[0.26,9.21]
Garland 2001	12/314	11/341		24.68%	1.18[0.53,2.65]
Ruschulte 2009	19/300	34/301		39.56%	0.56[0.33,0.96]
Timsit 2009	5/1056	10/995		16.16%	0.47[0.16,1.37]
Timsit 2012	5/980	5/283		12.84%	0.29[0.08,0.99]
Subtotal (95% CI)	**2800**	**2076**		**100%**	**0.65[0.4,1.05]**
Total events: 44 (Experimental), 62 (Control)					
Heterogeneity: Tau^2=0.08; Chi^2=5.38, df=4(P=0.25); I^2=25.58%					
Test for overall effect: Z=1.78(P=0.08)					
1.1.3 Medication-impregnated dressings versus all others					
Arvaniti 2012	3/150	2/156		5.57%	1.56[0.26,9.21]

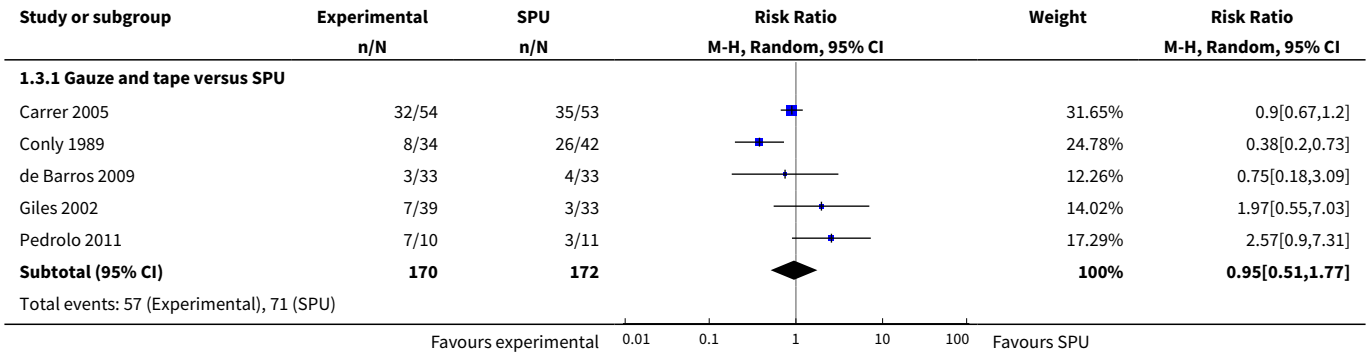
Favours experimental — Favours control

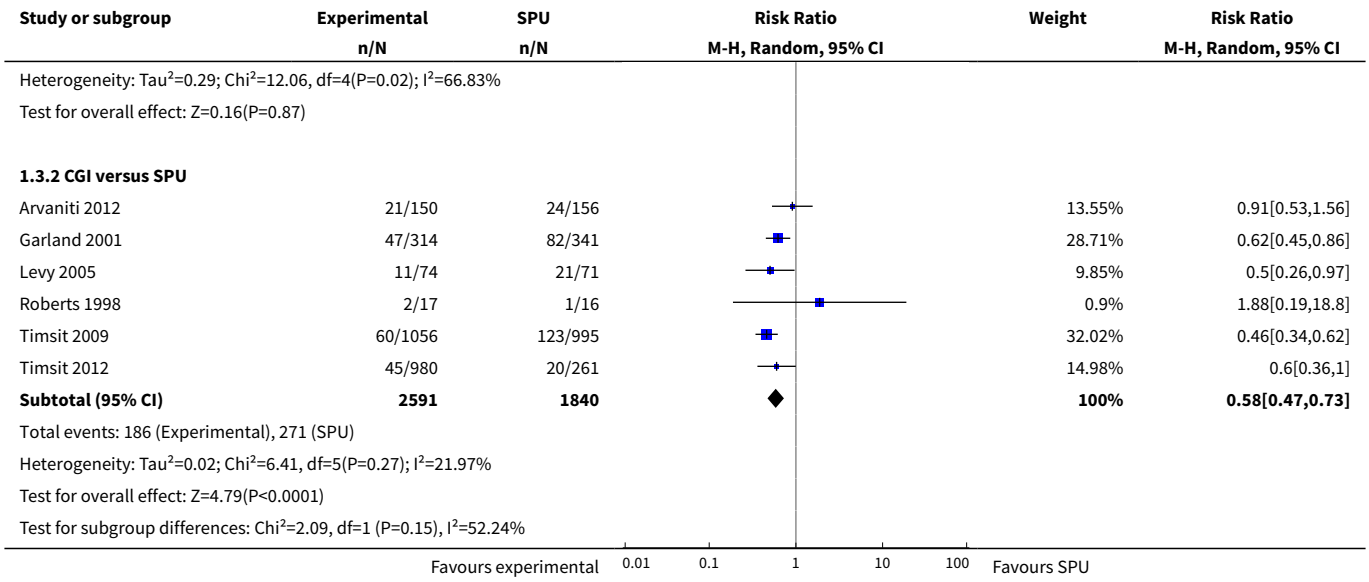


Analysis 1.2. Comparison 1 Primary analysis, Outcome 2 Frequency of catheter-related BSI per 1000 patient days.

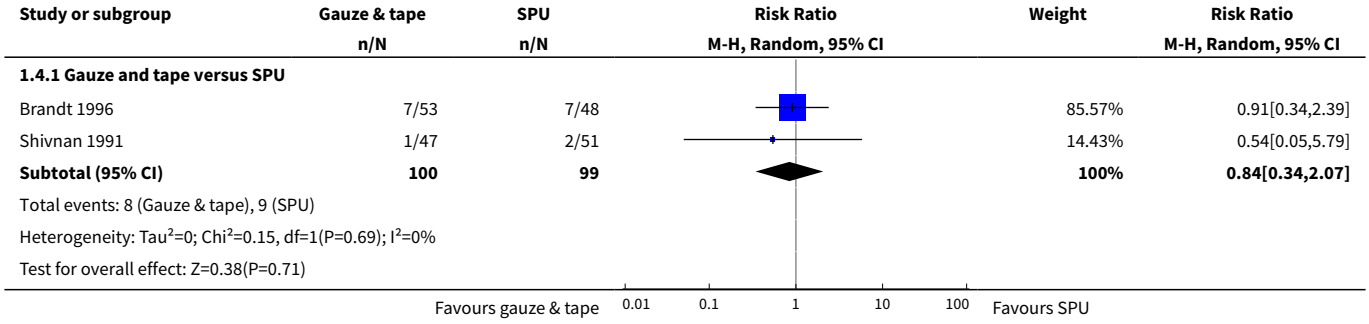


Analysis 1.3. Comparison 1 Primary analysis, Outcome 3 Catheter tip colonisation.

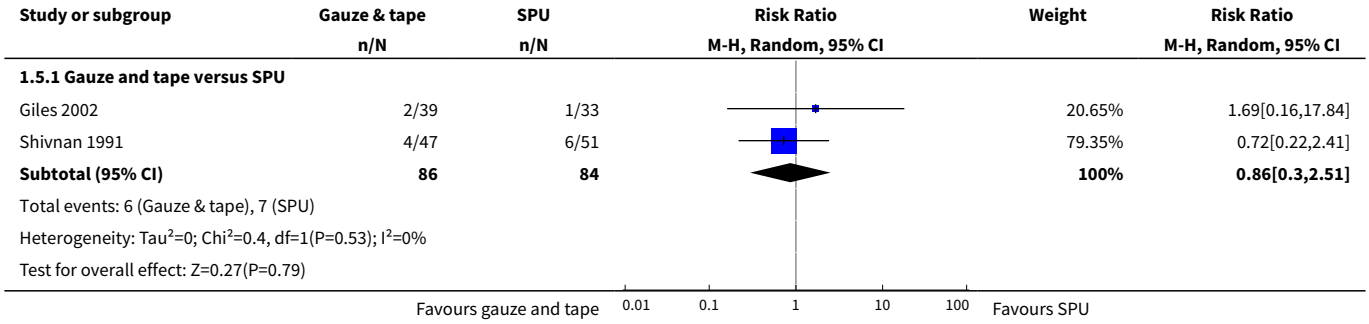




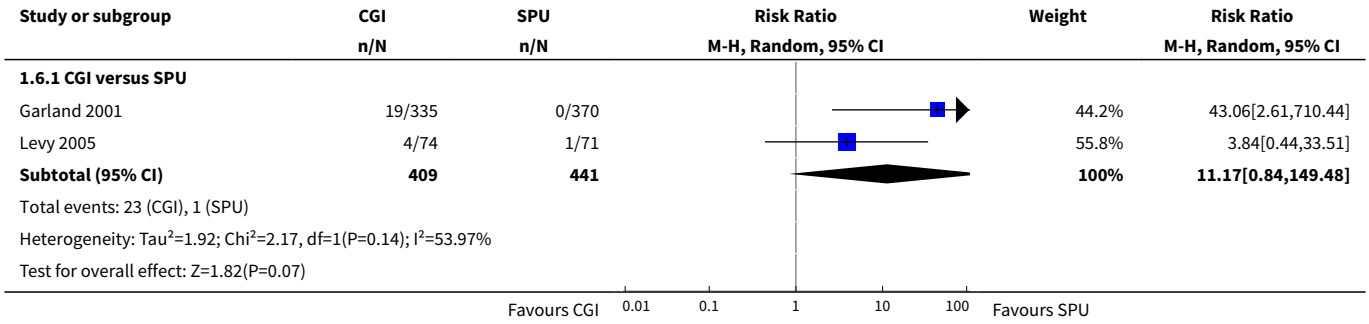
Analysis 1.4. Comparison 1 Primary analysis, Outcome 4 Entry- and exit-site infection.



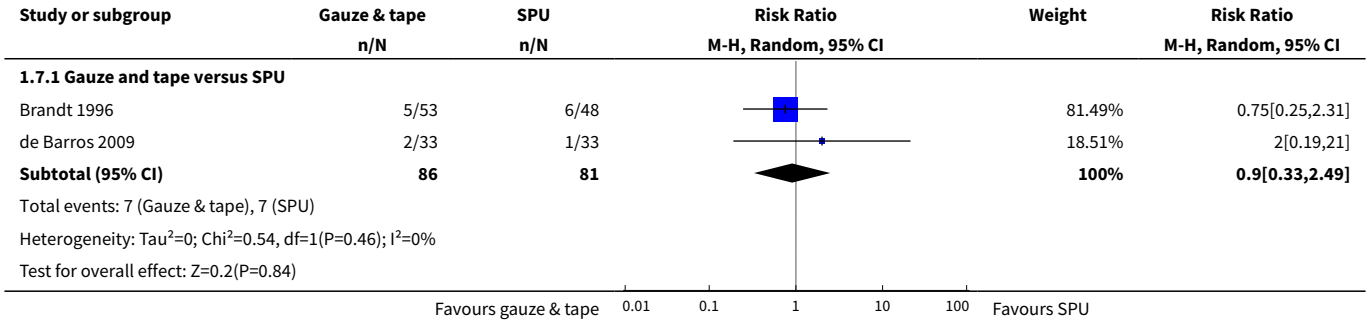
Analysis 1.5. Comparison 1 Primary analysis, Outcome 5 Skin/site colonisation.



Analysis 1.6. Comparison 1 Primary analysis, Outcome 6 Skin irritation or damage.



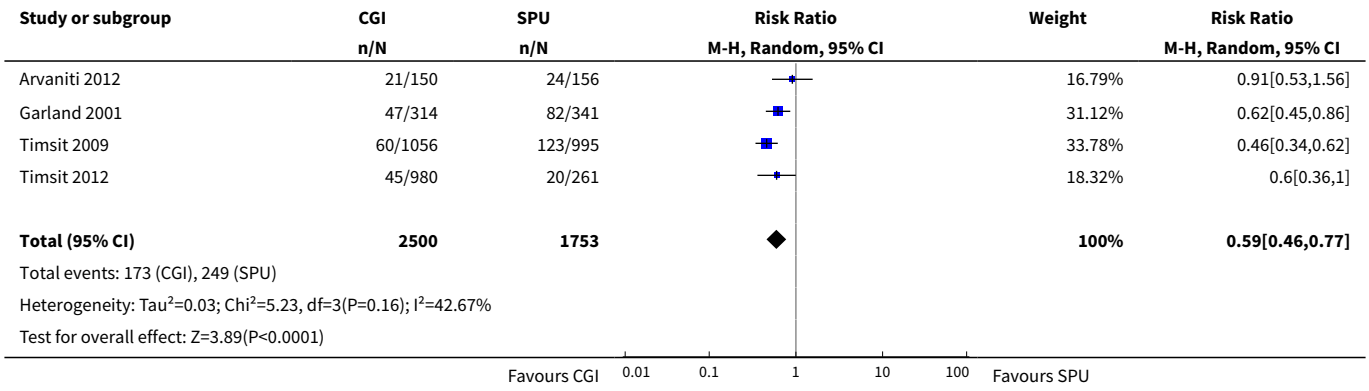
Analysis 1.7. Comparison 1 Primary analysis, Outcome 7 Failed catheter securement.



Comparison 2. Sensitivity analysis: studies at low risk of bias

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Catheter tip colonisation	4	4253	Risk Ratio (M-H, Random, 95% CI)	0.59 [0.46, 0.77]

Analysis 2.1. Comparison 2 Sensitivity analysis: studies at low risk of bias, Outcome 1 Catheter tip colonisation.



APPENDICES

Appendix 1. Types of central venous catheters (CVCs) used

Catheter type	Entry site	Length
Non-tunnelled central venous catheters	Percutaneously inserted into central veins (subclavian, internal jugular or femoral)	≥ 8 cm depending on patient size
Peripherally inserted central venous catheters (PICC)	Inserted into basilic, cephalic or brachial veins and enter the superior vena cava	≥ 20 cm depending on patient size
Tunnelled central venous catheters	Implanted into subclavian, internal jugular, or femoral veins	≥ 8 cm depending on patient size
Totally implantable	Tunnelled beneath skin and have subcutaneous port accessed with a needle; implanted in subclavian or internal jugular vein	≥ 8 cm depending on patient size

O'Grady 2011 pg. 22

≥ = greater than or equal to

Appendix 2. Additional search strategy

Ovid MEDLINE

1 exp Catheterization, Central Venous/ (12023)
2 (venous adj3 (catheter* or line*)).tw. (12967)
3 (central adj3 (catheter* or line*)).tw. (12809)
4 ((hickman or broviac or cook) adj catheter*).tw. (667)
5 exp Catheters, Indwelling/ (16113)
6 (implantable vascular access device or IAVD or PortACath).tw. (58)
7 (peripherally inserted central catheter or PICC).tw. (585)
8 h?emodialysis catheter*.tw. (762)
9 or/1-8 (34316)
10 exp Occlusive Dressings/ (3511)
11 exp Bandages, Hydrocolloid/ (631)
12 exp Silver/ (14667)
13 exp Silver Sulfadiazine/ (809)
14 exp Polyurethanes/ (7439)
15 exp Iodine/ (18302)
16 exp Chlorhexidine/ (6308)
17 ((occlusive* or hydrocolloid* or silver* or polyurethane* or permeable or nonpermeable or non-permeable or transparent or chlorhexidine or iodine* or gauze or tape) adj3 (dressing* or sponge*)).tw. (2517)
18 or/10-17 (51952)
19 9 and 18 (748)
20 randomized controlled trial.pt. (387973)
21 controlled clinical trial.pt. (89778)
22 randomi?ed.ab. (340534)
23 placebo.ab. (150625)
24 clinical trials as topic.sh. (173007)
25 randomly.ab. (200735)
26 trial.ti. (123439)
27 or/20-26 (904765)
28 exp animals/ not humans.sh. (4009223)

29 27 not 28 (832096)
30 19 and 29 (224)
31 2014*.ed. (584053)
32 30 and 31 (3)

Ovid EMBASE

1 exp central venous catheter/ (12794)
2 exp central venous catheterization/ (7021)
3 (venous adj3 (catheter* or line*)).tw. (18144)
4 (central adj3 (catheter* or line*)).tw. (19024)
5 ((hickman or broviac or cook) adj catheter*).tw. (776)
6 exp vascular access device/ (12794)
7 (implantable vascular access device or IAVD or PortACath).tw. (102)
8 (peripherally inserted central catheter or PICC).tw. (1340)
9 h?emodialysis catheter*.tw. (1069)
10 or/1-9 (31589)
11 exp occlusive dressing/ (508)
12 exp hydrocolloid dressing/ (628)
13 exp silver/ (27276)
14 exp sulfadiazine silver/ (3015)
15 exp sulfathiazole silver/ (19)
16 exp polyurethan/ (9963)
17 exp iodine/ (36182)
18 exp chlorhexidine/ (12160)
19 ((occlusive* or hydrocolloid* or silver* or polyurethane* or permeable or nonpermeable or non-permeable or transparent or chlorhexidine or iodine* or gauze or tape) adj3 (dressing* or sponge*)).tw. (3408)
20 or/11-19 (89926)
21 10 and 20 (1216)
22 Randomized controlled trials/ (57946)
23 Single-Blind Method/ (18790)
24 Double-Blind Method/ (117793)
25 Crossover Procedure/ (40165)
26 (random$ or factorial$ or crossover$ or cross over$ or cross-over$ or placebo$ or assign$ or allocat$ or volunteer$).ti,ab. (1366645)
27 (doubl$ adj blind$).ti,ab. (149833)
28 (singl$ adj blind$).ti,ab. (14881)
29 or/22-28 (1437406)
30 exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/ (20630118)
31 human/ or human cell/ (15052414)
32 and/30-31 (15005735)
33 30 not 32 (5624383)
34 29 not 33 (1242391)
35 21 and 34 (220)
36 2014*.em. (1159417)
37 35 and 36 (14)

EBSCO CINAHL

S38S25 AND S37
S37S26 or S27 or S28 or S29 or S30 or S31 or S32 or S33 or S34 or S35 or S36
S36TX allocat* random*
S35(MH "Quantitative Studies")
S34(MH "Placebos")
S33TX placebo*
S32TX random* allocat*
S31(MH "Random Assignment")
S30TX randomi* control* trial*
S29TX ((singl* n1 blind*) or (singl* n1 mask*)) or TX ((doubl* n1 blind*) or (doubl* n1 mask*)) or TX ((tripl* n1 blind*) or (tripl* n1 mask*)) or TX ((trebl* n1 blind*) or (trebl* n1 mask*))
S28TX clinic* n1 trial*
S27PT Clinical trial
S26(MH "Clinical Trials+")
S25S11 and S24

S24S12 or S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20 or S21 or S22 or S23
S23TI (occlusive* N3 sponge* or hydrocolloid* N3 sponge* or silver* N3 sponge* or polyurethane* N3 sponge* or permeable N3 sponge* or nonpermeable N3 sponge* or non-permeable N3 sponge* or transparent N3 sponge* or chlorhexidine N3 sponge* or iodine* N3 sponge* or gauze N3 sponge* or tape N3 sponge* N3 sponge*) OR AB (occlusive* N3 sponge* or hydrocolloid* N3 sponge* or silver* N3 sponge* or polyurethane* N3 sponge* or permeable N3 sponge* or nonpermeable N3 sponge* or non-permeable N3 sponge* or transparent N3 sponge* or chlorhexidine N3 sponge* or iodine* N3 sponge* or gauze N3 sponge* or tape N3 sponge* N3 sponge*)
S22TI (occlusive* N3 dressing* or hydrocolloid* N3 dressing* or silver* N3 dressing* or polyurethane* N3 dressing* or permeable N3 dressing* or nonpermeable N3 dressing* or non-permeable N3 dressing* or transparent N3 dressing* or chlorhexidine N3 dressing* or iodine* N3 dressing* or gauze N3 dressing* or tape N3 dressing*) OR AB (occlusive* N3 dressing* or hydrocolloid* N3 dressing* or silver* N3 dressing* or polyurethane* N3 dressing* or permeable N3 dressing* or nonpermeable N3 dressing* or non-permeable N3 dressing* or transparent N3 dressing* or chlorhexidine N3 dressing* or iodine* N3 dressing* or gauze N3 dressing* or tape N3 dressing*)
S21(MH "Chlorhexidine")
S20(MH "Iodine")
S19(MH "Transparent Dressings")
S18(MH "Polyurethanes")
S17(MH "Gauze Dressings")
S16(MH "Ionic Silver Dressings")
S15(MH "Silver Sulfadiazine")
S14(MH "Silver")
S13(MH "Hydrocolloid Dressings")
S12(MH "Occlusive Dressings")
S11S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9 or S10
S10TI (hemodialysis catheter* or haemodialysis catheter*) OR AB (hemodialysis catheter* or haemodialysis catheter*)
S9TI (peripherally inserted central catheter or PICC) OR AB (peripherally inserted central catheter or PICC)
S8TI (implantable vascular access device or IAVD or PortACath) OR AB (implantable vascular access device or IAVD or PortACath)
S7(MH "Vascular Access Devices, Implantable")
S6TI cook catheter* OR AB cook catheter*
S5TI broviac catheter* OR AB broviac catheter*
S4TI hickman catheter* OR AB hickman catheter*
S3TI (central N3 (catheter* or line*)) OR AB (central N3 (catheter* or line*))
S2TI (venous N3 (catheter* or line*)) OR AB (venous N3 (catheter* or line*))
S1(MH "Central Venous Catheters+")

FEEDBACK

Feedback from Tom Macmillan, Information Specialist, 11 August 2016

Summary

Comment: I believe there is an error in your analysis in section 1.1.8. The text states:

"There were fewer cases of catheter-related BSI with SPU than sutureless securement devices in a single study in adult general acute and home care settings."

This references Yamamto et al. (2002); however, looking at the original paper the result is the complete opposite. They found fewer suspected and confirmed cases of CRBSI with the sutureless securement device (both statistically significant results).

Although this is not the main focus of the study, I think it probably merits a correction.

Reply

Many thanks to Tom MacMillan for alerting us to an error when summarising the results of a single study (Yamamoto 2002) included within our review examining central venous catheter dressing and securement. The data from this study were correctly included within each of the network meta-analyses, however the individual results within the outcome of catheter-related BSI were inverted. We have now corrected this mistake within the appropriate results section of the text. We wish to apologise for any confusion caused.

Contributors

Amanda Ullman, Author.

HISTORY

Protocol first published: Issue 2, 2013
Review first published: Issue 9, 2015

Date	Event	Description
28 September 2016	Feedback has been incorporated	Feedback submitted and author response added to the review.

CONTRIBUTIONS OF AUTHORS

Amanda Ullman: conceived, designed and coordinated the review. Extracted data and checked quality of data extraction. Undertook and checked quality assessment. Analysed and interpreted data. Performed statistical analysis and checked quality of statistical analysis. Wrote and edited the review. Advised on the review and approved the final review prior to submission. Wrote to study authors/experts/companies. Is the guarantor of the review.
Marie Cooke: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission.
Marion Mitchell: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission.
Frances Lin: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission.
Karen New: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission. Wrote to study authors/experts/companies.
Debbie Long: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission. Wrote to study authors/experts/companies.
Gabor Mihala: conceived the review. Extracted data and analysed and interpreted data. Performed statistical analysis and checked quality of statistical analysis. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission.
Claire Rickard: conceived the review. Extracted data and undertook quality assessment. Performed part of writing and editing the review, advised on the review and made an intellectual contribution to the review. Approved the final review prior to submission.

Contributions of editorial base:

Nicky Cullum: edited the review, advised on methodology, interpretation and review content. Approved the final review prior to submission.
Sally Bell-Syer: coordinated the editorial process. Advised on methodology, interpretation and content. Edited the review.
Ruth Foxlee: designed the search strategy and edited the search methods section.

DECLARATIONS OF INTEREST

Griffith University received an unrestricted educational grant from 3M (a manufacturer of CVC dressings and securement devices) to assist with the costs of Claire Rickard's (CR) research nurses' travel to a conference in 2014. Griffith University received a consultancy payment from 3M in 2013 for CR to present an educational lecture based on her independent research. Griffith University received an unrestricted investigator initiated research grant from 3M in 2014 to support a research study on which CR is an investigator, but this study was unrelated to CVC dressings and securement. Studies involving 3M's CVC dressings (Tegaderm range) are included in this review but the conclusions do not recommend these over competitor products. Griffith University received an unrestricted investigator-initiated research grant from Centurion Medical (manufacturer of CVC dressings) as part-funding for the CASCADE Pilot Trial led by CR, and for a PhD student scholarship Top Up for Amanda J Ullman. No trials investigating Centurion Medical's dressings were included in this review.

Marie L Cooke: nothing to declare
Marion Mitchell: nothing to declare
Frances Lin: nothing to declare
Karen New: has received a research grant from The University of Queensland for research related to preconception and early pregnancy care; has been paid for preparing and delivering education on obtaining informed consent for research; and as the Professional Officer of the Australian College of Neonatal Nurses has been supported by an unrestricted eduction grant from Johnson and Johnson Pacific to deliver education on the AWHONN skin care guidelines and the Every Newborn Action Plan.
Debbie A Long: nothing to declare
Gabor Mihala: nothing to declare

Editorial base comment: this review is not currently compliant with Cochrane's Commercial Sponsorship policy. The review is expected to be updated within the next twelve months and the majority of authors and the Lead Author will be free of conflicts of interest for this new update.

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- NIHR/Department of Health (England), (Cochrane Wounds Group), UK.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

Our protocol planned to calculate hazard ratios (HR) to estimate the effect of interventions for time-to-event data. HR can only be calculated from full data sets, log-rank results, KaplanMeier curves or Cox results. Instead we have calculated Incidence Rate Ratio, which is also appropriate for time-to-event data as it considers the at-risk periods (Deeks 2011; Parmar 1998).

INDEX TERMS

Medical Subject Headings (MeSH)

*Bandages; *Central Venous Catheters; Catheter-Related Infections [*prevention & control]; Catheterization, Central Venous [instrumentation] [*methods]; Chlorhexidine [administration & dosage] [analogs & derivatives]; Randomized Controlled Trials as Topic

MeSH check words

Humans