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Double gloving to reduce surgical cross-infection (Review)

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[Intervention Review]

Double gloving to reduce surgical cross-infection

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ABSTRACT

Background

The invasive nature of surgery, with its increased exposure to blood, means that during surgery there is a high risk of transfer of pathogens. Pathogens can be transferred through contact between surgical patients and the surgical team, resulting in post-operative or blood borne infections in patients or blood borne infections in the surgical team. Both patients and the surgical team need to be protected from this risk. This risk can be reduced by implementing protective barriers such as wearing surgical gloves. Wearing two pairs of surgical gloves, triple gloves, glove liners or cloth outer gloves, as opposed to one pair, is considered to provide an additional barrier and further reduce the risk of contamination.

Objectives

The primary objective of this review was to determine if additional glove protection reduces the number of surgical site or blood borne infections in patients or the surgical team. The secondary objective was to determine if additional glove protection reduces the number of perforations to the innermost pair of surgical gloves. The innermost gloves (next to skin) compared with the outermost gloves are considered to be the last barrier between the patient and the surgical team.

Search methods

For this second update we searched the Wounds Group Specialised Register (June 2009), the Cochrane Central Register of Controlled Trials (CENTRAL) (Issue 2, 2009), Ovid MEDLINE (1950 to May Week 5 2009), Ovid EMBASE (1980 to 2009 Week 22) and EBSCO CINAHL (1982 to May Week 4 2009).

Selection criteria

Randomised controlled trials involving: single gloving, double gloving, triple gloving, glove liners, knitted outer gloves, steel weave outer gloves and perforation indicator systems.

Data collection and analysis

Both authors independently assessed the relevance and quality of each trial. Data was extracted by one author and cross checked for accuracy by the second author.

Main results

Two trials were found which addressed the primary outcome, namely, surgical site infections in patients. Both trials reported no infections.

Thirty one randomised controlled trials measuring glove perforations were identified and included in the review.

Fourteen trials of double gloving (wearing two pairs of surgical latex gloves) were pooled and showed that there were significantly more perforations to the single glove than the innermost of the double gloves (OR 4.10, 95% CI 3.30 to 5.09).

Eight trials of indicator gloves (coloured latex gloves worn underneath latex gloves to more rapidly alert the team to perforations) showed that significantly fewer perforations were detected with single gloves compared with indicator gloves (OR 0.10, 95% CI 0.06 to 0.16) or with standard double glove compared with indicator gloves (OR 0.08, 95% CI 0.04 to 0.17).

Two trials of glove liners (a glove knitted with cloth or polymers worn between two pairs of latex gloves)(OR 26.36, 95% CI 7.91 to 87.82), three trials of knitted gloves (knitted glove worn on top of latex surgical gloves)(OR 5.76, 95% CI 3.25 to 10.20) and one trial of triple gloving (three pairs of latex surgical gloves)(OR 69.41, 95% CI 3.89 to 1239.18) all compared with standard double gloves, showed there were significantly more perforations to the innermost glove of a standard double glove in all comparisons.

Authors' conclusions

There is no direct evidence that additional glove protection worn by the surgical team reduces surgical site infections in patients, however the review has insufficient power for this outcome.

The addition of a second pair of surgical gloves significantly reduces perforations to innermost gloves. Triple gloving, knitted outer gloves and glove liners also significantly reduce perforations to the innermost glove. Perforation indicator systems results in significantly more innermost glove perforations being detected during surgery.

PLAIN LANGUAGE SUMMARY

Double gloving to reduce surgical cross-infection

Surgical operations are undertaken within a clean environment and with members of the surgical team wearing sterile gloves. Sterile surgical gloves aim to protect the patient from contamination with bacteria from members of the surgical team and protect the surgical team from the body fluids of the patient. Double-gloving (wearing two sets of gloves) is becoming more common, especially for surgery where sharp surfaces are formed (such as orthopaedic or dental surgery). The review found that a second pair of gloves does protect the inner pair, without apparently affecting surgical performance. A glove liner between the two pairs of gloves reduces breaks to the inner glove even further, and extra-thick gloves seem to be as good as two pairs.

BACKGROUND

The invasive nature of surgery means that during surgery there is a high risk of transfer of pathogens. Pathogens can be transferred from the surgical team to their patients and from patients to their surgical teams. This transfer may occur through a number of routes including contact with skin or blood. For the patient, this transfer of pathogens can result in a surgical wound infection which may compromise the success of their surgery, prolong their hospital stay or may become life threatening. A national audit of 149,745 surgical patients in England from 1997 to 2003 found a total of 5,457 surgical site infections (SSISS 2004).The surgical team are also at risk with surgeons, for example, having three times the incidence rate of Hepatitis B compared with the general public (Rabussay 1997). In an attempt to prevent contamination from hand contact during surgery the surgical team wear sterile gloves (Jagger 1998; Panlilo 1991). However, gloves can become perforated and their protective function is then compromised. Perforations usually occur as a result of injuries from sharps, such as sutures, instruments, bone fragments and also through natural wear and tear.

A number of products are available which are meant to offer additional protection to single gloving. These include double gloving (wearing two pairs of surgical latex gloves), perforation indicator systems, glove liners and cloth outer gloves (Kovavisarach 2002; Laine 2004a; Sutton 1998; Underwood 1993).

The decision to use additional glove protection is influenced by a variety of factors such as the surgical procedure involved, prior knowledge of the 'risk' status of the surgical patient, abrasions on the hands of the surgical team and personal preference. For example, orthopaedic surgery is considered to have a high risk of glove perforation due to the nature of the surgery which usually involves sawing, drilling and contact with sharp objects such as bone. Therefore the practice of double gloving is more common among the orthopaedic surgical team. The risk status of a surgical patient is also influential; if a patient is known or considered to be a high risk for pathogens then double gloving is one of the precautionary practices instituted.

Gloving practice varies between different countries and different surgical specialities. In the UK, Europe and the USA single gloving appears to be standard practice in all specialities except for orthopaedics and maxillofacial surgery where double gloving is employed. Glove liners and cloth outer gloves are rare in the UK and Europe. In the USA, most orthopaedic surgeons wear additional protection, which also includes triple gloving, glove liners and cloth outer gloves. Other surgical specialities in the USA do not routinely double glove (Patterson 1998; St Germaine 2003). Some surgeons have resisted double gloving, citing a reduction in dexterity and sensation (Matta 1988; St Germaine 2003). However, the use of double gloving for specialities outside of orthopaedics is increasing (Berridge 1998).

Following the publication of the original Cochrane review of double gloving (Tanner 2002), a number of professional organisations have issued guidelines or statements supporting or incorporating the Cochrane recommendations for practice. These include The Royal College of Surgeons of England (Rainsworth 2005), The National Association of Theatre Nurses (NATN 2005), The Association of PeriOperative Nurses (AORN 2005) and the Australian College of Operating Room Nurses (ACORN 2004). This review is an update of the previous review.

OBJECTIVES

- To determine if double gloving compared with single gloving reduces the risk of infections, including surgical site infections, blood borne infections in surgical patients and blood borne infections in the surgical team.
- To determine if double gloving reduces the incidence of glove perforations compared with single gloving. Perforations in both innermost and outermost gloves will be included. All systems of double gloving will be compared; double latex gloving, triple latex gloving, double latex gloving with liners, double latex indicator gloves, latex inner with cloth outer gloves and latex inner with steel weave outer gloves.

METHODS

Criteria for considering studies for this review

Types of studies

All randomised controlled trials were considered for inclusion in this study, irrespective of language and publication status.

Types of participants

All members of the surgical team practicing in a designated surgical theatre, in any surgical speciality, in any country. This includes first surgeon, second or assistant surgeon and scrub staff.

Types of interventions

A comparison of two or more of the following:

- Single gloves
- Double gloves
- Glove liners
- Coloured perforation indicator systems
- Cloth outer gloves
- Steel outer gloves
- Triple gloves

Types of outcome measures

Primary outcomes

- Rates of surgical site infections in surgical patients

Secondary outcomes

- Rates of perforations in innermost surgical gloves
- Rates of blood borne infections in post-operative patients or the surgical team

Search methods for identification of studies

Electronic searches

The search methods sections of previous versions of this review can be found in Appendix 1 and Appendix 2.

For this second update we searched the following electronic databases:

- Cochrane Wounds Group Specialised Register (Searched 9/6/09);

- The Cochrane Central Register of Controlled Trials (CENTRAL) - The Cochrane Library Issue 2 2009;
- Ovid MEDLINE - 1950 to May Week 5 2009;
- Ovid EMBASE - 1980 to 2009 Week 22;
- Ovid CINAHL - 1982 to May Week 4 2009.

The following search strategy was used in The Cochrane Central Register of Controlled Trials (CENTRAL):
#1 MeSH descriptor Gloves, Surgical explode all trees
#2 "glove" or "gloves":ti,ab,kw
#3 "double gloving":ti,ab,kw
#4 (#1 OR #2 OR #3)
#5 MeSH descriptor Surgical Wound Infection explode all trees
#6 MeSH descriptor Surgical Wound Dehiscence explode all trees
#7 MeSH descriptor Cross Infection explode all trees
#8 surg* NEAR/5 infection*
#9 surg* NEAR/5 wound*
#10 wound* NEAR/5 infection*
#11 "cross infection"
#12 (postoperative or post-operative) NEAR/5 infection*
#13 (#5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12)
#14 (#4 AND #13)

The search strategies for Ovid MEDLINE, Ovid EMBASE and Ovid CINAHL can be found in Appendix 3, Appendix 4 and Appendix 5 respectively. The Ovid MEDLINE search was combined with the Cochrane Highly Sensitive Search Strategy for identifying randomised trials in MEDLINE: sensitivity- and precision-maximizing version (2008 revision); Ovid format (Lefebvre 2008). The EMBASE and CINAHL searches were combined with the trial filters developed by the Scottish Intercollegiate Guidelines Network (SIGN) (SIGN 2009). No date or language restrictions were applied.

Data collection and analysis

Selection of studies

The review authors (JT and HP) independently assessed all the potentially relevant studies identified through the search strategy. All articles that were noted as potentially relevant were retrieved in full. There were no disagreements over which studies to include. References identified from the searches were entered into the software package Review Manager 4.2.

Data extraction and management

One review author extracted details from these eligible studies onto a standardised form. The type of data extracted included:

- surgical wound infection rates;
- staff or patient blood borne infection (bacterial or viral count) taken at baseline and post operatively;
- type of surgery;
- role of the glove wearer;
- intervention - single, double, triple, liner or indicator glove;
- quality of the glove - type of material, thickness, method of manufacture;
- the number and distribution of punctures;
- details of the method used to test for perforations, for example filling glove with 500 mls of water and squeezing glove.

Data extraction was cross-checked for accuracy by the second author. Attempts were made to obtain missing data through contacting 11 trial authors (Aarnio 2001; Avery 1999a; Avery 1999b; Berridge 1998; Kovavisarach 2002; Laine 2001; Laine 2004a; Marin Bertolin 1997; Pieper 1995; Thomas 2001; Underwood 1993). Seven authors have responded to date providing additional information (Aarnio 2001; Avery 1999a; Avery 1999b; Berridge 1998; Pieper 1995; Thomas 2001; Underwood 1993). Each of these studies has been included in the updated review.

Assessment of risk of bias in included studies

Each study was critically appraised using the following checklist to assess methodological quality:

- method of randomisation;
- allocation concealment;
- clear inclusion and exclusion criteria;
- baseline comparability of groups for surgical procedures and the role of the glove wearer;
- extent of non compliance;
- blinded assessment;
- statistical power calculated before the trial;

RESULTS

Description of studies

Results of the search

The search for the second update retrieved 52 citations, of these four full text papers were obtained for further assessment. This resulted in two studies, one of which was a systematic review, being added to the excluded studies table (Rogers 2000; Florman 2005). One additional study was added to awaiting assessment (Gaujac 2007) bringing the number of studies awaiting assessment to two (Ganczak 2004; Gaujac 2007). One duplicate publication of a trial already included in the review was identified and was listed as a secondary references to the primary study (Punyatanasakchai 2004). The number of included studies remains unchanged.

Included studies

The 31 included trials were divided into the following categories (Characteristics of included studies):

- single compared with double gloves (20 trials: Aarnio 2001; Avery 1999b; Berridge 1998; Caillot 1999; Doyle 1992; Gani 1990; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Laine 2001; Laine 2004a; Laine 2004b; Marin Bertolin 1997; Naver 2000; Punyatanasakchai 2004; Rudiman 1999; Thomas 2001; Turnquest 1996; Wilson 1996)
- double compared with indicator gloves (five trials: Avery 1999a; Duron 1996; Laine 2001; Laine 2004a; Nicolai 1997)
- double compared with double latex plus glove liner (four trials: Hester 1992; Pieper 1995; Sebold 1993; Sutton 1998)
- double compared with latex inner with knitted outer gloves (four trials: Hester 1992; Sanders 1990; Tanner 2006: Underwood 1993)
- double compared with latex inner with steel weave outer glove (one trial: Louis 1998)
- double compared with triple gloves (one trial: Pieper 1995)

Type of surgery

In the single glove versus double gloving category, trials were carried out in dental surgery (Avery 1999b), obstetrics and gynaecology surgery (Doyle 1992; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Punyatanasakchai 2004; Turnquest 1996), abdominal surgery (Caillot 1999; Jensen 1997; Laine 2004b), plastic surgery (Marin Bertolin 1997), gastro-intestinal surgery (Naver 2000), general surgery (Gani 1990; Rudiman 1999; Thomas 2001; Wilson 1996), arthroscopic (Laine 2004a), orthopaedic (Laine 2001) and vascular surgery (Berridge 1998). Of the 11 trials comparing various combinations of double and triple gloves, seven were for orthopaedic surgery (Hester 1992; Louis 1998; Nicolai 1997; Sanders 1990; Sebold 1993; Sutton 1998; Tanner 2006) two were for maxillo-facial surgery (Avery 1999a; Pieper 1995) one was for central venous cannulation and insertion of implantable catheters with ports (Duron 1996), one was for vascular surgery (Aarnio 2001) and one was for sternal wiring following cardiac surgery (Underwood 1993).

Glove manufacturer

Twelve trials used Regent Biogel gloves (Aarnio 2001; Avery 1999a; Avery 1999b; Duron 1996; Laine 2001; Laine 2004a; Laine 2004b; Naver 2000; Nicolai 1997; Sutton 1998; Tanner 2006; Underwood 1993) ten trials used Ansell gloves (Aarnio 2001; Gani 1990; Jensen 1997; Kovavisarach 1999; Kovavisarach 2002; Laine 2001; Laine 2004a; Laine 2004b; Louis 1998; Sutton 1998), three trials used Smith and Nephew gloves (Marin Bertolin 1997; Sanders 1990; Turnquest 1996), four trials used Baxter gloves (Caillot 1999; Hester 1992; Louis 1998; Pieper 1995), one trial used Dial Rubber Industries gloves (Thomas 2001), one trial used Johnson and Johnson gloves (Rudiman 1999), one trial used Medigloves (Punyatanasakchai 2004), three trials used Perry orthopaedic gloves (Hester 1992; Sebold 1993; Turnquest 1996), one trial used Assistance Publique des Hopitaux de Paris gloves (Duron 1996) and another trial used Becton Dickinson gloves (Turnquest 1996). Knitted outer gloves were produced by Protek (Hester 1992; Sanders 1990), Sallis (Tanner 2006) and Dent (Underwood 1993). The glove liners were produced by Centurian (Pieper 1995), Paraderm (Sutton 1998), Repel (Pieper 1995; Sebold 1993) and Protek (Hester 1992). Polyester/stainless steel weave gloves were produced by Sceptor (Louis 1998). The remaining trials (Berridge 1998; Doyle 1992; Kovavisarach 1998; Wilson 1996) did not report this information.

Excluded studies

For this second update two studies were added to the excluded studies table (Rogers 2000; Florman 2005), bringing the total of excluded studies to 95. See Characteristics of excluded studies.

Risk of bias in included studies

Method of randomisation

Six trials used a method of sequence generation that we regarded as random. The randomisation was generated by computer in one trial (Turnquest 1996), using random number tables in two trials (Doyle 1992; Tanner 2006), using a calculator randomisation function in one trial (Berridge 1998) and by tossing a coin in one trial (Avery 1999a). In one trial (Wilson 1996) participants picked one of 4 envelopes containing a card representing each of the 4 groups. Five trials described inadequate randomisation; allocation by patient birth date (Aarnio 2001; Laine 2001); hospital admission date (Hester 1992) and patient hospital number (Gani 1990, Rudiman 1999). The remaining 20 trials did not report details of the method of sequence generation (Avery 1999b; Caillot 1999; Duron 1996; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Laine 2004a; Laine 2004b; Louis 1998; Marin Bertolin 1997; Naver 2000; Nicolai 1997; Pieper 1995; Punyatanasakchai 2004; Sanders 1990; Sebold 1993; Sutton 1998; Thomas 2001; Underwood 1993).

In nineteen trials the unit of randomisation was the glove wearer (Avery 1999a; Avery 1999b; Doyle 1992; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Laine 2004a; Laine 2004b; Louis 1998; Marin Bertolin 1997; Naver 2000; Pieper 1995; Punyatanasakchai 2004; Sanders 1990; Tanner 2006; Thomas 2001; Turnquest 1996; Wilson 1996) and in eleven trials the patient was the unit of randomisation (Aarnio 2001; Caillot 1999; Duron 1996; Gani 1990; Hester 1992; Laine 2001; Nicolai 1997; Rudiman 1999; Sebold 1993; Sutton 1998; Underwood 1993). In one trial it was not clear who was randomised (Berridge 1998).

Allocation concealment

Sealed envelopes, were used in 16 of the 31 included trials (Avery 1999b; Doyle 1992; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Louis 1998; Naver 2000; Nicolai 1997; Punyatanasakchai 2004; Sanders 1990; Sebold 1993; Sutton 1998; Tanner 2006; Thomas 2001; Turnquest 1996; Underwood 1993). Seven trials used inadequate concealment (Aarnio 2001 - date of birth, Avery 1999a - coin toss, Gani 1990 - hospital number, Hester 1992 - admission date, Laine 2001 - date of birth, Rudiman 1999 - hospital number, Wilson 1996 - picking 1 of 4 cards). The remaining 8 trials did not report details regarding allocation concealment (Berridge 1998; Caillot 1999; Duron 1996; Kovavisarach 2002; Laine 2004a; Laine 2004b; Marin Bertolin 1997; Pieper 1995)

Blinding

It was not possible to blind the glove wearers as it was obvious to the glove wearer if they were wearing one or two pairs of gloves, an indicator system, an additional glove liner or a knitted outer glove. In an attempt to reduce bias the outcome assessor (perforation tester) should be blinded to the allocation, however, only Kovavisarach 2002, Sutton 1998 and Tanner 2006 stated that the outcome assessor was blind. The participants in Gani's study (Gani 1990) tested their own gloves and the remaining trials did not provide any details regarding the glove testers.

Outcome assessment

Two trials (Sanders 1990; Sebold 1993) reported on the primary outcome of this review, that is surgical site infections in patients. Both these trials had glove perforation as their main outcome. Neither trial reported how surgical site infection was assessed, who carried out the assessment or how long after surgery the assessment was carried out. Both trials reported that there were no reports of post-operative infections. The sample sizes were small; Sanders 1990 had 50 participants in a two arm study and Sebold 1993 had 75 participants in a three arm study. None of the trials reported findings for the secondary outcome; blood borne infections in participants or the surgical team.
All 31 included trials reported data on the secondary outcome, namely, glove perforations.

Outcome measures

Nine trials (Aarnio 2001; Laine 2001; Laine 2004a; Laine 2004b; Louis 1998; Naver 2000; Nicolai 1997; Sanders 1990; Tanner 2006)

used the standard test recognised by The American Society for Testing and Materials and The European Standards Committee to measure glove perforations. This test involves filling a glove with 1000 mls of water, suspending the glove by the cuff using a clip and allowing the water to drip through. The remaining trials used one of the following methods to test for perforations. Six trials (Avery 1999b; Doyle 1992; Hester 1992; Marin Bertolin 1997; Pieper 1995; Punyatanasakchai 2004) filled the gloves with 500 mls of water and squeezed the gloves while observing for leaks. The following studies did not state how much water they used to fill the gloves (Avery 1999a; Berridge 1998; Jensen 1997; Sebold 1993; Turnquest 1996). The following studies used the method of detection described by Brough (Brough 1988), (Duron 1996; Gani 1990; Rudiman 1999; Underwood 1993). This is the same as the American and European standard except that gloves are filled with 500 mls of water rather than 100 mls. Sutton (Sutton 1998) filled his gloves with water to a diameter around the palm of 10 cm. Three trials filled the gloves with air, submerged them in water and observed for bubbles (Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002). Thomas (Thomas 2001) used two tests on each glove, filling the gloves with air and then also filling them with water. One trial (Caillot 1999) used an electrical resistance signal to detect perforations in gloves. Wilson 1996 does not report details regarding his method for detecting perforations.

Size of trial

The larger trials were undertaken by Kovavisarach 1998 - 2058 gloves / 700 participants in a two arm study, Laine 2001- 2462 gloves / 885 operations in a two arm study and Laine 2004a - 1769 gloves / 349 operations in a two arm study. The smallest trials were carried out by Louis 1998 - 50 participants in a two arm study, Sanders 1990 - 50 participants in a two arm study, Sebold 1993 - 75 participants in a three arm study and Underwood 1993 - 42 participants in a two arm study. Only two trials (Tanner 2006; Turnquest 1996) described a priori sample size calculation, whilst one trial stated the power of their study (Doyle 1992).

Effects of interventions

Primary outcome: surgical site infections in patients

Two trials (Sanders 1990; Sebold 1993) were included which addressed the primary outcome of this review, which is surgical site infection and both trials reported no surgical site infection. However individually and collectively these trials were underpowered for this outcome (Sanders 1990 - 50 participants in a two arm trial, Sebold 1993 - 75 participants in a three arm trial).

Secondary outcome: blood borne infections in surgical patients or the surgical team

No trials were found which provided data on transferred blood borne infections in surgical patients or the surgical team in relation to gloving method

Secondary outcome: surgical glove perforations

Thirty one trials providing data on glove perforation rates met the inclusion criteria for this review. Results of dichotomous variables are presented as Odds Ratio (OR) with 95% confidence intervals (CI).

Single latex gloves compared with double latex gloves

This category compares single gloving with double gloving. It includes two types of single gloves; standard gloves (standard thickness) and orthopaedic gloves (thicker than standard). Two double gloving products are also included in this category; standard double gloving and perforation indicator systems. Standard double gloving is the practice of wearing one pair of standard latex surgical gloves on top of another. A perforation indicator system is a system intended to enable the glove wearer to detect perforations to their gloves more easily. It involves wearing a standard latex glove on top of a coloured (usually green) standard latex glove. In the event of a perforation to the outermost glove, moisture from the operating site seeps into the layer between the two pairs of gloves. The moisture then becomes highly visible as a bright green spot.

In double gloving, the gloves worn next to the skin are known as the innermost gloves and the gloves worn on top are the outermost gloves. In this category the number of perforations is compared in (a) the single glove compared with the innermost glove and (b) the single glove compared with the outermost glove. Overall data is presented first followed by data for each of the four subgroups contributing to this comparison. In (c) the number of perforations detected by the glove wearer during surgery as a proportion of the total number of perforations are compared in single gloves and indicator gloves.

(a) Number of perforations in single gloves compared with innermost double gloves

Twenty trials compared single with double gloving (Aarnio 2001; Avery 1999b; Berridge 1998; Caillot 1999; Doyle 1992; Gani 1990; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Laine 2001; Laine 2004a; Laine 2004b; Marin Bertolin 1997; Naver 2000; Punyatanasakchai 2004; Rudiman 1999; Thomas 2001; Turnquest 1996; Wilson 1996). Five trials did not report sufficient data on the number of gloves or perforations and could not be included in a meta-analysis (Berridge 1998; Caillot 1999; Laine 2001; Laine 2004a; Laine 2004b). However all of these trials reported that perforations to innermost gloves were reduced when wearing two pairs of gloves. In Marin Bertolin 1997's study one surgeon with eczema wore vinyl innermost gloves. This study has been excluded from the meta analysis which compared latex gloves; it reported 31/335 (9%) single gloves perforated and 14/343 (4%) double innermost gloves perforated.

Fourteen trials had evaluable data and were all carried out in low risk surgical specialities. Wilson 1996 compared three groups made up of double gloves of different combinations of sizes, for example, a larger glove worn on top of a smaller glove, these have been combined for the purposes of this review. The data from these fourteen trials were pooled in a meta-analysis giving a total sample size of 8885 gloves. Nine percent of single gloves had a perforation compared with 2% of innermost double gloves. A fixed-effects model was used (I^2 = 51%). During low risk surgery, there were significantly more perforations to the single glove than the innermost glove, OR 4.10 (95% CI 3.30 to 5.09)(Analysis 1.1).

The 14 evaluable trials in this comparison were analysed in 4 subgroups, which had not been pre specified in the original review;

- single compared with standard double gloves,

- single compared with perforation indicator systems,
- single compared with standard double gloves and perforation indicator systems combined,
- single orthopaedic gloves compared with standard double gloves.

Number of perforations in single gloves compared with innermost standard double gloves

Ten of the 14 trials had evaluable data for this outcome (Doyle 1992; Gani 1990; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Punyatanasakchai 2004; Rudiman 1999; Thomas 2001; Wilson 1996). These ten trials were carried out in low risk surgical specialities and used the same thickness of glove. The data from these ten trials was pooled in a meta analysis giving a total of 6163 gloves. Eleven percent of single gloves had a perforation compared with 3% of innermost double gloves. A fixed-effects model (I^2 = 15%) showed that there were significantly more perforations to the single glove than the innermost double glove; OR 4.14 (95% CI 3.26 to 5.26)(Analysis 1.1).

Number of perforations in the single glove compared with the indicator innermost glove

Three trials (Aarnio 2001; Laine 2001; Naver 2000) compared single gloves with indicator gloves. It is not possible to include Laine 2001 in the meta-analysis as it does not provide data on the number of perforations in single gloves. The remaining two trials (Aarnio 2001; Naver 2000) were carried out in vascular and gastrointestinal surgery respectively and used similar gloves. Eight percent (65/816) of single gloves were perforated compared with 1% (6/716) of indicator innermost gloves. The data from these two trials demonstrates significantly more perforations in the single glove than the innermost indicator glove; OR 9.42 (95% CI 4.18 to 21.23)(Analysis 1.1).

Number of perforations in single gloves compared with innermost standard double gloves and indicator systems combined

Three trials used a combination of both standard double gloving and perforation indicator systems (Avery 1999b; Laine 2004a; Laine 2004b. It was not possible to use the data from Laine 2004a and Laine 2004b as the total numbers of gloves are not clear. Avery 1999b reported no significant difference between single gloves and innermost standard double gloves/indicator systems; OR 2.87 (95% CI 0.12 to 70.85)(Analysis 1.1).

Number of perforations in single orthopaedic compared with double innermost glove

One trial carried out in obstetric surgery was included with a total of 682 gloves (Turnquest 1996). Three per cent of the single latex orthopaedic gloves were perforated compared with 3% of the innermost gloves in the double latex glove group; OR 0.98 (95% CI 0.43 to 2.22)(no statistically significant difference)(Analysis 1.1).

b) Number of perforations in single gloves compared with outermost double gloves

The same 20 trials comparing single gloving with double gloving were analysed for the outcome of outer glove perforation (Aarnio 2001; Avery 1999b; Berridge 1998; Caillot 1999; Doyle 1992; Gani 1990; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Laine 2001; Laine 2004a; Laine 2004b; Marin Bertolin 1997; Naver 2000; Punyatanasakchai 2004; Rudiman 1999; Thomas 2001; Turnquest 1996; Wilson 1996). Six of these trials did not report sufficient data on the number of gloves or perforations and could not be included in a meta-analysis (Berridge 1998; Caillot 1999; Laine 2001; Laine 2004a; Laine 2004b; Wilson 1996). In Marin Bertolin 1997's study one surgeon with eczema wore vinyl inner gloves. This study has been excluded from the meta analysis which compared latex gloves; it reported 31/335 (9%) single gloves perforated and 38/342 (11%) double outermost gloves perforated.

Thirteen of the 20 trials had evaluable data for this outcome and were all carried out in low risk surgical specialities. The data from these trials was combined in a meta-analysis giving a total sample size of 8531 gloves. Nine percent of single gloves were perforated compared with 11% of outermost gloves in the double gloving group. There is no statistically significant difference in the number of perforations between single gloves and outermost double gloves, pooled OR using a random effects model (I^2 = 70%) was 0.85 (95% CI 0.63 to 1.15)(Analysis 2.1).

The 13 evaluable trials in this comparison were analysed in 4 subgroups, which had not been pre specified in the original review:

- single compared with standard double gloves,
- single compared with perforation indicator systems,
- single compared with standard double gloves and perforation indicator systems combined,
- single orthopaedic gloves compared with standard double gloves.

Number of perforations in single gloves compared with outermost standard double gloves

Nine of the 13 trials had evaluable data (Doyle 1992; Gani 1990; Jensen 1997; Kovavisarach 1998; Kovavisarach 1999; Kovavisarach 2002; Punyatanasakchai 2004; Rudiman 1999; Thomas 2001). The data from these nine trials were pooled in a meta analysis giving a total of 5806 gloves. Eleven percent of single gloves had a perforation compared with 11.5% of outermost double gloves. There is no statistically significant difference in the number of perforations between single gloves and outermost double gloves. Pooled OR using a random effects model (I^2=0%) was 0.95 (95% CI 0.80 to 1.12)(Analysis 2.1).

Number of perforations in the single glove compared with the indicator outermost glove

Three trials (Aarnio 2001; Laine 2001; Naver 2000)) compared single gloves with indicator gloves. It is not possible to include Laine 2001 in the meta-analysis as it does not provide data on the number of perforations in single gloves. The remaining two trials (Aarnio 2001; Naver 2000) were carried out in vascular and gastrointestinal surgery respectively and used similar gloves. Data from these two trials showed that 8% (65/816) of single gloves were perforated compared to 8.8% (63/716) of indicator outermost gloves (no statistically significant difference, OR 1.53; 95% CI 0.29 to 8.11) (Analysis 2.1).

Number of perforations in single gloves compared with outermost standard double gloves and indicator systems combined

Three trials used a combination of both standard double gloving and perforation indicator systems (Avery 1999b; Laine 2004a; Laine 2004b). It was not possible to use the data from Laine 2004a and Laine 2004b as the total numbers of gloves are not clear. Avery 1999b reported no significant difference between single gloves and

outermost standard double gloves/indicator systems; OR 0.32 (95% CI 0.03 to 3.09)(Analysis 2.1).

Number of perforations in single orthopaedic compared with double outermost glove

One trial was included (Turnquest 1996) and found 3% of the single latex orthopaedic gloves were perforated compared with 19% of the outermost standard latex gloves. There were significantly fewer perforations to the single pair of orthopaedic latex gloves than the outermost gloves of a double layer; OR 0.16 (95% CI 0.08 to 0.30) (Analysis 2.1).

(c) Proportion of total number of perforations detected during surgery by glove wearer - single gloves compared with indicator systems

Previous outcomes have compared the actual number of perforations detected at the end of a surgical procedure by an assessor using one of the methods described in the section on testing. This analysis compares the proportion of perforations detected by the glove wearer during the surgical procedure.

Five trials (Aarnio 2001; Laine 2001; Laine 2004a; Laine 2004b; Naver 2000) compared the number of perforations detected by the glove wearer during surgery as a proportion of the total number of perforations in single gloves compared with indicator gloves. Only Aarnio 2001 presented data for innermost and outermost gloves separately and found that of the 12 perforations sustained during surgery when wearing single gloves 6 were detected by the glove wearer, and 3 out of the 3 perforations sustained in the outermost indicator gloves were detected by the glove wearer. There were no perforations in the innermost gloves. Laine 2001, Laine 2004a, Laine 2004b and Naver 2000 present combined data for the innermost and outermost indicator glove groups. This meta-analysis compares perforations in both the innermost and outermost gloves. Of the 192 actual perforations sustained while wearing single gloves 71 (37%) were detected during surgery by the glove wearer, whilst 193 of the 225 (86%) actual perforations sustained while wearing indicator systems were detected by the glove wearer during the procedure. Pooling the data using a fixed effects model (I^2 = 28%) demonstrates significantly fewer perforations are detected in the absence of an indicator system (OR 0.10, 95% CI 0.06 to 0.16)(Analysis 3.1).

Double latex gloves compared with perforation indicator systems

This category compares two pairs of standard latex surgical gloves with a perforation indicator system. Perforation indicator systems have been described previously. This category compares:
(a) the number of perforations in the double innermost glove with the indicator innermost glove
(b) the number of perforations in the double outermost glove with the indicator outermost glove
(c) the number of perforations detected by the glove wearer during surgery as a proportion of the total number of perforations in double gloves compared with indicator gloves.

(a) Number of perforations in double innermost gloves compared with indicator innermost gloves

Five trials were identified which compared double gloving with indicator gloves (Avery 1999a; Duron 1996; Laine 2001; Laine 2004a; Nicolai 1997). Avery 1999a and Laine 2001 did not report the number of perforations to the innermost gloves and were excluded from the meta-analysis. The data from Laine 2004 were not sufficiently clear to be included in the meta-analysis. The Duron 1996 study was carried out in low risk general surgery and Nicolai 1997 in high risk orthopaedic surgery, however both trials show similar results. The gloves used in both studies are similar and though Nicolai 1997 stated that sealed envelopes were used neither trial provided sufficient detail of the randomisation or the blinding of the glove testers. Due to their similarity, these two trials representing a total of 396 gloves were pooled in a meta-analysis. A random-effects model was used due to possible heterogeneity resulting from different types of surgery. There is no statistically significant difference in the number of perforations to innermost gloves when wearing double gloves or double indicator gloves (10% versus 7.5% of inner gloves respectively) (OR 1.38; 95% CI 0.65 to 2.90)(Analysis 4.1).

(b) Number of perforations in double outermost gloves compared with indicator outermost gloves

Five trials were identified which compared double gloving with indicator gloves (Avery 1999a; Duron 1996; Laine 2001; Laine 2004a; Nicolai 1997) with only Duron 1996 and Nicolai 1997 reporting data on the number of perforations, pooling these two trials using a random-effects model gave an OR 1.46 (95% CI 0.69 to 3.08)(Analysis 5.1) which demonstrated no statistically significant difference between the two groups. Twenty three per cent of the outermost gloves in the double gloving group were perforated compared with 17% of the outermost gloves in the indicator group.

(c) Proportion of total number of perforations detected during surgery by glove wearer - double gloves compared with indicator gloves

Previous outcomes have compared the actual number of perforations detected at the end of a surgical procedure by an assessor using one of the methods described in the section on testing. This analysis compares the proportion of perforations detected by the glove wearer during the surgical procedure.

This category compared the number of perforations detected by glove wearers during surgery as a proportion of the total number of perforations. Five trials were included (Avery 1999a; Duron 1996; Laine 2001; Laine 2004a; Nicolai 1997). Laine 2001 and Laine 2004a present combined data from both inner and outer gloves (though Laine 2004a presents data on inner gloves in the text this is inconsistent with data presented in tables). Avery 1999a presents data on inner and outer gloves, however the data relating to inner gloves is incomplete. Duron 1996 found no perforations in the inner double glove and only 1 perforation in the inner indicator group which was not detected by the glove wearer during the procedure. The other trial (Nicolai 1997) found that out of 16 actual perforations in the innermost indicator glove, 3 were detected compared with 0 out of 16 actual perforations in the inner double glove group. This comparison is underpowered. For these reasons it was decided to combine the data for the inner and outer gloves and state the overall effect of indicator gloves on perforation detection.

Though the five trials were conducted in different types of surgery, they were included in the meta analysis as the outcome was the ability to detect a proportion of perforations during surgery . The validity of the trials is weak, Duron 1996 and Laine 2004a do not provide any design details and Laine 2001 attempted randomisation using patient numbers, whilst Avery 1999a tossed a coin to assign group status and Nicolai 1997 used sealed envelopes.

A random effects model was used in recognition that there were differences in the type of surgery. Twenty one per cent (52/244) of actual perforations were detected during surgery by the glove wearer when wearing standard double gloves compared with 77% (260/338) when wearing a perforation indicator system OR 0.08 (95% CI 0.04 to 0.17)(Analysis 6.1). There were significantly fewer perforations detected when not wearing a perforation indicator system.

Double latex compared with double latex with liner

Glove liners are intended to provide additional protection. They are worn between two pairs of gloves and can be made of a knitted fabric, such as cloth, extended chain polyethylene fibres, long molecule chains of poly paraphenylene terephtalamide (Kevlar) or steel and polyester weave. This category of studies compares the number of perforations in (a) the innermost gloves and (b) the outermost gloves in standard latex double gloving and standard latex double gloving with a glove liner.

(a) Double latex innermost gloves compared with double latex with liner innermost gloves

Four trials (Hester 1992; Pieper 1995; Sebold 1993; Sutton 1998) were included in this category. Pieper 1995, Sebold 1993 and Sutton 1998 used similar gloves and were all carried out in high risk surgery (maxillofacial and orthopaedics). Pieper 1995 arbitrarily placed the surgeons into groups and Sebold 1993 does not provide details of the randomisation process beyond "sealed envelopes". These two trials were included in a meta-analysis. Hester 1992 was excluded from the meta-analysis as the double glove group was made up of a pair of standard latex worn on top of orthopaedic gloves. Hester found 9% (8/87) innermost gloves perforated in the double gloving (with orthopaedic gloves) group and 4% (4/92) innermost gloves perforated in the double latex plus liner group. Sutton 1998 was excluded from the meta-analysis as he provides information on the number of perforations per operation rather than gloves. Sutton 1998 found 17 perforations in the double inner gloves from 62 operations and five perforations in the liner group inner glove in 56 operations.

Pooling these trials (Pieper 1995; Sebold 1993) using a fixed effects model (I^2 = 0%) gave an OR of 26.36 (95% CI 7.91 to 87.82)(Analysis 7.1) which demonstrated there were significantly more perforations in the double latex innermost gloves than with the double latex plus liner glove. Twenty eight per cent of innermost gloves in the double gloving group were perforated compared with 1% of innermost gloves in the double latex plus liner group.

(b) Double latex outermost gloves compared with double latex with liner outermost gloves

Four trials (Hester 1992; Pieper 1995; Sebold 1993; Sutton 1998) were included in this category. Hester 1992 was excluded from the analysis as the double glove group was made up of a pair of standard latex worn on top of orthopaedic gloves and did not provide data on the number of outer glove perforations. Pieper 1995 did not provide sufficient details of outermost glove perforations and was excluded from the analysis. Sutton 1998 provided data on the number of perforations per operation rather than per glove. Sutton 1998 found 142 perforations in the double outermost gloves from 62 operations and 177 perforations in the liner group outermost glove in 56 operations. The remaining trial (Sebold 1993) was carried out in orthopaedic surgery and had a sample size of 121 gloves. It did not provide details of the randomisation process beyond "sealed envelopes". The analysis shows the number of gloves with at least 1 hole, there is no statistically significant difference in the number of outermost gloves perforated when comparing double latex gloves compared with double latex with liner gloves (OR 0.53 95% CI 0.23 to 1.21) (Analysis 8.1).

Double latex compared with latex innermost with knitted cloth outermost gloves

This category compares double gloving using two pairs of latex gloves compared with a knitted cloth glove worn on top of a standard latex surgical glove. The knitted cloth gloves can be covered or woven with extended chain polyethylene fibres or long molecule chains of poly paraphenylene terephtalamide (Kevlar). The number of perforations in the innermost gloves are compared. Due to the porous nature of the cloth glove it is not possible to test outermost gloves for perforations.

(a) Innermost gloves from the double latex glove group compared with innermost gloves from the knitted glove plus latex group

Four trials were included (Hester 1992; Sanders 1990; Tanner 2006; Underwood 1993). Sanders 1990, Tanner 2006 and Underwood 1993 were carried out in high risk surgery, orthopaedic and sternal wiring, and used similar gloves. Tanner 2006 had a larger sample size (406 innermost gloves tested) than Sanders 1990 or Underwood 1993 (110 gloves and 80 gloves respectively). Hester 1992 was excluded from the meta-analysis as the double glove group was made up of a pair of standard latex gloves worn on top of orthopaedic gloves. Hester found 8/87 (9%) innermost gloves perforated in the double gloving (with orthopaedic gloves) group and 7/88 (8%) innermost gloves perforated in the latex and cloth group. In total 24% of innermost gloves were perforated in the double latex glove group compared with 5% of innermost gloves in the latex innermost with knitted outer group. Three trials were pooled using a fixed effects model (I^2 = 11.5%) and found there were significantly more perforations in the innermost standard glove than with the innermost plus knitted outer glove (OR 5.76; 95% CI 3.25 to 10.20)(Analysis 9.1).

Double latex compared with latex innermost with steel weave outermost gloves

This category compares double gloving using two pairs of latex surgical gloves compared with a steel weave glove worn on top of a standard latex glove. Fine stainless steel wire is incorporated into a polyester fibre which is then knitted into a glove. The number of perforations in the innermost gloves is compared. Due to the porous nature of the steel weave glove it is not possible to test outermost gloves for perforations.

(a) Innermost gloves from the double glove group compared with innermost gloves from the latex and steel weave group

One trial involving 223 gloves was included (Louis 1998), 19% of innermost gloves were perforated in the double latex group compared with 15% of innermost gloves in the latex inner with steel weave outer glove. There is no statistically significant difference between the groups (OR 1.30, 95% CI 0.64 to 2.64)(Analysis 10.1).

Double latex compared with triple latex

This category compares two pairs of standard latex gloves compared with three pairs of standard latex surgical gloves worn on top of each other. Number of perforations are compared for the innermost gloves only.

(a) Innermost gloves from double gloving compared with innermost gloves from triple gloving

One trial (Pieper 1995) was included in this category. This trial was carried out in high risk maxillofacial surgery, sample sizes were small (30 gloves in each group) and the randomisation was poor (surgeons were arbitrarily allocated to groups). Fifty three percent (16/30) perforations were found in the double gloving group compared with no perforations in the triple gloving group. There were significantly more perforations to the innermost glove of the double glove than the innermost glove of the triple glove (OR 69.41; CI 95% 3.89 to 1239.18)(Analysis 11.1) .

DISCUSSION

Outcome measures

Although the primary aim of wearing additional glove barriers during surgery is to provide extra protection against infections no trials set out to measure the relationship between gloves and infections in patients or staff. The aim of all 31 trials included in this review was to determine glove perforations. Two small trials did report that no infections had been found in their patients, but it is not possible to draw any conclusions from this as no information was given regarding the measurement of this outcome. While there is evidence of transferred pathogens between the surgical team and patients (Esteban 1996; Harpez 1996) there are no studies which show a direct link between glove perforations and transferred pathogens. It is assumed that glove perforations allow the transfer of infections and therefore increase the risk of infection. Very large RCTs of infection rates when wearing different gloving methods would be necessary to identify the real impact of wearing additional glove protection and the unit of randomisation should be the surgeon or surgical team.

Double gloving with either two pairs of standard latex gloves or a perforation indicator system is significantly more effective than single gloving in reducing glove perforations. In a meta-analysis of just under 9,000 gloves (Analysis 01), perforations in single gloves were reduced from 9% to 2% for double innermost gloves. It is interesting to note that all of the studies included in this comparison were conducted in specialities which are considered to be low risk for perforation, this means specialities which did not include drilling, sawing or wiring. One of the subgroups in the single versus double gloving analysis involved single orthopaedic gloves. Though overall double gloving is more effective than single gloving, single orthopaedic gloves appear to offer the same level of protection as double gloving. The glove wearer also had fewer perforations in the orthopaedic glove than the double outermost glove which suggests that a single pair of orthopaedic gloves may not be as cumbersome.

There has been some resistance to double gloving by surgeons who feel their dexterity is compromised (St Germaine 2003). However double gloving did not result in significantly more outer glove perforations than single gloves, suggesting that the dexterity of the glove wearer is not sufficiently compromised leading to additional perforations.

Perforation indicator systems are effective in enabling glove wearers to detect perforations more easily. Two meta-analyses, one comparing single gloves with a perforations indicator system (582 gloves) and one comparing double gloves with a perforation indicator system (417 gloves) both showed that glove wearers detected significantly more perforations when using a perforation indicator system.

Almost all of the additional glove measures evaluated in this review - glove liners, knitted cloth gloves and triple gloving all provide significantly more protection than standard double gloving. The only exception is steel weave gloves which appeared to provide the same level of protection, with respect to the number of perforations, as standard double gloving.

Comparison with other reviews

This review updates the previous Cochrane review published in 2002 (Tanner 2002). One trial which was under assessment has been included (Wilson 1996) and an additional 13 trials have been added giving a total of 31 included trials. Despite the large amount of new data the findings for each of the comparisons are similar. This review presents the same findings and conclusions as the previous review. The only new comparison is triple gloving.

Methodological quality

Thirty-one eligible RCTs were included in this review. The methodological quality and reporting of methods of most of these trials was poor. Three trials were identified as being high quality (Doyle 1992; Tanner 2006; Turnquest 1996). Around half of the trials did not provide sufficient details of their process of randomisation or allocation to allow us to judge their validity. Only 5 out of 31 trials described sufficient randomisation and seven trials used inadequate methods of randomisation - patient number, admission date and patient birth dates. Just over half the trials randomised the glove wearer with the remaining trials randomising the patient. Only four trials stated that the testers were unaware of the allocation status of the gloves and only two trials carried out sample size calculations during the study design.

Sample size

Sample sizes were either given as the number of gloves tested or the number of operations included in the study. In some studies the number of gloves tested was confusing as authors did not specify if the figures represented individual gloves, pairs of gloves - or in the case of double gloving, sets of gloves (that is, four individual gloves). Judging the size of the sample was difficult due to the following variables - number of staff scrubbed for each operation and number of gloves worn by each person.

Outcome assessment

The confidence with which we can draw firm conclusions from these trials is influenced by weaknesses in their methods of testing for perforations. The standard perforation test recognised by the American Society for Testing and Materials and the European Standards Committee was used in only nine trials. However, there is some consistency among the remaining trials in that most used similar amounts of water, allowing comparisons to be made. Only

three trials, all with the same author and conducted in Thailand, tested for perforations by filling the gloves with air and then submerging them in water.

Surgical specialities

It was intended in the protocol to group trials by surgical speciality. However, it transpired that the trials had already separated themselves by surgical speciality and method of intervention. For example, trials involving the highest levels of protection (double and triple gloving options) were exclusively conducted in orthopaedic and maxillofacial surgery. This conforms with the current perception of specialities as being low or high risk for perforations. For example, double gloving is routine practice in orthopaedic surgery and rare in general surgery. However, rather than labelling entire surgical specialities as high or low risk it might be more appropriate to identify the risk for individual procedures. It might appear that the risk of glove perforation increases with procedures which involve bone and metal work, deep cavities or confined spaces.

Limitations

Almost all of the trials included in this review were limited in some way. Reporting of the trial design was usually poor in that most authors did not provide details of the randomisation, allocation concealment or blinding. Though the testing methods were comparable, future trials should use the standard test for measuring glove perforations.

Publication bias

We addressed attempts to overcome potential publication bias in the search strategy. One article was found which required translation. We contacted manufacturers and professional organisations for information. None of the companies and organisations which replied provided information which had not already been identified. We contacted nine trial authors for further information. Seven responded and all these trials are included in the review.

AUTHORS' CONCLUSIONS

Implications for practice

There is no evidence to determine the effect of wearing additional gloves on transferred infections.

Wearing two pairs of latex surgical gloves is associated with significantly fewer inner glove perforations. This evidence comes from trials undertaken in 'low risk' surgical specialties (there were none in orthopaedic joint surgery for example). There does not appear to be an increase in the number of perforations to outermost gloves when two pairs of gloves are worn, suggesting that wearing two pairs of gloves does not reduce dexterity to the extent that the glove wearer sustains more perforations. Wearing one pair of orthopaedic gloves (thicker than standard latex) is as effective as wearing two pairs of standard latex gloves in reducing the number of perforations to innermost gloves. Wearing glove perforation indicator systems enables the glove wearer to detect perforations to gloves more easily than when wearing standard double latex gloves. Wearing a perforation indicator system does not affect the number of perforations sustained.

Wearing a glove liner between two pairs of latex surgical gloves when undertaking joint replacement surgery is not associated with more perforations to the outermost glove and significantly reduces the number of perforations to the innermost glove. Wearing knitted outer gloves when undertaking joint replacement surgery significantly reduces the number of perforations to the innermost glove. Wearing steel weave outer gloves when undertaking joint replacement surgery does not appear to reduce the number of perforations to innermost gloves. Triple gloving offers more protection than double gloving.

When choosing a method of glove protection, triple gloving, knitted outer gloves and glove liners offer more protection than standard latex double gloving, Standard double gloving and perforation indicator systems offer more protection than single gloving.

Implications for research

- Randomised controlled trials are needed using an objective measures of cross infection, namely, surgical site infection, as the outcome
- Authors should use the CONSORT statement as a guideline for reporting trials.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

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

Aarnio 2001

Methods	Patients were randomised to one of two groups by year of birth. Testers details not given. Standard test used.
Participants	Primary and assistant surgeon. Vascular surgery. 200 gloves were collected
Interventions	Single versus perforation indicator system
Outcomes	Number of perforations. Proportion of total number of perforations detected during surgery by glove wearer.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Avery 1999a

Methods	Principal surgeon randomised to one of two groups by tossing a coin. The assistant was then assigned to the other group. Perforation test by inflating with water.
Participants	Principal surgeon and assistant. Maxillofacial surgery. 242 outer double gloves and 289 outer indicator gloves were collected.
Interventions	Double versus perforation indicator system
Outcomes	Number of perforations. Proportion of total number of perforations detected during surgery by the glove wearer..
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Avery 1999b

Methods	Surgical teams were randomised to one of two groups - details of method of randomisation not given. Allocation concealment using sealed envelopes. Perforation test gloves filled with 500 mls water
Participants	Surgical operator and assistant. Dental surgery. 260 single gloves and 251 double outer gloves were collected
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Berridge 1998

Methods	Surgical teams were randomised to one of two groups. Randomisation using a calculator randomisation function. Details of allocation concealment not given. Perforation test - 'high pressure of water'
Participants	Surgeon, assistant and scrub nurse. Vascular surgery. 258 single gloves and 248 double outer gloves were collected.
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.

Berridge 1998 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Caillot 1999

Methods	Surgical procedures randomised to one of two groups. Randomisation and concealment details not given
Participants	Principal surgeon and assistant. General surgery. Sample size of 80 procedures.
Interventions	Single versus standard double gloving.
Outcomes	Glove perforation, porosity or gown wetting.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Doyle 1992

Methods	Surgeons and surgeons assistant were randomised to wear either single or double gloves. Details of method of randomisation not given. Concealment by sealed envelopes. Perforations tested by filling with 'approximately 500 mls of water', gentle manipulation and observing leaks.
Participants	Surgeons and surgeons assistant. Obstetric and gynaecology surgery. 136 single gloves and 158 double outer gloves were collected.
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Duron 1996

Methods	Patients were randomly assigned to one of two groups. Details of method of randomisation and concealment are not given. Perforation test - gloves placed in labelled bag, tested in a laboratory by filling with water, cuff tied and palm and digit expressed to identify leaks of water.
Participants	Surgeons and scrub nurses. central venous cannulation and insertion of implantable catheters with ports. 92 double outer gloves and 108 indicator outer gloves were collected.
Interventions	Standard double versus indicator system
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Gani 1990

Methods	Patients randomised to one of two groups by hospital record number. Wearers tested own gloves. Test method - glove filled with unspecified amount of water and squeezed.
Participants	Surgeons and scrub staff. Mix of surgical procedures. Sample size of 233 patients.
Interventions	Single versus standard double gloving.
Outcomes	Number of perforations
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Hester 1992

Methods	Patients randomised to one of three groups by admission date. Tester details given. Glove filled with 500 mls and squeezed.
Participants	Surgeons and assistants. Total joint arthroplasty. Sample size of 75 patients.
Interventions	Group 1 - orthopaedic gloves with latex gloves on top. Group 2 - orthopaedic gloves with cotton gloves on top. Group 3 - orthopaedic gloves, cotton gloves and latex gloves on top.
Outcomes	Number of perforations
Notes	

Hester 1992 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Jensen 1997

Methods	Principle and first surgeons randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforations tested by filling with water, gently manipulating water into each digit and observing for leaks.
Participants	Principle and first surgeons. Abdominal surgery. 200 single gloves and 200 double outer gloves were collected.
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Kovavisarach 1998

Methods	Residents randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforations tested by filling glove with 1.5-2 times its normal capacity and immersing in water. Air bubbles indicated perforation
Participants	Residents. Obstetric surgery - perineorrhaphy. 742 single gloves and 658 double outer gloves were collected.
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Kovavisarach 1999

Methods	Surgeons randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforations tested by filling glove with 1.5-2 times its normal capacity and immersing in water. Air bubbles indicated perforation.
Participants	Primary surgeons. Obstetric surgery - caesarian section. 300 single gloves and 300 double outer gloves were collected.
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Kovavisarach 2002

Methods	Surgeons were randomised to one of two groups. Randomisation and allocation concealment details not given. Testers were unaware of glove group status. Glove filled with air and submerged in water.
Participants	Primary surgeons. Abdominal hysterectomy. Sample size - 170 patients.
Interventions	Single versus standard double gloving.
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Laine 2001

Methods	Patient randomised by birth date. Tester details not given. Standard test used.
Participants	Primary and assistant surgeon. Orthopaedic, trauma and gastrointestinal surgery. Sample - 885 patients in a 2 arm study.
Interventions	Single versus standard double versus perforation indicator gloves.
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery.
Notes	

Laine 2001 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Laine 2004a

Methods	Glove wearer randomised. Details of randomisation, concealment or tester not given. Standard test used.
Participants	Primary and assistant surgeon. Conventional and arthroscopic orthopaedic and trauma surgery. Sample - 349 patients
Interventions	Single versus standard double versus perforation indicator gloves.
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Laine 2004b

Methods	Glove wearer randomised. Details of randomisation, concealment and tester not given. Standard test used.
Participants	Primary and assistant surgeon. Abdominal surgery. Sample - 274 patients, 1,628 gloves (814 pairs).
Interventions	Single versus perforation indicator gloves
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Louis 1998

Methods	Surgeons randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves filled with 1000 mls of water, suspended from occluded cuff five feet above ground. The gloves and digits were pressurised and water jets noted.
Participants	Surgeon and assistant. Orthopaedic surgery. 117 double inner gloves and 106 latex/steel inner gloves were collected.
Interventions	Standard double gloves versus latex inner glove with polyester/stainless steel wire weave outer glove
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Marin Bertolin 1997

Methods	Surgeons and scrub nurses randomly wore single or double gloves. One surgeon wore vinyl rather than latex gloves. No details of the randomisation or concealment were given. Gloves were filled with 500 mls water and gently squeezed.
Participants	Surgeons and scrub nurses. Plastic surgery. Sample size 335 single gloves and 333 double outer gloves.
Interventions	Single versus standard double gloves.
Outcomes	
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Naver 2000

Methods	Surgical team were randomised to one of two groups using a sealed envelope. Details of method of randomisation not given. Perforation test - gloves were filled with water to detect perforations
Participants	Surgeons, assistants and scrub nurses. Gastrointestinal surgery. 612 single gloves and 520 double outer gloves were collected.
Interventions	Single versus perforation indicator system.
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery. Blood contamination on hands

Naver 2000 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Nicolai 1997

Methods	Patients were randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves filled with 1000 mls of water and cuff twisted through 360 degrees.
Participants	Surgeon, assistant and scrub nurse. Orthopaedic surgery - major joint replacement. 153 double outer gloves and 209 indicator outer gloves were collected.
Interventions	Standard double versus perforation indicator system.
Outcomes	Number of perforations. Proportion of total number of perforations detected by glove wearer during surgery.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Pieper 1995

Methods	Glove wearer randomised. Details of randomisation, concealment and tester not given. Gloves filled with 500 mls of water and squeezed.
Participants	Primary and assistant surgeon. maxillofacial surgery. Sample - 30 patients with 2 surgeons per case.
Interventions	Standard double versus triple gloving (triple latex, or double latex plus liner).
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Unclear risk	B - Unclear

Punyatanasakchai 2004

Methods	Glove wearer randomised. Details of randomisation and tester not given. Sealed envelopes used. Gloves filled with 500 mls of water and squeezed.
Participants	Primary surgeons. Gynaecological surgery. 150 sets of double gloves, 150 sets of single gloves were collected.
Interventions	Single versus standard double gloving.
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Rudiman 1999

Methods	Patient randomised by hospital number. Details of glove tester not given. Glove filled with unspecified amount of water and squeezed.
Participants	Primary and assistant surgeon. General surgery. sample - 60 patients.
Interventions	Single versus standard double gloving.
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

Sanders 1990

Methods	Surgeons were randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves were filled with 1000 mls of water, suspended by occluded cuff five feet above ground. Digits were squeezed and jets of water noted.
Participants	Surgeons. Orthopaedic surgery involving the manipulation of bone or application of implants. 58 double inner gloves and 52 cloth/latex inner gloves were collected.
Interventions	Standard double versus latex inner with cloth outer glove.
Outcomes	Number of perforations. Commented on surgical site infections though this was not the focus for the study.
Notes	

Sanders 1990 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Sebold 1993

Methods	Patients were randomised to one of three groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves were filled with water and individual digits were squeezed.
Participants	Primary surgeon. Orthopaedic surgery - total joint replacements. 58 double outer gloves and 63 latex/liner outer gloves were collected.
Interventions	Standard double versus latex inner with orthopaedic outer versus double latex with cloth liner insert
Outcomes	Number of perforations. Commented on surgical site infections though this was not the focus for the study.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Sutton 1998

Methods	Patients were randomised into one of two groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves were filled with water to a diameter of 10 cm around the palm and fingers squeezed to a diameter of 4cms. The investigator was blind as to which group the glove came from.
Participants	Primary surgeon. Orthopaedic surgery - primary or revision, hip or knee arthroplasty. 124 double outer gloves and 112 latex/liner outer gloves were collected.
Interventions	Standard double versus double latex with liner insert
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Tanner 2006

Methods	Individual surgeons and scrub staff were randomised using number tables and sealed envelopes into 2 groups. A priori sample size calculations were carried out. Testers were unaware of glove group status. Gloves were filled with 1000 mls of water and observed for leaks.
Participants	Primary surgeon, assistant surgeon and scrub staff. Patient undergoing primary hip or knee replacements. 406 gloves were collected.
Interventions	Standard double versus latex inner with knitted outer glove
Outcomes	Number of perforations
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Thomas 2001

Methods	Surgeons were randomised into two groups using sealed envelopes immediately prior to scrubbing. Details of method of randomisation not given. Perforations were tested by 2 methods: filling the gloves with air and submerging them in water and filling the gloves with water and observing for leaks.
Participants	Primary surgeon and assistant surgeon. General surgery
Interventions	Single versus standard double gloves
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Turnquest 1996

Methods	Surgical team were randomised to one of two groups using computer generated numbers in sealed envelopes. Perforation test - gloves were filled with water by investigators, cuffs were occluded and observed for leaks.
Participants	Residents, scrub person and medical students. Obstetric surgery. 344 single gloves and 338 double outer gloves were collected.
Interventions	Single orthopaedic latex gloves versus double standard latex gloves
Outcomes	Number of perforations.

Turnquest 1996 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Underwood 1993

Methods	Cases were randomised to one of two groups using sealed envelopes. Details of method of randomisation not given. Perforation test - gloves were filled with water, squeezed and observed for leaks.
Participants	Surgeon and assistant. Cardiac surgery - sternal closure. 40 double inner gloves and 40 latex/cloth inner gloves were collected.
Interventions	Standard double versus latex inner with cloth outer glove
Outcomes	Number of perforations.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	Low risk	A - Adequate

Wilson 1996

Methods	Surgeons were randomised to 1 of 4 gloving groups. Randomisation was achieved through taking a card out of an envelope with numbers 1-4 printed on it. No details regarding the method used to detect perforations are given.
Participants	Surgeons only.
Interventions	Single gloves versus 3 standard double gloving combinations. Group 1- normal size inside with half size larger outside. Group 2 - normal size outside with half size larger inside. Group 3 two pairs of normal size.
Outcomes	Subjective effects - comfort, sensitivity and dexterity. Perforations
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment?	High risk	C - Inadequate

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

Study	Reason for exclusion
Ablett 1995	Only double gloving was assessed. No comparison group was included.
Adoumie 1994	A laboratory study, not a clinical study. Outcome was perception of temperature
Albin 1992	Survey of single glove perforations only. Not an RCT
Alwari 2001	Survey of all gloves used over period of time. Not an RCT
Barbosa 2004	Survey of all gloves used over a period of time. Not an RCT
Bebbington 1996	RCT of surgical closure using a surgical assist device
Beck 1994	Discussion paper only
Bennett 1991	Study looks at double gloves only. No comparison group included.
Bennett 1994	Laboratory test of blood inoculation from needles and sutures
Bliss 1992	Randomised controlled trial but compares brand A against brand B. No details are given of the differences between each brand
Botet 1998	RCT of a surgical instrument used during wound closure
Brown 1996	Study looks at glove indicator system only. No comparison group included
Brownson 1990	A laboratory test, not a clinical study.
Calliot 1997	Single versus double gloves but the outcome was electronic alarms rather than perforations
Calliot 1998	Single versus double gloves but the outcome was electronic alarms rather than perforations
Carter 1996	Insufficient randomisation. Study compares two types of single gloves; super sensitive and standard.
Chapman 1993	Investigated double gloves only, no comparison group.
Chen 1998	Laboratory test of various liners.
Chiu 1993	Study looks at double gloves only. No comparison group.
Cohen 1992	Study not randomised.
Cohn 1990	Study not randomised. Outcome compared blood on hands not perforations
Cole 1989	Study not randomised.
Cox 1994	Laboratory test of different brands of testing methods using electronic equipment.
Diaz Boxo 1991	Laboratory test rather than clinical trial
Dirschka 2004	Survey of perforation rate of all gloves used over period of time. Not an RCT
Dodds 1990	Study not randomised.

Study	Reason for exclusion
Driever 2001	Not an RCT - survey of all gloves used over period of time.
Dupre 1999	A letter written in response to an article
Eckersley 1990	Not randomised, surgeons chose which glove to wear.
Eggleston 1997	RCT of surgical trays to reduce glove perforation
Endres 1990	Study looks at double gloves only. No comparison group
Faisal 2004	Survey of all gloves used over set period of time. Not an RCT
Fay 1994	Study looked at perforation indicator gloves only. No comparison group.
Fell 1989	Survey of perforated gloves. Not an RCT
Fischer 1999a	Study looked at perforation indicator gloves only. No comparison group.
Fischer 1999b	Laboratory test, not clinical trial.
Florman 2005	Study of simulated surgery considering the speed of detection of the glove perforation. Perforations were created by laser.
Gerberding 1990	An observational study, not randomised into groups
Godin 1991	Observational study. No randomisation of interventions.
Greco 1995	Study looks at double gloves only. No comparison group.
Herscovici 1998	Laboratory test, not clinical trial.
Hollaus 1999	Study measures double gloves only. No comparison group
Housan 2000	Survey of all gloves used over period of time. Not an RCT
Hwang 1999	Randomised controlled trial which compared four different manufacturers brands of gloves. Perforation rates were only shown in a diagrammatic form.
Jackson 1999	Laboratory testing, not clinical trial
Johanet 1995	Observational study of blood exposure. Not an RCT
Johanet 1996	Observational study of blood exposure. Not an RCT
Johnson 1991	Laboratory test of various gloving methods with contaminated suture needles
Kelly 1993	Laboratory test on cadavers and patients. Not randomised.
Kim 2001	Evaluation of glove wearing compliance following an educational programme.
Konig 1992	Gloves were not randomised into different groups.
Korniewicz 1994	Non clinical test of examination gloves.
Kummer 1992	Laboratory test of liners

Study	Reason for exclusion
Larkin 1993	Not a randomised study. Two surgeons - 1 wore glove group A and the other surgeon wore glove group B
Lavernia 1996	Not a RCT, allocation on a consecutive basis
Lee 2001	An observational study of compliance. Not an RCT
Leslie 1996	Laboratory test, not clinical trial
Liew 1995	RCT . Intervention was one which was not addressed by this review -various combinations of standard and orthopaedic gloves.
Logan 2000	Tested 5 different brands of gloves. Divided into groups, not randomised.
Malhotra 2004	Survey of all double gloves used over period of time. Not an RCT
Manson 1995	Study looks at glove indicator system only. No comparison group.
Matta 1988	Study measures double gloves only. No comparison group.
McCue 1981	Only double gloves were tested. No comparison group.
McLeod 1989	Not randomised, surgeons chose which gloves to wear.
Meyer 1996	RCT of surgical closure using different needles
Nelson 1995	Gloves of varying thickness were tested in a laboratory for dexterity
Newsom 1993	Study not randomised.
Newsom 1998	Randomised controlled trial which compared latex free with latex gloves.
Novak 1999	Laboratory test of sensation when wearing double or single gloves.
Novi 1993	Literature review
Panduro 1996	Not randomised.
Patton 1995	Study looks at double gloves only. No comparison group.
Phillips 1979	Non clinical test of dexterity when wearing Kevlar gloves
Plucknet 1992	Measured blood contamination on hand - not perforations. Does not state if it is a randomised study.
Quebbeman 1992	Data from surgeons who did not comply with randomisation were still included in the study
Rogers 2000	Systematic review.
Rose 1994a	Observational study of glove usage. Not an RCT
Rose 1994b	Observational study of glove usage. Not an RCT
Salkin 1995	Laboratory test of glove liners

Study	Reason for exclusion
Savitz 1994	Looked at double gloves only - no comparison group
Schwimmer 1994	Looked at double gloves only - no comparison group
Tokars 1994	Survey not an RCT.
Tokars 1995	Observational study - looked at blood on hands not perforations
Tomichan 2000	Describes using a glove liner to cover the head of an orthopaedic prosthesis during surgery to prevent abrasions.
Twomey 2003	Discussion paper and literature review
Upton 1993	Looked at double gloves only - no comparison group
Vaughan-Lane 1993	Study measures glove indicator system only. No comparison group
Watts 1994	Laboratory test for dexterity only
Webb 1993	Lab comparison of single versus double gloving for tactile discrimination and dexterity.
Wigmore 1994	Study measures glove indicator system only. No comparison group.
Williams 1997	Discussion paper on electronic testing of gloves.
Woods 1996	Laboratory test for dexterity only
Wright 1993	RCT of new suture
Zimmerman 1996	Study measures glove indicator system only. No comparison group

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

Ganczak 2004

Methods	
Participants	
Interventions	
Outcomes	
Notes	Awaiting translation

Gaujac 2007

Methods	
Participants	

Gaujac 2007 *(Continued)*

Interventions	
Outcomes	
Notes	Awaiting full text

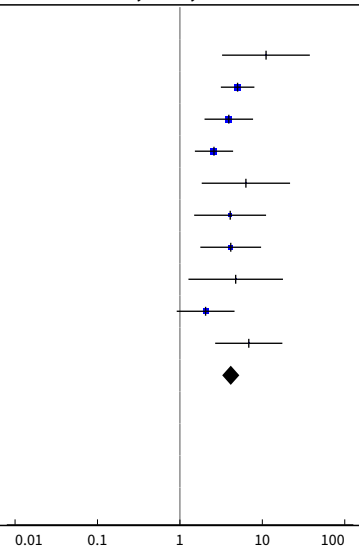
DATA AND ANALYSES

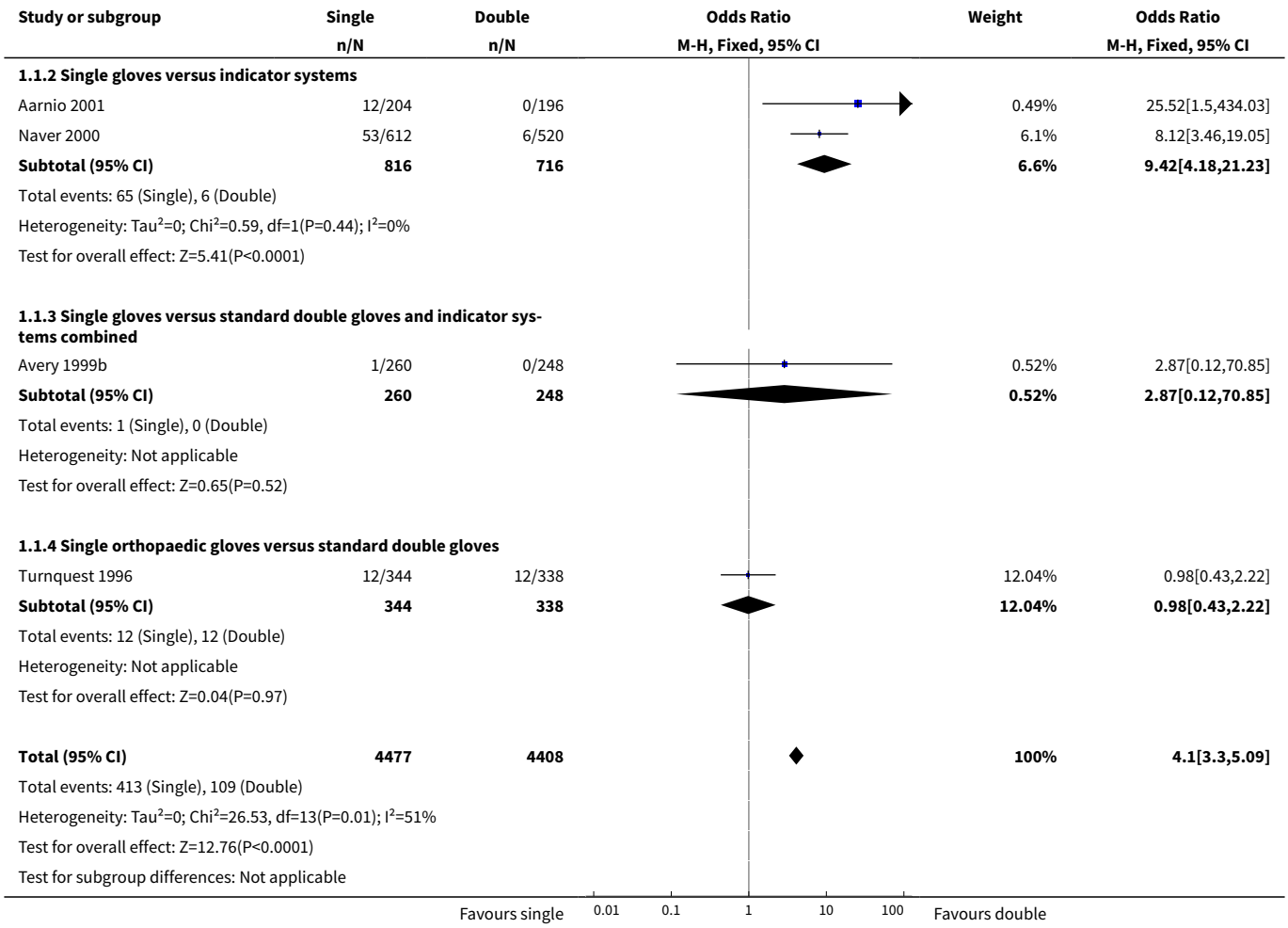
Comparison 1. Single gloves versus double gloves - innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations in innermost gloves	14	8885	Odds Ratio (M-H, Fixed, 95% CI)	4.10 [3.30, 5.09]
1.1 Single gloves versus standard double gloves	10	6163	Odds Ratio (M-H, Fixed, 95% CI)	4.14 [3.26, 5.26]
1.2 Single gloves versus indicator systems	2	1532	Odds Ratio (M-H, Fixed, 95% CI)	9.42 [4.18, 21.23]
1.3 Single gloves versus standard double gloves and indicator systems combined	1	508	Odds Ratio (M-H, Fixed, 95% CI)	2.87 [0.12, 70.85]
1.4 Single orthopaedic gloves versus standard double gloves	1	682	Odds Ratio (M-H, Fixed, 95% CI)	0.98 [0.43, 2.22]

Analysis 1.1. Comparison 1 Single gloves versus double gloves - innermost, Outcome 1 Number of perforations in innermost gloves.

Study or subgroup	Single n/N	Double n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
1.1.1 Single gloves versus standard double gloves					
Doyle 1992	24/136	3/158		2.35%	11.07[3.25,37.67]
Gani 1990	108/915	22/846		20.77%	5.01[3.14,8.01]
Jensen 1997	40/200	12/200		9.89%	3.92[1.99,7.72]
Kovavisarach 1998	53/742	19/658		19.26%	2.59[1.52,4.42]
Kovavisarach 1999	18/300	3/300		2.9%	6.32[1.84,21.69]
Kovavisarach 2002	20/176	5/164		4.73%	4.08[1.49,11.13]
Punyatanasakchai 2004	27/300	7/300		6.56%	4.14[1.77,9.66]
Rudiman 1999	12/60	3/60		2.47%	4.75[1.27,17.82]
Thomas 2001	19/132	10/132		8.82%	2.05[0.91,4.6]
Wilson 1996	14/96	7/288		3.08%	6.85[2.68,17.55]
Subtotal (95% CI)	**3057**	**3106**		**80.84%**	**4.14[3.26,5.26]**
Total events: 335 (Single), 91 (Double)					
Heterogeneity: Tau^2=0; Chi^2=10.61, df=9(P=0.3); I^2=15.2%					
Test for overall effect: Z=11.62(P<0.0001)					



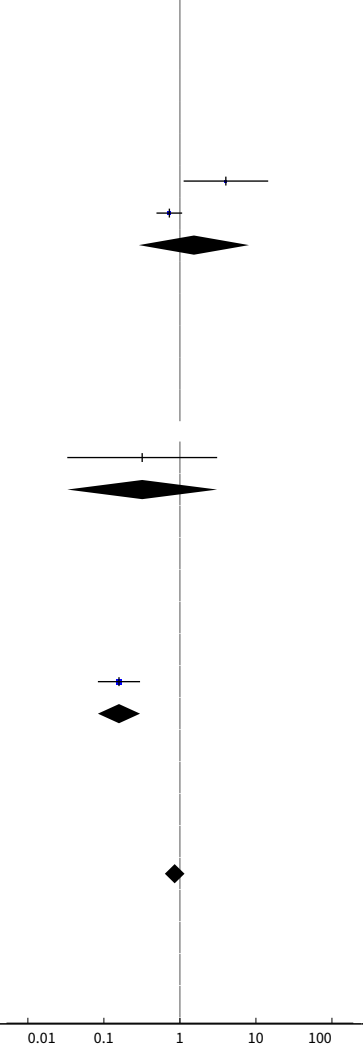


Comparison 2. Single gloves versus double gloves - outermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations in outermost gloves	13	8531	Odds Ratio (M-H, Random, 95% CI)	0.85 [0.63, 1.15]
1.1 Single gloves versus standard double gloves	9	5806	Odds Ratio (M-H, Random, 95% CI)	0.95 [0.80, 1.12]
1.2 Single gloves versus indicator systems	2	1532	Odds Ratio (M-H, Random, 95% CI)	1.53 [0.29, 8.11]
1.3 Single gloves versus standard double gloves and indicator systems combined	1	511	Odds Ratio (M-H, Random, 95% CI)	0.32 [0.03, 3.09]
1.4 Single orthopaedic gloves versus standard double gloves	1	682	Odds Ratio (M-H, Random, 95% CI)	0.16 [0.08, 0.30]

Analysis 2.1. Comparison 2 Single gloves versus double gloves - outermost, Outcome 1 Number of perforations in outermost gloves.

Study or subgroup	Single n/N	Double n/N	Odds Ratio M-H, Random, 95% CI	Weight	Odds Ratio M-H, Random, 95% CI
2.1.1 Single gloves versus standard double gloves					
Doyle 1992	24/136	21/158		7.98%	1.4[0.74,2.64]
Gani 1990	108/915	117/873		11.32%	0.86[0.65,1.14]
Jensen 1997	40/200	47/200		9.51%	0.81[0.51,1.31]
Kovavisarach 1998	53/742	41/658		10.04%	1.16[0.76,1.77]
Kovavisarach 1999	18/300	20/300		7.78%	0.89[0.46,1.73]
Kovavisarach 2002	20/176	16/164		7.46%	1.19[0.59,2.38]
Punyatanasakchai 2004	27/300	34/300		8.96%	0.77[0.45,1.32]
Rudiman 1999	12/60	10/60		5.65%	1.25[0.49,3.16]
Thomas 2001	19/132	22/132		7.7%	0.84[0.43,1.64]
Subtotal (95% CI)	**2961**	**2845**		**76.4%**	**0.95[0.8,1.12]**
Total events: 321 (Single), 328 (Double)					
Heterogeneity: Tau^2=0; Chi^2=4.55, df=8(P=0.8); I^2=0%					
Test for overall effect: Z=0.67(P=0.51)					
2.1.2 Single gloves versus indicator systems					
Aarnio 2001	12/204	3/196		3.77%	4.02[1.12,14.47]
Naver 2000	53/612	60/520		10.35%	0.73[0.49,1.07]
Subtotal (95% CI)	**816**	**716**		**14.12%**	**1.53[0.29,8.11]**
Total events: 65 (Single), 63 (Double)					
Heterogeneity: Tau^2=1.24; Chi^2=6.33, df=1(P=0.01); I^2=84.2%					
Test for overall effect: Z=0.5(P=0.62)					
2.1.3 Single gloves versus standard double gloves and indicator systems combined					
Avery 1999b	1/260	3/251		1.51%	0.32[0.03,3.09]
Subtotal (95% CI)	**260**	**251**		**1.51%**	**0.32[0.03,3.09]**
Total events: 1 (Single), 3 (Double)					
Heterogeneity: Not applicable					
Test for overall effect: Z=0.99(P=0.32)					
2.1.4 Single orthopaedic gloves versus standard double gloves					
Turnquest 1996	12/344	63/338		7.97%	0.16[0.08,0.3]
Subtotal (95% CI)	**344**	**338**		**7.97%**	**0.16[0.08,0.3]**
Total events: 12 (Single), 63 (Double)					
Heterogeneity: Not applicable					
Test for overall effect: Z=5.68(P<0.0001)					
Total (95% CI)	**4381**	**4150**		**100%**	**0.85[0.63,1.15]**
Total events: 399 (Single), 457 (Double)					
Heterogeneity: Tau^2=0.18; Chi^2=40.06, df=12(P<0.0001); I^2=70.05%					
Test for overall effect: Z=1.05(P=0.29)					
Test for subgroup differences: Not applicable					

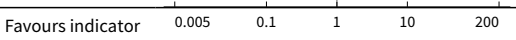


Comparison 3. Single gloves versus indicator systems - proportion of perforations detected during surgery

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Proportion of perforations detected during surgery	5	417	Odds Ratio (M-H, Fixed, 95% CI)	0.10 [0.06, 0.16]

Analysis 3.1. Comparison 3 Single gloves versus indicator systems - proportion of perforations detected during surgery, Outcome 1 Proportion of perforations detected during surgery.

Study or subgroup	Single gloves n/N	Indicator gloves n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Aarnio 2001	6/12	3/3		2.47%	0.14[0.01,3.35]
Laine 2001	28/76	77/89		41.29%	0.09[0.04,0.2]
Laine 2004a	3/13	37/41		12.63%	0.03[0.01,0.17]
Laine 2004b	12/38	29/32		19.85%	0.05[0.01,0.19]
Naver 2000	22/53	47/60		23.77%	0.2[0.09,0.45]
Total (95% CI)	**192**	**225**		**100%**	**0.1[0.06,0.16]**
Total events: 71 (Single gloves), 193 (Indicator gloves)					
Heterogeneity: Tau^2=0; Chi^2=5.59, df=4(P=0.23); I^2=28.46%					
Test for overall effect: Z=9.31(P<0.0001)					

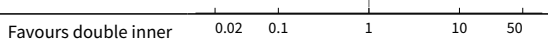


Comparison 4. Double gloves versus indicator glove - innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations in innermost gloves	2	396	Odds Ratio (M-H, Random, 95% CI)	1.38 [0.65, 2.90]

Analysis 4.1. Comparison 4 Double gloves versus indicator glove - innermost, Outcome 1 Number of perforations in innermost gloves.

Study or subgroup	Double n/N	Indicator n/N	Odds Ratio M-H, Random, 95% CI	Weight	Odds Ratio M-H, Random, 95% CI
Duron 1996	0/92	1/124		5.39%	0.45[0.02,11.05]
Nicolai 1997	16/76	16/104		94.61%	1.47[0.68,3.16]
Total (95% CI)	**168**	**228**		**100%**	**1.38[0.65,2.9]**
Total events: 16 (Double), 17 (Indicator)					
Heterogeneity: Tau^2=0; Chi^2=0.5, df=1(P=0.48); I^2=0%					
Test for overall effect: Z=0.84(P=0.4)					



Comparison 5. Double gloves versus indicator glove - outermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations in outermost gloves	2	396	Odds Ratio (M-H, Random, 95% CI)	1.46 [0.69, 3.08]

Analysis 5.1. Comparison 5 Double gloves versus indicator glove - outermost, Outcome 1 Number of perforations in outermost gloves.

Study or subgroup	Double n/N	Indicator n/N	Odds Ratio M-H, Random, 95% CI	Weight	Odds Ratio M-H, Random, 95% CI
Duron 1996	5/92	8/124		31.83%	0.83[0.26,2.64]
Nicolai 1997	33/76	30/104		68.17%	1.89[1.02,3.52]
Total (95% CI)	**168**	**228**		**100%**	**1.46[0.69,3.08]**
Total events: 38 (Double), 38 (Indicator)					
Heterogeneity: Tau^2=0.11; Chi^2=1.51, df=1(P=0.22); I^2=33.84%					
Test for overall effect: Z=0.99(P=0.32)					

Favours double outer — Favours ind. outer

Comparison 6. Double gloves versus indicator systems - proportion of perforations detected during surgery

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Proportion of perforations detected during surgery	5	582	Odds Ratio (M-H, Random, 95% CI)	0.08 [0.04, 0.17]

Analysis 6.1. Comparison 6 Double gloves versus indicator systems - proportion of perforations detected during surgery, Outcome 1 Proportion of perforations detected during surgery.

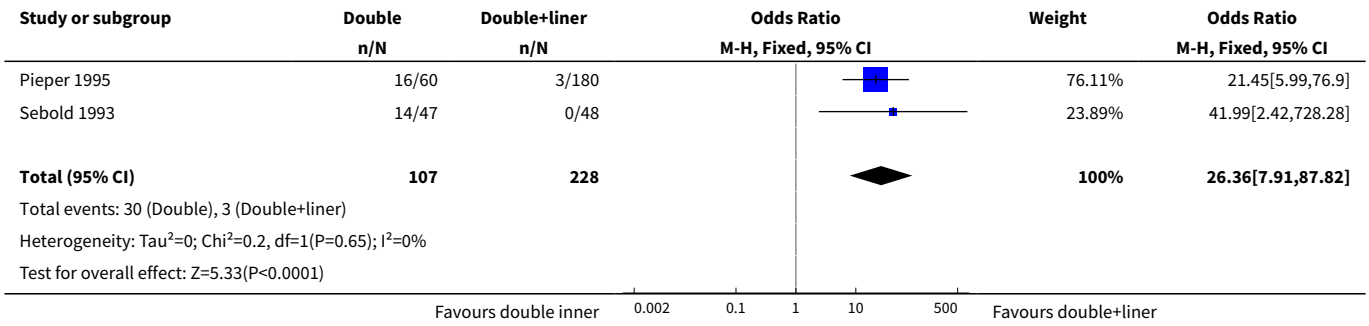
Study or subgroup	Double n/N	Indicator n/N	Odds Ratio M-H, Random, 95% CI	Weight	Odds Ratio M-H, Random, 95% CI
Avery 1999a	29/138	124/153		34.86%	0.06[0.03,0.11]
Duron 1996	0/5	9/9		2.84%	0[0,0.28]
Laine 2001	9/27	77/89		23.63%	0.08[0.03,0.21]
Laine 2004a	9/25	37/41		17.61%	0.06[0.02,0.23]
Nicolai 1997	5/49	13/46		21.06%	0.29[0.09,0.89]
Total (95% CI)	**244**	**338**		**100%**	**0.08[0.04,0.17]**
Total events: 52 (Double), 260 (Indicator)					
Heterogeneity: Tau^2=0.29; Chi^2=7.74, df=4(P=0.1); I^2=48.3%					
Test for overall effect: Z=6.88(P<0.0001)					

Favours indicator — Favours double

Comparison 7. Double gloves versus double plus liner glove - innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations to innermost gloves	2	335	Odds Ratio (M-H, Fixed, 95% CI)	26.36 [7.91, 87.82]

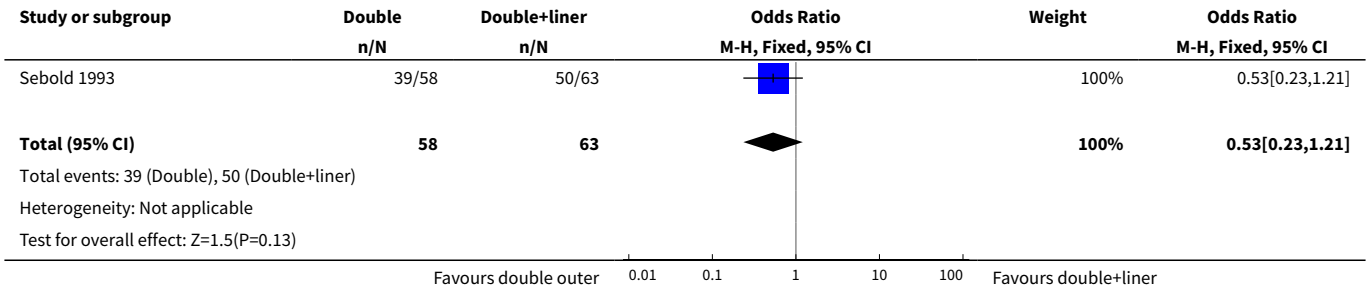
Analysis 7.1. Comparison 7 Double gloves versus double plus liner glove - innermost, Outcome 1 Number of perforations to innermost gloves.



Comparison 8. Double gloves versus double plus liner glove - outermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations to outermost gloves	1	121	Odds Ratio (M-H, Fixed, 95% CI)	0.53 [0.23, 1.21]

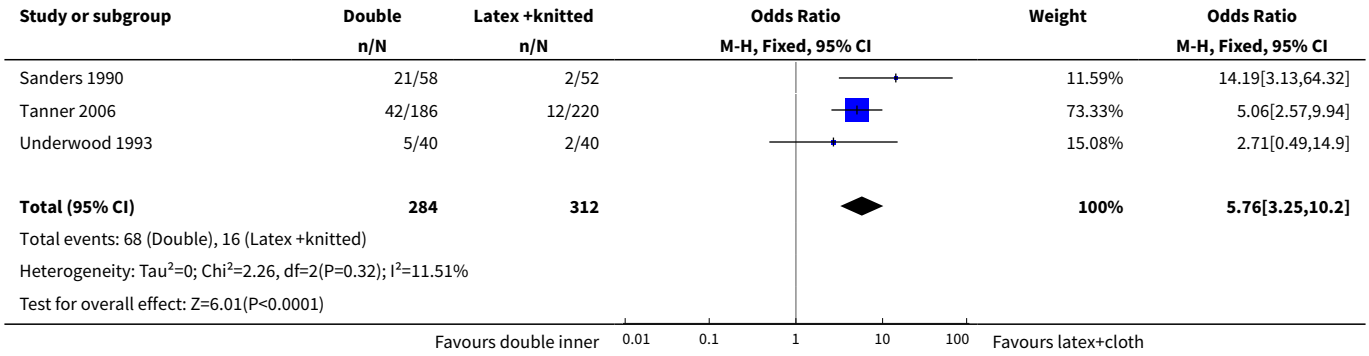
Analysis 8.1. Comparison 8 Double gloves versus double plus liner glove - outermost, Outcome 1 Number of perforations to outermost gloves.



Comparison 9. Double gloves versus latex plus knitted glove - innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations to innermost gloves	3	596	Odds Ratio (M-H, Fixed, 95% CI)	5.76 [3.25, 10.20]

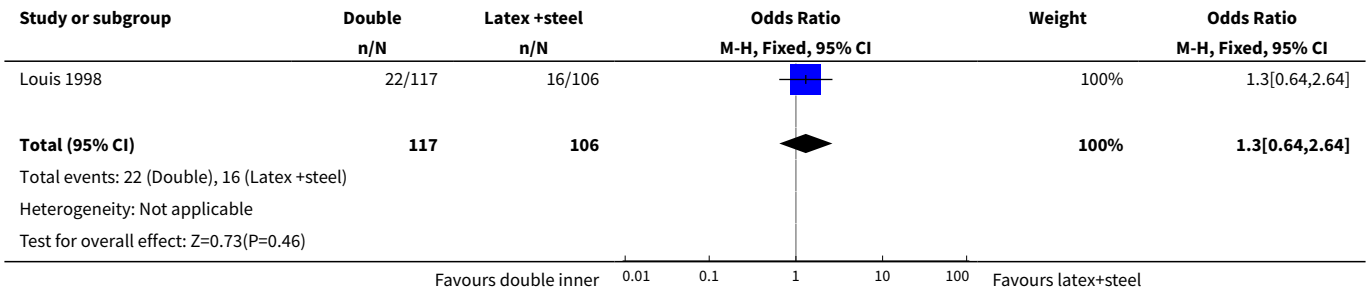
Analysis 9.1. Comparison 9 Double gloves versus latex plus knitted glove - innermost, Outcome 1 Number of perforations to innermost gloves.



Comparison 10. Double gloves versus latex plus steel weave glove -innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations to innermost gloves	1	223	Odds Ratio (M-H, Fixed, 95% CI)	1.30 [0.64, 2.64]

Analysis 10.1. Comparison 10 Double gloves versus latex plus steel weave glove -innermost, Outcome 1 Number of perforations to innermost gloves.



Comparison 11. Double gloves versus triple gloves - innermost

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Number of perforations to innermost gloves	1	60	Odds Ratio (M-H, Fixed, 95% CI)	69.41 [3.89, 1239.18]

Analysis 11.1. Comparison 11 Double gloves versus triple gloves - innermost, Outcome 1 Number of perforations to innermost gloves.

Study or subgroup	Double glove n/N	Triple glove n/N	Odds Ratio M-H, Fixed, 95% CI	Weight	Odds Ratio M-H, Fixed, 95% CI
Pieper 1995	16/30	0/30		100%	69.41[3.89,1239.18]
Total (95% CI)	**30**	**30**		**100%**	**69.41[3.89,1239.18]**
Total events: 16 (Double glove), 0 (Triple glove)					
Heterogeneity: Not applicable					
Test for overall effect: Z=2.88(P=0)					

APPENDICES

Appendix 1. Search strategy - Original 2002

Studies to be considered for the review were sought from Cochrane Wounds Group Specialised Trials Register. This database was searched on CD ROM 2002 Issue 1 using the following strategy:
1. GLOVES-SURGICAL*:ME
2. PROTECTIVE-CLOTHING*:ME
3. (GLOVE or GLOVES)
4. (GLOVE and LINER)
5. (PUNCTURE and INDICATOR*)
6. ((((#1 or #2) or #3) or #4) or #5)
7. OPERATING-ROOMS*ME
8. INFECTION-CONTROL*:ME
9. (#7 or #8)
10. (#6 and #9)

The Cochrane Wounds Group Specialised Trials Register has been compiled through searching the major health databases including MEDLINE, CINAHL and EMBASE and is regularly updated through hand searching of the Cochrane Controlled Trials Register. The American Journal of Infection Control (from 1990) was handsearched.

Reference lists of located trials and review articles were searched. Citation lists of obtained articles were scrutinised to identify additional studies. Details of published and unpublished studies were sought from the following glove manufacturing companies; SSL International, Regent Medical, Semper-med, Vernacare, BM Polyco Ltd, Ansell Medical, Safeskin and Allegiance. The language of publication of an article was not a barrier. The professional associations, National Association of Theatre Nurses (UK), European Operating Room Nurse Association, Association of Operating Room Nurses (USA), Infection Control Nurses Association (UK), Royal College of Surgeons (UK) and The British Association of Operating Department Assistants were approached for information. The conference proceedings of The National Association of Theatre Nurses were hand searched and an electronic search of the ZETOC database of conference proceedings was undertaken.

Of the glove manufacturers contacted, SSL International, Regent Medical and Allegiance Healthcare responded. Allegiance Healthcare provided the results of a literature search on double gloving. The National Association of Theatre Nurses gave details of a conference paper on double gloving. All of the trials identified by the glove manufacturers and professional associations were identified through the conventional search strategy.

Appendix 2. Search strategy - first update 2005

For this first update, we searched the Cochrane Wounds Group Specialised Register (January 2006) and the Cochrane Central Register of Controlled Trials (CENTRAL)(*The Cochrane Library,* Issue 4, 2005), using the following strategy:

1. GLOVES-SURGICAL explode all trees (MeSH)
2. PROTECTIVE-CLOTHING explode tree 1 (MeSH)
3. (glove or gloves or gloving)
4. (puncture and indicator*)
5. (#1 or #2 or #3 or #4)
6. SURGICAL WOUND INFECTION explode all trees (MeSH)
7. WOUND INFECTION single term (MeSH)
8. INFECTION CONTROL explode all trees (MeSH)
9. (wound* near infect*)
10. (surg* near infect*)
11. (surg* near wound*)
12. (surg* near complication*)
13. OPERATING ROOMS single term (MeSH)
14. (#6 or #7 or #8 or #9 or #10 or #11 or #12 or #13)
15. (#5 and #14)

The Cochrane Wounds Group Specialised Register has been compiled through searching the major health databases including MEDLINE, CINAHL and EMBASE and is regularly updated through hand searching of the Cochrane Central Register of Controlled Trials (CENTRAL).

We searched reference lists of located trials and review articles and scrutinised citation lists of obtained articles to identify additional studies. We also sought details of published and unpublished studies from the following glove manufacturing companies; Regent Medical, Semper-med, Vernacare, BM Polyco Ltd, Ansell Medical, Safeskin and Allegiance. We contacted the following professional associations: Association for Perioperative Practice (UK), European Operating Room Nurse Association, Association of Operating Room Nurses (USA), Infection Control Nurses Association (UK), Royal College of Surgeons (UK) and The British Association of Operating Department Assistants for information. In addition, we hand searched the conference proceedings of The Association for Perioperative Practice and undertook an electronic search of the ZETOC database of conference proceedings.

Of the glove manufacturers contacted, Regent Medical and Allegiance Healthcare responded. Allegiance Healthcare provided the results of a literature search on double gloving. The Association for Perioperative Practice gave details of a conference paper on double gloving. All of the trials identified by the glove manufacturers and professional associations were identified through the conventional search strategy.

For the original version of this review, we hand searched The American Journal of Infection Control 1990 to 2000. As no additional trials were found we did not repeat this process for this updated version.

Appendix 3. Ovid MEDLINE search strategy

1 exp Gloves, Surgical/
2 glove*1.ti,ab.
3 double gloving.ti,ab.
4 or/1-3
5 exp Surgical Wound Infection/
6 exp Surgical Wound Dehiscence/
7 exp Cross Infection/
8 (surg* adj5 infection*).ti,ab.
9 (surg* adj5 wound*).ti,ab.
10 (wound* adj5 infection*).ti,ab.
11 cross infection.ti,ab.
12 ((postoperative or post-operative) adj5 infection*).ti,ab.
13 or/5-12
14 4 and 13

Appendix 4. Ovid EMBASE search strategy

1 exp Surgical Glove/
2 glove*1.ti,ab.
3 double gloving.ti,ab.
4 or/1-3
5 exp Surgical Infection/
6 exp Wound Infection/

7 exp Wound Dehiscence/
8 exp Cross Infection/
9 (surg* adj5 infection*).ti,ab.
10 (surg* adj5 wound*).ti,ab.
11 (wound* adj5 infection*).ti,ab.
12 cross infection.ti,ab.
13 exp Postoperative Infection/
14 ((postoperative or post-operative) adj5 infection*).ti,ab.
15 or/5-14
16 4 and 15

Appendix 5. EBSCO CINAHL search strategy

S14 S4 and S13
S13 S5 or S6 or S7 or S8 or S9 or S10 or S11 or S12
S12 (MH "Cross Infection+")
S11 TI (postoperative N5 infection* or post-operative N5 infection*) or AB (postoperative N5 infection* or post-operative N5 infection*)
S10 TI cross infection or AB cross infection
S9 TI surg* N5 infection* or AB surg* N5 infection*
S8 TI surg* N5 wound* or AB surg* N5 wound*
S7 TI surg* N5 infection* or AB surg* N5 infection*
S6 (MH "Surgical Wound Dehiscence")
S5 (MH "Surgical Wound Infection")
S4 S1 or S2 or S3
S3 TI double gloving or AB double gloving
S2 TI glove* or AB glove*
S1 (MH "Gloves")

WHAT'S NEW

Date	Event	Description
29 July 2009	New search has been performed	New search, one study added to awaiting assessment, two new excluded studies and one additional secondary reference added. Conclusions of the review remain unchanged.

HISTORY

Protocol first published: Issue 2, 2001
Review first published: Issue 3, 2002

Date	Event	Description
22 September 2008	Amended	Converted to new review format.
11 April 2006	New citation required and conclusions have changed	Substantive amendment For this first update new searches were completed in January 2006. Twelve new RCTs have been included, giving a total of 31 included trials, and 34 new excluded studies. One trial which was awaiting assessment (Wilson 1996) has been included in this update.

CONTRIBUTIONS OF AUTHORS

JT wrote the protocol, screened citations for eligibility, extracted data, contacted authors, contacted glove manufacturers, entered data into RevMan, wrote the review and undertook the update.
HP commented on the protocol, screened citations for eligibility, checked extracted data, contacted authors, contacted professional organisations, hand searched conference proceedings, commented on review.

DECLARATIONS OF INTEREST

JT and HP received payment from Regent Medical for disseminating the findings of the original version of this review. JT was involved in one of the studies included in this updated review.

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- Derby Hospitals NHS Foundation Trust, UK.
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- The University of Leeds, UK.

External sources

- The National Association of Theatre Nurses, UK.
- The Theatre Nurses Trust Fund, UK.

INDEX TERMS

Medical Subject Headings (MeSH)

*Gloves, Surgical; Blood-Borne Pathogens; Cross Infection [*prevention & control]; Infectious Disease Transmission, Patient-to-Professional [*prevention & control]; Infectious Disease Transmission, Professional-to-Patient [*prevention & control]; Postoperative Complications [*prevention & control]; Randomized Controlled Trials as Topic

MeSH check words

Humans