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Hand Deserve Better: global clinical consensus recommendations on surgical gloving practice

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SUMMARY

Background: Surgical gloves provide an important aseptic barrier between the patient and the surgical team, helping to prevent the transfer of micro-organisms. The overall objective of the Hands Deserve Better project was to determine the best available evidence for key fundamental principles of surgical gloving practice and to inform operating room staff on the importance of optimal gloving practice to ensure provider and patient safety.

Methods: Four parallel systematic reviews of the literature were undertaken in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement, using four distinct research questions regarding glove fit, double gloving, indicator gloves, and the association of glove damage to glove change frequency. The Delphi technique for health sciences was used to develop consensus statements based on the systematic reviews.

Results: Across the systematic reviews, 10,137 articles were identified; 7,979 abstracts were screened, of which 411 full-text articles were assessed for inclusion. Twelve potential consensus statements were drafted based on the 258 included articles. The expert panel reached consensus on 10 clinical practice recommendations regarding glove use during surgical procedures.

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Conclusions: This comprehensive review on surgical gloving issued 10 consensus recommendations regarding glove fit, double gloving, use of indicator gloves, and glove change frequency.

Introduction

Surgical gloves are a principal component of the personal protective equipment (PPE) worn by surgical team members. Gloves provide an important barrier, preventing the transfer of micro-organisms between the patient and surgical team [1]. While historically the focus of PPE, including surgical gloves, was seen as a method to protect the surgical team from the patient, in fact, surgical gloving also protects the patient from the surgical team.

A perforation or microleak in a surgical glove constitutes a breach of the aseptic barrier. This can result in exposure of the surgeon to the blood or bodily fluids of the patient. Conversely, the patient is exposed to potential pathogens from the team, which could result in surgical wound infections [2]. Glove perforations are frequent and may result from damage due to sharp or rotating instruments, shearing forces when handling equipment, exposure to bone fragments, or the use of needles while suturing [3]. It is estimated that there may be over one million injuries from needlesticks annually in Europe [4]. These exposure incidences may be reduced by access to PPE, sufficient training of surgical team members, sharps management, and managing surgical team fatigue. However, further interventions to prevent infection are essential [4].

Measures that can reduce the risk of surgical glove breach include ensuring proper glove fit, double gloving, the use of indicator gloves, and timely glove change. Optimal glove fit impacts the surgeon's comfort and manual dexterity. Poor fitting of surgical gloves may compromise manual dexterity and impact factors such as fatigue, cramping, safety, comfort, and influences glove perforation, with an increase in the perforation rate observed in oversized gloves [5]. Correct glove selection is an important step that should be optimized to the healthcare providers' practice, surgical specialty, and unique anatomical and sex-specific needs [1].

Double gloving, where two gloves are worn on top of each other, is thought to decrease the risk of exposure of the hand caused by glove perforation by means of a second layer [6]. If the outer glove is compromised, the aseptic barrier often remains intact as the inner glove provides an additional protective layer [4]. An indicator system is a form of double gloving where a different coloured inner glove and a special outer glove are worn, which is specifically designed to illuminate when the aseptic barrier of the outer glove has been breached [7]. The transmission of fluid between the outer glove and inner glove enhances visualization of the breach and alerts surgical team members to an outer glove perforation, prompting the user to change compromised gloves [8]. For single gloves, glove change after visible glove perforation or at predefined time points may be beneficial to maintain the surgical barrier. In recent years, specific surgical specialties have recommended frequent glove changes to ensure ongoing barrier asepsis due to the risk of glove damage, unseen perforations, contamination of gloves, or proteinaceous build-up leading to a reduction of tactile sensitivity [9]. However, there is no agreed protocol to advise when gloves should be changed, and this may vary across different surgical specialties.

Current guidelines detail some recommendations for double gloving practice but lack guidance for all surgical glove practices. The World Health Organization (WHO) guidelines include recommendations for double gloving for countries with a high prevalence of HIV and hepatitis B/C, for procedures where there is contact with large amounts of blood/bodily fluid, and for some high-risk orthopaedic procedures [10]. However, recent WHO guidelines found insufficient evidence available to recommend double gloving for the reduction of surgical site infection (SSI) [11]. The Association of Surgical Technologists (AST) 'Standards of Practice for Gloving and Gowning' recommends the use of double gloving for all surgical procedures, along with the use of a different coloured inner glove [12]. Additionally, the Association for Perioperative Practice in the United Kingdom recommends double gloving to '*reduce the risk of perforation*' and that indicator gloves enable better detection of outer glove perforations [13]. There is a lack of specific guidelines on ensuring optimum glove fit, frequency of glove change, and the use of indicator gloves from the major healthcare organizations. Challenges in implementing updated gloving practices may include perceptions among surgical team members regarding a loss of manual dexterity and touch sensitivity while double gloving.

The objective of the Hands Deserve Better project was to determine the best available evidence to ensure provider and patient safety by describing four key fundamental principles of surgical gloving practice: glove fit, double gloving, the use of glove indicator systems, and glove change frequency. The surgical team includes all healthcare professionals who are engaged in the surgical case at the operating table. Therefore, the recommendations from this review and Delphi expert panel are intended to benefit the entire surgical team, from surgeon to trainee, equally.

Methods

Four parallel systematic reviews of the literature were conducted, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [14] and following the published checklist for reporting. One overarching search was used. The databases used for the literature searches were PubMed, Embase, Cochrane Collaboration of Systematic Reviews and Meta-analyses, and Google Scholar. The systematic reviews were performed between 1st May 2022 and 24th January 2023, with four distinct research questions:

- For healthcare providers scrubbed into surgical procedures, what is the association between poor glove fit and

provider performance in the operating room? A secondary aim of this research asks, is there an established standard to determine appropriate glove size?
- For healthcare providers scrubbed into surgical procedures, how does the practice of double gloving compared with single gloving impact the risk of provider and patient during surgery?
- For healthcare providers scrubbed into surgical procedures, what is the difference between specialized double gloving indicator systems compared with wearing two standard gloves on identification of glove perforation?
- For healthcare providers scrubbed into surgical procedures, how are rates of glove damage associated with recommendations for glove change frequency during a surgical case?

Detailed methods and data of each systematic review will be published separately (data on file). Initially, two members of the team (T.B. and J.B.R.) executed searches, with keyword combinations and search string results detailed and catalogued by database. Titles and abstracts were screened for each research question, and lists of abstracts were prepared for the reviewers. A research team consisting of 13 international researchers (surgeons, nurses, an infection control specialist, and surgical technologists) was divided into four groups based on the total number of identified abstracts for each of the individual research questions, to provide peer review of abstracts and full texts according to established inclusion and exclusion criteria. Critical appraisal was carried out during monthly meetings to discuss inclusion vs exclusion designation. Additionally, inter-rater reliability of study scoring, including strength of evidence and risk of bias, was determined via reviewer-blinded and randomly assigned peer review of team members. Level of agreement was calculated using Cohen's Kappa. If group member agreement on study scoring was less than 0.4, the initial reviewer and auditor evaluated the study together. If agreement could not be established after review, the principal investigator (A.E.) was called to render final opinion. The reviewers used an encrypted sharing platform via Microsoft Teams, which was only accessible by invitation.

Reviewers independently reviewed all full-text manuscripts and met to determine the final studies for analysis. Meta-analysis was not the intention of this systematic review due to methodological heterogeneity among the studies. Meta-synthesis of study outcomes was used. The data collection process for extraction of each study was performed in tandem, where data reporting was categorized by outcome domains and transferred, along with study demographics, into evidence tables. Visual tables outlining the final included studies, with their level of evidence and risk of bias scores, guided identification of the level of evidence by which to draft consensus statements.

Delphi technique: process and variants

The Delphi technique for health sciences was used to develop consensus statements based on the four systematic reviews. A modified group technique was used, defined as anonymous voting by an expert panel on a list of statements during a live, virtual meeting, which allowed for justification of deviating responses through group discussion [15]. The purpose of using the Delphi technique was to accomplish three specific objectives:

1. Summarize the current state of surgical gloving knowledge, based on systematic reviews of the literature.
2. Formulate recommendations for clinical practice change in the operating theatre.
3. Resolve controversial differences between existing evidence and common practice.

Expert member selection

Expert member selection for the Delphi group was determined based on the respective research questions and specific to the clinical practice setting of the operating room. Expert identification was focused on representation from a global community of diverse clinical backgrounds, licensed professions, years of expertise, geographic representation, sex diversity, and surgical specialty. The study chair was chosen based on recognized expertise in surgical gloving research [16—21]. Fifteen experts accepted an invitation to participate but two withdrew during the early stages of the project due to scheduling conflicts, leaving 13 experts. The demographics of the participants are listed in Table I.

Statement development

Statement development involved analysis and interpretation of the four parallel systematic reviews of the literature using PRISMA methodology. The researchers in their respective groups created specific statements with associated

Table I
Participant demographics

Demographic	Participants (N)
Sex	
Male	10
Female	3
Country	
USA	6
Germany	2
UK	2
Japan	1
Netherlands	1
Norway	1
Licensed profession	
Physician-surgeon	9
Physician-medical microbiology	1
Registered nurse	2
Surgical technologist	1
Specialty	
Orthopaedics	4
Gastrointestinal, general	2
Multispecialty	2
Plastic surgery	2
Infection prevention and control	1
Obstetrics and gynaecology	1
Transplant	1

N, number of participants.

rationale and references. Group consensus statements were provided to the entire research team for review three weeks prior to the Delphi consensus meeting.

Definition and measurement of consensus

Consensus voting was conducted virtually via Microsoft Teams using an encrypted polling app, which facilitates anonymous voting and blinded presentation of polling results. A quorum for this group, defined as (N/2) + 1 members, was established for this study, with a total of 13 members and a quorum of eight members. Ultimately, 12 of 13 members were able to attend live voting. The study chair moderated group discussions after each voting session. A group Delphi technique was used, whereby the reviewers for each respective systematic review group represented the contextual justification and evidence-based rationale for formulating each consensus statement and reviewed the strength of evidence, quality, and risk of bias for each supporting study. Modifications of a statement, if required based on group feedback, were made in real time during the meeting, and statements were amended for the next round of voting. Three rounds of voting with a threshold for consensus of 75% were established *a priori*. Following three rounds of voting, the results were handled as follows:

1. Consensus of ≥75%: accept the statement and include in definite recommendations.
2. Near consensus: 50—75%: do not include in recommendations but consider obstacles to consensus as topics for future research recommendations.
3. No consensus <50%: do not include in recommendations.

Clinical practice change and evidence base

The final clinical recommendations that reached consensus are reported in the following format:

- Consensus statement.
- Level of evidence and quality using the Johns Hopkins Nursing Evidence-Based Practice Model [22].
- Risk of bias scoring (ROB-2; Robis 1.2; Newcastle—Ottawa Scale [NOS] scoring tool) [23—25].
- Rationale and references from respective systematic reviews.
- Clinical practice recommendations accompany each statement for potential adoption based on aggregate strength of evidence:
  - **Change practice** — practice change is supported by high-level research of good quality and low bias.
  - **Consider this** — practice change should be considered based on moderate- to high-level research and low to moderate bias.
  - **Expert opinion** — the recommendation is made by the expert panel for consideration based on clinical experience and general common sense and may be supported by *in vitro,* qualitative, or similar studies of low to moderate quality and moderate to high levels of bias.

Results

Figure 1 represents the scope of the literature search. PubMed, Embase, Cochrane Collaboration of Systematic Reviews and Meta-analyses, and Google Scholar identified 10,137 records. After elimination of duplicate articles, the remaining 7,966 records were screened by abstract, according to the inclusion/exclusion criteria. A total of 7,559 studies were excluded from further analysis, with 413 records considered as suitable for full-text review and 260 of these studies assessed as eligible for inclusion across the four systematic reviews. Level of evidence, quality assessments, and risk of bias scores were detailed for each article included (data not shown). Results from the four systematic reviews are summarized below, while detailed methods and data of each individual systematic review will be published separately. The consensus convergence track with full voting trajectory for each statement across arounds, including total votes, agrees and disagrees on counts, percent agreement, and resulting outcomes, is included in Supplement S1.

General practice recommendations

Glove fit (consensus statements 1—3)

The systematic literature review for glove fit is reported in detail in a separate publication [26]. The panel discussed the importance of the correct size gloves for surgeons, acknowledging that different glove types from different manufacturers may have a different 'feel'. Two IA studies [1,27], one IC study [28], and a IIA study [29] demonstrated differences in tactile sensitivity, 2-point discrimination, comfort and performance between manufacturers' gloves, and within-manufacturer glove styles. 'Preferred' or 'Regular' glove size is reported in the literature; however, there are no practical examples of how this is determined in practice. Glove sizes are indicated by a number that reflects the circumference measurements of the hand and wrist [30]. Glove size is critical to performance. A study by Powell *et al.* indicates that properly fitted gloves decrease exertion force compared with ambidextrous gloves and thus influence comfort [31]. Additionally, two studies identified finger length and fingertip fit to be indicators of poor fit [30,32] (Table II).

The importance of a specific glove-fitting session for trainees to select the optimum gloves while learning to scrub, gown, and glove was discussed, and the value of input and support from experienced surgical team members, such as nurses, was highlighted. A glove-fitting session should include the trying on of different sizes, types, and suppliers of gloves to ensure the best possible glove fit. Glove choice may need to be further tailored to the procedure to be performed, by considering the tactile sensitivity, performance, and protection required for a specific surgery.

The panel reflected that changing hand size and performance over the course of a long surgical career may necessitate additional glove-fitting sessions over time or when glove suppliers/tenders change. The need to be remeasured for appropriate gloves is essential after manufacturer change, particularly if the surgical team member should notice a change in glove performance or experience issues such as chronic musculoskeletal pain.

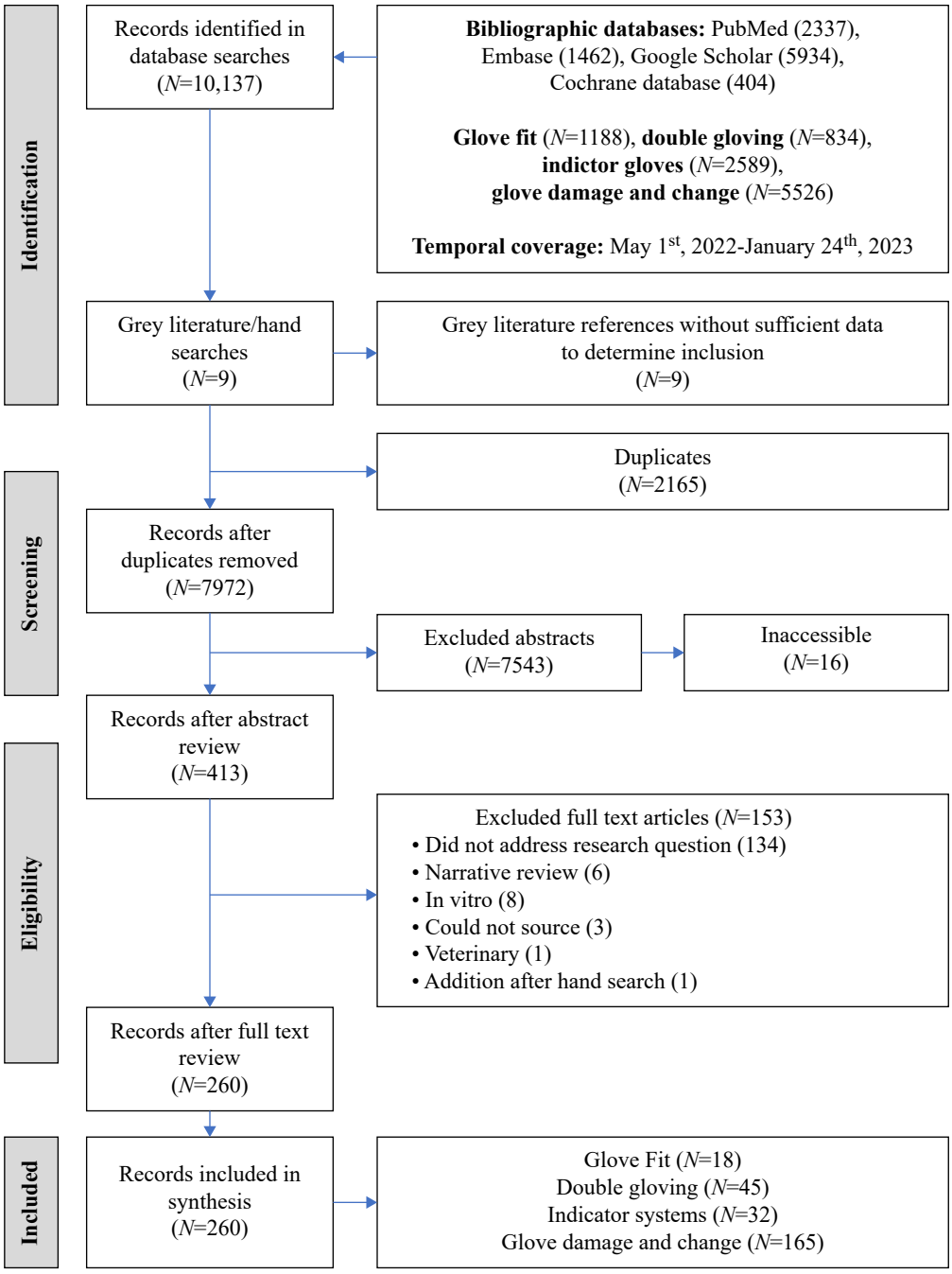

Figure 1. PRISMA flow chart. Flow diagram illustrating the number of records identified, screened, included, and excluded at each stage of the review process, in accordance with the PRISMA 2020 guidelines. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis; N, number of records.

Statement 3 is the only recommendation with a low level of evidence. Although direct evidence is limited, the panel included this as an 'expert opinion' recommendation because appropriate glove fit is a prerequisite for safe and effective surgical performance, and ensuring access to a range of sizes and styles is a low-risk, high-feasibility systems measure that supports equitable fit across the surgical workforce.

Double gloving (consensus statement 4)

Professional title may drive who double gloves; for example, in one orthopaedic surgery study, the surgeon and the first assistant always double gloved, whereas the scrub nurse and second assistants did not [33]. In a recent ethnographic qualitative research study of 387 operating room healthcare professionals from Germany, India, Italy, and the USA, responses were highly variable for frequency of double gloving by country, yet universally higher rates were observed when comparing surgeons with scrub nurses and surgical technologists. Respondents used single gloving as part of their routine for 52% of their surgical time, and the decision to single vs double glove was dependent on factors including perceived risk of surgery, knowledge of patient blood-borne illnesses, performance and

Table II
Summary table of the 10 clinical practice recommendations that reached consensus

Clinical question	Statement No.	Consensus statement	Aggregate level of evidence	Recommendation	Strength of evidence	Risk of bias	Rounds of voting	Consensus on statement
Glove fit	#1	All members of the surgical team should undergo a glove fitting (glove size and type) before scrubbing into the operating room for the first time.	IB	Expert opinion	Good quality	Some	**2**	**100%**
	#2	Additional glove fitting should occur in the event of a manufacturer change and/or when elements of comfort or performance are impacted.	IB	Change practice	Good quality	Some	**1**	**82%**
	#3	Appropriately fitting gloves of variable sizes and styles should be available to members of the surgical team, regardless of sex or race.	V	Expert opinion	Low quality	High	**1**	**82%**
Double gloving	#4	Double gloving should be considered in surgery for the purpose of reducing the risk of aseptic barrier breach and exposing surgical team members to risk.* *The panel recognized that there are clinical or procedural circumstances whereby single gloving may be appropriate. However, the level of evidence supports double gloving for provider safety. Glove change of single gloves at regular time intervals or risk increased surgical steps has been demonstrated as a sufficient measure to cope with the risk of glove perforation and exposure.	IA	Change practice	High quality	Low	**1**	**92%**
Indicator systems	#6	When double gloving, all scrubbed surgical team members should use an indicator inner glove for all surgeries to facilitate glove perforation detection.	IA	Change practice	High quality	Low	**2**	**100%**
Glove damage and glove change frequency	#7	In any surgical procedure, the surgical team members may consider changing single gloves or outer gloves at regular intervals during the procedure and/or depending on surgery-specific activities. Based on the risk of glove damage,	IIIA	Consider this practice change	Good quality	Some	**2**	**90%**

Table II (*continued*)

Clinical question	Statement No.	Consensus statement	Aggregate level of evidence	Recommendation	Strength of evidence	Risk of bias	Rounds of voting	Consensus on statement
		this interval is advised to be 60—120 min.						
	#8	During orthopaedic procedures (excluding arthroplasty), surgical team members may consider glove change at regular intervals of 60—120 min.	IIB	Consider this practice change	Good quality	Some	**1**	**100%**
	#9	In total joint arthroplasties, surgeons should change outer gloves at routine procedural steps, including after draping, before and after cement, before prosthetic handling, before closure, if the procedure extends beyond 60 min, and immediately when a perforation is seen.	IB	Change practice	Good quality	Some	**1**	**92%**
	#10	During general surgery procedures, surgical team members should change gloves prior to abdominal closure as part of a bundle.	IA	Change practice	Good quality	Some	**1**	**90%**
	#12	During Caesarean sections, surgical team members should change gloves after placenta delivery and prior to abdominal closure.	IA	Change practice	High quality	Low	**2**	**100%**

NB: Statements that did not reach consensus are detailed in the text.

tactile sensitivity, and comfort and fatigue. Clinicians were more concerned with ensuring tactile sensitivity and technical performance during surgical cases than with their personal safety [34]. Two Cochrane systematic reviews and meta-analyses have demonstrated that double gloving reduces the risk of occupational blood exposure to surgeons [4,35] Table II).

The evidence supporting double gloving practice is demonstrated in the significant differences between single glove perforation rates and inner glove, double glove perforations identified in a systematic review of 45 studies (manuscript in review). Studies were drawn from a large group of specialties including mixed surgical cases (17), orthopaedics (9), obstetrics and gynaecology (6), general surgery (3), and single studies across nine additional specialties. In total, seven 1A studies support double gloving, with four assessed as low risk of bias and three with some risk of bias. Eight level II and 31 level III studies were similarly identified.

Many double gloving studies assessed differences in the rate of glove perforation during surgery, but not all examined the impact on SSI or clinical outcomes. The expert panel agreed that double gloving may not be necessary for all sterile procedures, such as arterial line insertion, bedside procedures, or some emergency department procedures. With respect to the decision to double glove, the following should be considered:

- The risk of glove perforation in particular surgeries may be higher if handling instruments, manipulating bone, or suturing, which indicates double gloving.
- Studies demonstrate that over 70% of perforations are not visible to the provider during surgery and were only detected on postoperative water leak testing [36—40]. Moreover, these studies demonstrate that perforations were more readily identified in double gloves than in single gloves. One study found that 95.5% of glove perforations were unnoticed by the wearer, supporting double gloving to protect surgical teams [36]. A further study noted that small tears in gloves are more common than needlestick punctures [41], with multiple studies finding that longer surgical time leads to a higher risk of glove perforation [42—44].
- Four studies [45—48] reported an increased risk of SSI and glove perforation or an association with SSI and glove perforation. A case—control analysis in Hong Kong of 1,226 primary total knee arthroplasties, where both inner and outer glove perforations were noted during the operation, was compared with a case—control subset (n=183) where no perforation was noted. The rate of superficial SSI was significantly higher in the perforated group, but no difference was noted in prosthetic joint infection. A study by Rehman *et al.* in 389 spinal fusion patients demonstrated a

statistically significant reduction in the infection rate from 3.35% in group A (control) to 0.48% in group B (double glove and removal of outer gloves prior to handling instrumentation) (P=0.0369) [48]. Conversely, studies by Nagai *et al.* and Misteli *et al.* did not show a difference in SSI related to differences in perforation rates [49,50]. One study focusing on the potential for bacterial migration through unnoticed micro-perforations via a modified Gashen method confirmed microbiologically that migration in micro-perforations of surgical gloves does occur under real surgical conditions [51]. Overall, the panel concluded that studies reporting on the association between infection and glove perforation were not sufficiently powered to assess this relationship. There is currently insufficient evidence to suggest causality between double gloving and SSI in patients.

- The panel reflected that the risk of glove perforation during surgery needs to be balanced against the risk to aspects of surgical performance related to effects on tactile sensitivity of double gloving. However, the panel was conflicted on this issue, with some members indicating that, after an adjustment period, there is no limitation in tactile sensitivity when double gloving, while others cited specific instances where they preferred single glove for added sensitivity. A loss of manual dexterity during double gloving has been reported, but the lack of a standardized method for the measurement of manual dexterity makes the clinical importance of this finding difficult to interpret [4].
- Double gloving may be unnecessary in situations such as small, short procedures or operations where the surgeon has scrubbed in but is supervising/teaching.

Indicator systems (consensus statement 6)

The benefits of indicator glove usage to detect perforations are detailed in multiple studies, including a Cochrane review and a systematic review, using different coloured gloves from multiple manufacturers. The systematic review demonstrated the highest aggregate level of evidence across all studies of any research question, to support a practice change recommendation [52]. Of the 32 articles identified, 10 were level I studies (eight — IA low risk of bias [3,8,53—58]; two — IA moderate risk of bias [59,60] Table II.

Glove perforation detection with indicator gloves is reported to be twofold to sixfold higher than using two gloves of the same colour [3,8,43,54—56,59]. Consensus statement 6 was agreed upon unanimously by all members based on strong supporting evidence. Multiple suppliers offer indicator systems, and glove fitting, perforation detection effectiveness, comfort, and surgical performance should be evaluated.

Glove damage and glove change frequency (consensus statements 7—12)

In a systematic analysis (manuscript in review), 165 articles met the inclusion criteria, demonstrating the overwhelming awareness of the challenge of glove damage and barrier breach during surgical practice.

The panel discussed the evidence regarding increased glove damage observed over time during all surgeries, regardless of surgical specialty. Forty-five articles recommended glove changes at specific time points during surgery based on the frequency of perforations (Figure 2). Several review studies, covering multiple specialties, recommended implementing a routine glove change protocol [42,44,47,61]. Glove damage was observed at varying surgical times, but there was a clear

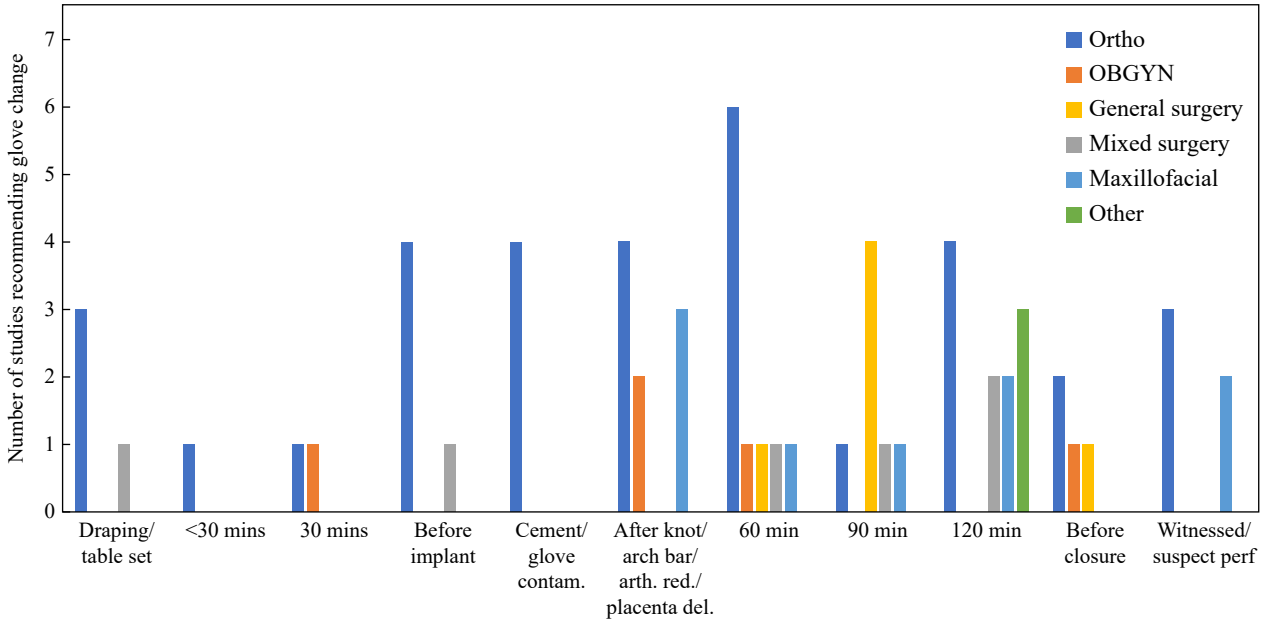

Figure 2. Glove change recommendations at specific time points during the surgical case based on glove perforation frequency. Bar chart showing the number of studies recommending surgical time point of glove changes. Studies were grouped by surgical specialty and specific surgical time point and plotted against the number of studies recommending change. NB: One study recommending a 40-min change was included in the 30- min group; one study suggesting change at 'halfway/midpoint' of surgery was classed as 60 min. min, minutes; OBGYN, obstetrics and gynaecology; ortho, orthopaedics.

trend of increasing chance of glove damage over time [62,63]. Numerous studies demonstrated a high rate of glove perforations when surgical duration exceeded 2 h [47,60,64,65]. Fourteen of the reviewed studies recommended changing gloves within the interval of 60–120 min. The panel recognized that many surgeons routinely change gloves during surgeries, often at specific steps during the procedure, but the actual frequency of glove damage necessitates changes at regular intervals even when visual damage is not observed. The data also demonstrated the importance of glove changes for the entire surgical team [36,66], with studies showing comparable rates of perforation between nurses and scrub technologists/first assistants with surgeons in 11 studies [62,65,67–75] and greater frequency of perforations compared with surgeons in nine studies [40,47,76–82] Table II).

During orthopaedic surgery, the surgical team may handle instruments, saws, sharp implants, and wires, thus increasing the risk of glove perforation [42,72]. The duration of orthopaedic surgery was associated significantly with an increase in the perforation rate over time in the majority of identified studies (Figure 3). Eleven of the reviewed papers recommended optimum times for glove change, of which nine papers (81%) presented level I or level II evidence. The suggested glove change time ranged from 20 min to 120 min, with a mean time of 60 min [44,47,64,65,83]. The panel agreed that frequent glove changes may be required during long orthopaedic procedures.

Five studies demonstrated that revision arthroplasty had higher perforation rates than primary procedures, with rates of glove damage 2–3 times higher than those in primary operation [16,19,65,70,84]. One study demonstrated that glove perforations in revision surgery were significantly higher for the first assistant than for other team members [70].

Several high-quality studies recommended glove changes at particular points during arthroplasty surgeries, including after draping [65,85,86], before cementing [65,85,86], and after cementing [85,86], with further changes advised during both implantation phases and arthroplasty reduction [85], or every 20 min or when a visible perforation is seen [65].

During orthopaedic arthroplasties, different rates of glove damage were identified with different procedures, such as draping, cementing, bone preparation, plating, nailing, partial and total hip replacement, and total knee replacement. In the 2005 study by Al-Maiyah *et al.*, the experimental group changed their outer gloves at 20-min intervals and before cementing [65]. The control group changed outer gloves prior to cementation and with any visible perforation. At each glove change, researchers compared rates of glove contamination using agar cultures and glove perforation rates. A statistically significant decrease in bacterial contamination and perforation was observed when gloves were changed at 20-min intervals during total hip arthroplasty. During primary knee arthroplasty, glove damage was most frequently associated with component reduction [87]. Risk factors associated with a higher glove failure rate in orthopaedic surgery by multivariate regression included patient body mass index (BMI) (odds ratio [OR]: 0.974, $P = 0.681$), operating time (OR: 0.996, $P=0.327$), and experience of the surgeon (OR: 14.448, $P<0.01$) [88]. One study identified a statistically significant difference in the rate of perforation between emergency arthroplasty (41.4%) and elective cases (30.0%), $P<0.05$ [69]. A systematic review of 12 arthroplasty studies (3 randomized controlled trials [RCTs] and 9 cohort studies) recommended glove changes at four intervals to reduce the risk of prosthetic joint infection: after draping, before handling implants, when visual perforation is seen, or at least once per hour [9].

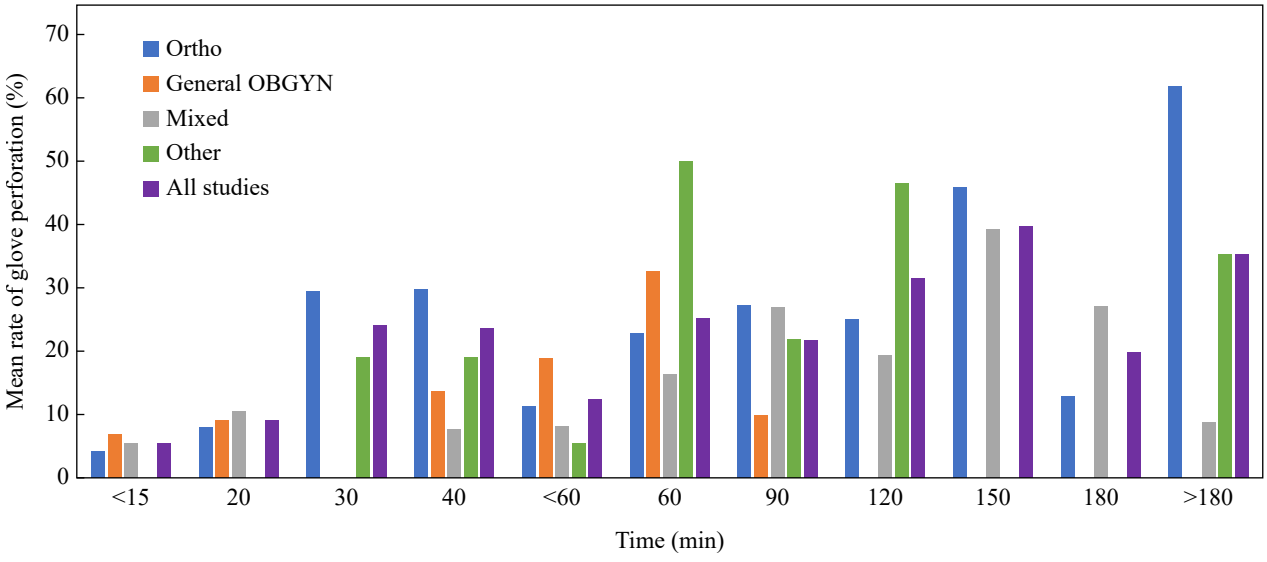

Figure 3. Mean glove perforation rate by time and surgical specialty. Bar chart showing rates of glove perforations by surgical time and specialty. Studies were grouped by surgical specialty and time to glove perforation plotted against the glove perforation rate. For studies where the glove perforation rate was reported for a time range, the mean time was used (e.g. 30–60 min = 40 min, 60–120 min = 90 min). For studies that report perforation rate by provider by time but did not analyse total perforation/time, the perforation rate for the surgeon was used as the plotted number. No maxillofacial studies reported a perforation rate by time; there was one OBGYN study that was combined with general surgery. min, minutes; OBGYN, obstetrics and gynaecology; ortho, orthopaedics.

The panel discussed the evidence supporting glove change as an important part of a bundle. A bundle may be defined as a set of evidence-based interventions that improve patient outcomes when performed together [89]. The evidence shows a clear improvement in clinical outcomes, such as SSI, when gloves are changed as part of a bundle of care interventions [90]. Ademuyiwa *et al*. published the CHEETAH (ClustHr EandomisEd Trial of sterAile glove and instrument cHange at the time of abdominal wound closure) study, an international, multi-site, cluster-RCT performed in seven low- and middle-income countries (Benin, Ghana, India, Mexico, Nigeria, Rwanda, and South Africa), examining the use of a bundle of glove and instrument changes before abdominal closure on the rates of SSI [91]. Any hospital performing abdominal surgery was eligible, and facilities were clustered and randomized into the standard of practice (42 hospitals using their usual practice, respectively) and 39 hospitals where gloves and instruments were changed. Procedures included emergency and elective abdominal surgeries and were classified as clean-contaminated, contaminated, or dirty (CDC designation). Caesarean section operations were excluded. In total, 13,301 consecutive patients were enrolled (7,151 to usual practice and 6,144 to the intervention). Changing gloves and instruments prior to abdominal closure was found to be statistically significant compared with standard care: SSI rate 1280 (18.9%) of 6,768 in the current practice group vs 931 (16.0%) of 5,789 in the intervention group (adjusted risk ratio: 0.87, 95% confidence interval [CI]: 0.79—0.95; P=0·0032). In several of the reviewed studies on the use of bundles, a change of gloves in combination with instrument change prior to abdominal closure was recommended [90,92,93], with one of the three studies reporting a reduction in SSI incidence for up to 30 days after surgery [92].

During general surgical procedures, glove damage is associated with wound closure due to suturing and possible surgeon fatigue [59,87]. A similar finding was noted with knot tying during suturing in orthopaedic cases [19]. Three studies observed that the type of needle used to close the abdominal fascia impacted glove perforation, with blunt tapered needles significantly reducing the risk of glove damage compared with cutting or sharp needles [94—96]. Two studies identified greater glove perforation risks when using the 'hands-in' closure technique, where the surgeon's hand is used within the wound, compared with the 'no-touch' technique, where the wound edges are manipulated by the use of instruments only [97,98].

A high frequency of glove perforation is observed during Caesarean section procedures, along with a higher risk of SSI due to contamination from the genital tract [93]. Two systematic reviews with meta-analysis recommend changing gloves after delivery of the placenta but before closure of the abdominal wall as this intervention significantly decreased the incidence of SSIs [99,100]. Further studies found that glove change prior to abdominal closure significantly reduced the rate of postoperative wound complications [92,93,100,101]. Two level III evidence studies recommend a glove change at a mean of 50 min of surgical time to avoid glove perforation risks [61,102].

Discussion

Four parallel systematic reviews identified the current evidence regarding surgical gloving practice addressing four areas of concern: glove fit, double gloving, indicator gloves, and glove change frequency. Results highlight the importance of proper glove fit for the optimization of surgical dexterity, the additional benefit of an indicator glove system for the detection of glove perforations, and evidence supporting the routine changing of gloves, particularly during long or high-risk procedures, for the maintenance of an effective aseptic barrier.

The glove fit recommendations devised from the systematic review align with existing guidelines supporting the importance of proper glove sizing for the optimization of surgical manual dexterity, comfort, and glove performance [10,12]. The recommendations here extend beyond current guidelines, emphasizing the importance of routine, individualized glove-fitting sessions that address sex and anatomical differences that are repeated during training, after manufacturer glove changes, and throughout a surgical career.

The indicator glove consensus recommendations align with current guidelines and include a recommendation to extend the use of indicator systems to all procedures. This highlights strong evidence that the use of indicator gloves can improve the rate of detection of glove perforation by 2—6 times compared with standard double gloving alone [3,8,43,54—56,59].

The double gloving systematic review results were consistent with a Cochrane systematic review and multiple studies that have observed a statistically significant reduction in the rate of surgical glove perforation when double gloves were used compared with single gloves [4,35,36,41,42]. The recommendations align with existing WHO and AST guidelines, with further recommendations for the broad adoption of double gloving practice across all specialties while acknowledging that double gloving may not be appropriate in all surgical circumstances [10,12].

Consensus recommendations for glove change frequency are based on evidence from several studies, including systematic reviews, which have demonstrated that an increase in glove perforation rates is associated with an increase in surgical duration [47,60,62—65]. Current guidelines recommend glove change when gloves are compromised; however, these consensus recommendations advocate for routine glove changes, at a predefined surgical time point (60—120 min) or procedural step, regardless of visible glove perforation. This addresses the problem of micro-perforations that may occur in up to 70% of surgeries and often remain undetected [36—40]. Furthermore, it was noted that a difference in glove change frequency may be required depending on whether single or double gloving is used.

The evidence synthesis reflects the literature available up to the final search date (24th January 2023). Following peer review, we performed a targeted post hoc check and identified two subsequent publications focused on hand hygiene and/or non-sterile examination glove practices, with no direct implications for sterile surgical glove change frequency; therefore, the present perioperative recommendations remain unchanged [103,104].

Considerations for future research

Draft statement #5 did not reach consensus during voting (30% agreement). The statement read, '*When double gloving, surgical team members may consider donning the inner underglove a half size larger than the outerglove*.' The statement was not accepted based on the limited evidence to support it. More research is needed to determine the appropriate sizing convention when double gloving.

Draft statement #11 did not reach consensus during voting (73% agreement). The statement read '*During general surgical procedures consider using an "instrument only/no-touch" technique and use blunt-tipped suture needles during abdominal wound closure to reduce the risk of glove damage*.' The statement was not accepted due to lack of evidence as well as clinical and technical considerations, such as potentially damaging effects of a blunt-tip needle on the fascia of the abdominal wall, which may outweigh unproven benefits in reducing glove damage.

Future research is needed to determine the rate of inner glove puncture frequency when an outer glove perforation occurs. There is currently insufficient evidence to inform when inner gloves should be changed, or when donning a new, sterile outer glove to cover a punctured inner glove is sufficient. Furthermore, studies that are sufficiently designed and powered to detect a causal relationship between glove perforation and subsequent SSIs in patients are lacking. However, the feasibility of designing a study with sufficient control and sample size to detect a direct relationship is likely cost prohibitive. Finally, research is needed to determine sex-related differences in palm width, finger length, wrist circumference, and associated measurements that influence glove fit. As most gloves are made from a standard former/cast, sex-specific measurements are required to inform manufacturers and enable them to produce appropriate glove dimensions for fit and performance across the surgical team.

In conclusion, the expert panel reached consensus on 10 clinical practice recommendations around glove use in surgical practice. These clinical practice recommendations were based on the results of four systematic reviews with research questions focused on glove fit, double gloving, indicator glove systems, glove damage, and glove change frequency. This comprehensive systematic review on surgical gloving may contribute to the discussion regarding the best practice for glove selection and use during surgery.

CRediT authorship contribution statement

A. Enz: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing - original draft, Writing - review and editing, Visualization, Supervision, Project Admin, Funding acquisition.

C.T. Brindle: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - original draft, Writing - review and editing, Visualization, Project Admin, Funding acquisition.

All other authors: Validation, Formal Analysis, Investigation, Writing - original draft, Writing - review and editing.

Ethics statement

Ethical approval was not required for this work because it involved published literature and expert consensus procedures only and did not include any patient-level data.

Data availability statement

The data that support the findings of this consensus document are available from the corresponding author upon reasonable request.

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Conflict of interest statement

All study investigators received compensation at fair market value from Mölnlycke Health Care for their research time. C.T.B. was an employee of Mölnlycke Health Care during this project. There are no other conflicts of interest for any of the authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2026.03.025.

References

[1] Johnson RL, Smith HM, Duncan CM, Torsher LC, Schroeder DR, Hebl JR. Factors that influence the selection of sterile glove brand: a randomized controlled trial evaluating the performance and cost of gloves. Can J Anaesth J Can Anesth 2013 July;60:700—8.

[2] Rippon MG, Rogers AA, Ousey KJ. Glove breach occurrence during surgical procedures: the benefits of double/indicator system gloves. J Hosp Infect 2025 July;161:92—113.
[3] Tanner J, Parkinson H. Double gloving to reduce surgical cross-infection. Cochrane Database Syst Rev 2006 July 19;2006:CD003087.
[4] Mischke C, Verbeek JH, Saarto A, Lavoie MC, Pahwa M, Ijaz S. Gloves, extra gloves or special types of gloves for preventing percutaneous exposure injuries in healthcare personnel. Cochrane Database Syst Rev 2014 Mar 7. CD009573.
[5] Gunasekera PC, Fernando RJ, de Silva KK. Glove failure: an occupational hazard of surgeons in a developing country. J R Coll Surg Edinb 1997 Apr;42:95—7.
[6] Edlich RF, Wind TC, Hill LG, Thacker JG. Resistance of double-glove hole puncture indication systems to surgical needle puncture. J Long Term Eff Med Implants 2003;13:85—90.
[7] Wigmore SJ, Rainey JB. Use of coloured undergloves to detect glove puncture. Br J Surg 1994 Oct;81:1480.
[8] Lee SY. What Role Does a Colored Under Glove Have in Detecting Glove Perforation in Foot and Ankle Procedures? Clin Orthop 2022 Dec 1;480:2327—34.
[9] Kim K, Zhu M, Munro JT, Young SW. Glove change to reduce the risk of surgical site infection or prosthetic joint infection in arthroplasty surgeries: a systematic review. ANZ J Surg 2019;89:1009—15.
[10] World Health Organisation. Glove use. Information Leaflet [Internet]. 2009 [cited 2023 Oct 20]. Available from: https://cdn.who.int/media/docs/default-source/integrated-health-services-(ihs)/infection-prevention-and-control/hand-hygiene/tools/glove-use-information-leaflet.pdf?sfvrsn=13670aa_10.
[11] World Health Organisation. Global guidelines for the prevention of surgical site infection [Internet]. 2018 [cited 2023 Oct 20]. Available from: https://iris.who.int/bitstream/handle/10665/277399/9789241550475-eng.pdf?sequence=1.
[12] Association of Surgical Technologists. Standards of practice for gowning and gloving. [Internet]. 2014 [cited 2025 July 8]. Available from: https://www.ast.org/uploadedFiles/Main_Site/Content/About_Us/Standard_%20Gowning_and_Gloving.pdf.
[13] The Association for Perioperative Practice. Infection control. [Internet]. 2020 [cited 2025 July 8]. Available from: https://www.afpp.org.uk/filegrab/afpp-infection-control-0820.pdf?ref=2319.
[14] Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 2015 Jan 2;350:g7647.
[15] Niederberger M, Spranger J. Delphi Technique in Health Sciences: A Map. Front Public Health 2020;8:457.
[16] Enz A, Klinder A, Mittelmeier H, Kundt G, Mittelmeier W, Zaatreh S. Damages with High Consequences: Analysis of Perforations in Surgical Latex Operation Gloves from Orthopedic Surgeries. Eur J Microbiol Immunol 2018 Dec 23;8:159—62.
[17] Enz A, Kostuj T, Warnke P, Osmanski-Zenk K, Mittelmeier W, Klinder A. Intraoperative damage to surgical gloves during various operations on the musculoskeletal system: a multicenter study. Arch Orthop Trauma Surg 2022 Jan;142:57—65.
[18] Enz A, Kamaleddine I, Groß J, Schafmayer C, Alwafai E, Sievers L, et al. Is Single Gloving Still Acceptable? Investigation and Evaluation of Damages on Sterile Latex Gloves in General Surgery. J Clin Med 2021 Aug 29;10:3887.
[19] Enz A, Klinder A, Bisping L, Lutter C, Warnke P, Tischer T, et al. Knot tying in arthroplasty and arthroscopy causes lesions to surgical gloves: a potential risk of infection. Knee Surg Sports Traumatol Arthrosc 2023;31:1824—32.
[20] Enz A, Kostuj T, Warnke P, Osmanski-Zenk K, Mittelmeier W, Klinder A. Intraoperative damage to surgical gloves during various operations on the musculoskeletal system: a multicenter study. Arch Orthop Trauma Surg 2022 Jan;142:57—65.
[21] Zaatreh S, Enz A, Klinder A, König T, Mittelmeier L, Kundt G, et al. Prospective data collection and analysis of perforations and tears of latex surgical gloves during primary endoprosthetic surgeries. GMS Hyg Infect Control 2016;11. Doc25.
[22] Dang D, Dearholt S, Bissett K, Ascenzi J, Whalen M. Johns Hopkins evidence-based practice for nurses and healthcare professionals: Model and guidelines. 4th ed. Sigma Theta Tau International; 2022.
[23] Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019 Aug 28;366:l4898.
[24] Whiting P, Savović J, Higgins JPT, Caldwell DM, Reeves BC, Shea B, et al. ROBIS: A new tool to assess risk of bias in systematic reviews was developed. J Clin Epidemiol 2016;69:225—34.
[25] Wells G, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle—Ottawa Scale (NOS) for assessing the quality of non-randomized studies in meta-analysis. [Internet]. 2000. Available from: https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
[26] Chatterjee A, Spratt DL, Enz A, Bah-Rösman J, Brindle CT, Chatterjee A, et al. Hands Deserve Better: A Systematic Review on Surgical Glove Fit and Provider Performance. J Clin Med 2025 Oct 30;14(21):7695.
[27] Man T, Jiang J, Schulz M, Kükrek H, Betzl J, Machens HG, et al. Surgical experience and different glove wearing conditions affect tactile sensibility. Heliyon 2022 Dec;8:e12550.
[28] Wilson SJ, Sellu D, Uy A, Jaffer MA. Subjective effects of double gloves on surgical performance. Ann R Coll Surg Engl 1996 Jan;78:20—2.
[29] Carter S, Choong S, Marino A, Sellu D. Can surgical gloves be made thinner without increasing their liability to puncture? Ann R Coll Surg Engl 1996 May;78:186—7 (Pt 1).
[30] Rudolph Ross, Chopra Christina, Van Etten Susan, Glaser Dale. An Unmet Need - Surgical Gloves With Variable Finger Lengths. In: Wound Repair regen 2022 Annu Meet wound heal Soc SAWC-SpringWHS Jt Meet [Internet]; 2022 Mar [cited 2022 Dec 14];30(2). Available from: https://onlinelibrary.wiley.com/doi/10.1111/wrr.13004.
[31] Powell BJ, Winkley GP, Brown JO, Etersque S. Evaluating the fit of ambidextrous and fitted gloves: implications for hand discomfort. J Am Dent Assoc 1939 1994 Sept;125:1235—42.
[32] Aggarwal M, Manson TT, VanMeter B, Thacker JG, Edlich RF. Biomechanics of surgical glove expansion. J Long Term Eff Med Implants 1994;4:133—40.
[33] Ajibade A, Oluwadiya KS, Olaitan PB, Ogunlusi JD. Glove perforation in orthopaedic surgery: Pattern and predictors. Niger J Orthop Trauma 2020 July 1;19:49.
[34] Red Associates. Glove Survey. Unpubl data. 2021.
[35] Zhang Z, Gao X, Ruan X, Zheng B. Effectiveness of double-gloving method on prevention of surgical glove perforations and blood contamination: A systematic review and meta-analysis. J Adv Nurs 2021 Sept;77:3630—43.
[36] Guo YP, Wong PM, Li Y, Or PPL. Is double-gloving really protective? A comparison between the glove perforation rate among perioperative nurses with single and double gloves during surgery. Am J Surg 2012 Aug;204:210—5.
[37] Sayın S, Yılmaz E, Baydur H. Rate of Glove Perforation in Open Abdominal Surgery and the Associated Risk Factors. Surg Infect 2019 June;20:286—91.
[38] Sadat-Ali M, Al-Habdan I, AlBluwi M, Corea JR, Al-Othman A, Shriyan D, et al. Can double gloves improve surgeon-patient barrier efficiency? Int Surg 2006 June;91:181—4.
[39] Hollaus PH, Lax F, Janakiev D, Wurnig PN, Pridun NS. Glove perforation rate in open lung surgery. Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg 1999 Apr;15:461—4.
[40] Korniewicz DM, Garzon L, Plitcha S. Health care workers: risk factors for nonlatex and latex gloves during surgery. AIHA J J Sci Occup Environ Health Saf 2003;64:851—5.

[41] de Castro-Peraza ME, Garzón-Rodríguez E, Rodríguez-Pérez V, Sosa-Alvarez I, Gutierrez-Hernández J, Asiain-Ugarte C. [Glove perforation in surgery and protective effect of double gloves]. Enfermeria Clin 2010;20:73—9.
[42] Dhar D. Occult Glove Perforation During Adult Elective Orthopaedic Surgery. Maced J Med Sci 2011 Dec 1;4:399—402.
[43] Aarnio P, Laine T. Glove perforation rate in vascular surgery-a comparison between single and double gloving. VASA Z Gefasskrankheiten 2001 May;30:122—4.
[44] Dube AS, Vardhan R. Glove Puncture Injuries in Orthopaedics: single versus double gloving. Ann Natl Acad Med Sci India 2010;46:225—39.
[45] Jid LQ, Ping MW, Chung WY, Leung WY. Visible glove perforation in total knee arthroplasty. J Orthop Surg Hong Kong 2017 Jan;25:2309499017695610.
[46] Al-Habdan I, Corea JR, Sadat-Ali M. Double or single gloves: which is safer in pediatric orthopedic surgery. J Pediatr Orthop 2006 June;26:409—11.
[47] Al-Habdan I, Sadat-Ali M. Glove perforation in pediatric orthopedic practice. J Pediatr Orthop 2003 Dec;23:791—3.
[48] Rehman A, Rehman AU, Rehman TU, Freeman C. Removing Outer Gloves as a Method to Reduce Spinal Surgery Infection. J Spinal Disord Tech 2015 July;28:E343—6.
[49] Nagai T, Taguchi K, Isobe T, Matsuyama N, Hattori T, Unno R, et al. A A Multicenter, Prospective, Non-randomized Study Evaluating Surgical Hand Preparation between Double-Gloving and Single-Gloving for Preventing Postoperative Infection in Robotic and Laparoscopic Minimally Invasive Surgeries. Urol J 2023 Mar 1;20(2):109—15.
[50] Misteli H, Weber WP, Reck S, Rosenthal R, Zwahlen M, Fueglistaler P, et al. Surgical glove perforation and the risk of surgical site infection. Arch Surg Chic Ill 1960 2009 June;144:553—8. discussion 558.
[51] Hübner NO, Goerdt AM, Stanislawski N, Assadian O, Heidecke CD, Kramer A, et al. Bacterial migration through punctured surgical gloves under real surgical conditions. BMC Infect Dis 2010 July 1;10:192.
[52] Wharton KR, Sawyer RG, Enz A, Bah-Rösman J, Brindle CT, Wharton KR, et al. Hands Deserve Better: A Systematic Review of Surgical Glove Indicator Systems and Identification of Glove Perforation. J Clin Med 2025 Nov 11;14(22):7977.
[53] Tanner J, Wraighte P, Howard P. Knitted Outer Gloves in Primary Hip and Knee Arthroplasty. HIP Int 2006 Jan 1;16:62—5.
[54] Naver LP, Gottrup F. Incidence of glove perforations in gastrointestinal surgery and the protective effect of double gloves: a prospective, randomised controlled study. Eur J Surg Acta Chir 2000 Apr;166:293—5.
[55] Nicolai P, Aldam CH, Allen PW. Increased awareness of glove perforation in major joint replacement. A prospective, randomised study of Regent Biogel Reveal gloves. J Bone Joint Surg Br 1997 May;79:371—3.
[56] Avery CM, Taylor J, Johnson PA. Double gloving and a system for identifying glove perforations in maxillofacial trauma surgery. Br J Oral Maxillofac Surg 1999 Aug;37:316—9.
[57] Abdulkarim A, Moriarty A, Chen Y, Devine D, Sheehan E. The effect of orthopaedic surgery on the intrinsic properties of surgical gloves. Int J Surg 2015 Nov 1;23:S24.
[58] Cox MJ, Bromberg WJ, Zura RD, Foresman PA, Morgan RG, Edlich RF. New advances in electronic devices for hole detection. J Appl Biomater Off J Soc Biomater 1994;5:257—64.
[59] Laine T, Aarnio P. Glove perforation in orthopaedic and trauma surgery: a comparison between single, double indicator gloving and double gloving with two regular gloves. J Bone Joint Surg Br 2004;86:898—900.
[60] Laine T, Aarnio P. How often does glove perforation occur in surgery? comparison between single gloves and a double-gloving system. Am J Surg 2001 June;181:564—6.
[61] Khoo SK, Isbester A. The integrity of surgical gloves during gynaecological operations. Aust N Z J Obstet Gynaecol 1999 Aug;39:357—9.
[62] Partecke LI, Goerdt AM, Langner I, Jaeger B, Assadian O, Heidecke CD, et al. Incidence of microperforation for surgical gloves depends on duration of wear. Infect Control Hosp Epidemiol 2009 May;30:409—14.
[63] Rudiman R, Karnadihardja W, Ruchiyat Y, Hanafi B. Efficacy of double versus single gloving in laparotomy procedures - Record details - Embase. Asian J Surg 1999;22:85—8.
[64] Louis SS, Steinberg EL, Gruen OA, Bartlett CS, Helfet DL. Outer gloves in orthopaedic procedures: a polyester/stainless steel wire weave glove liner compared with latex. J Orthop Trauma 1998 Feb;12:101—5.
[65] Al-Maiyah M, Bajwa A, Mackenney P, Port A, Gregg PJ, Hill D, et al. Glove perforation and contamination in primary total hip arthroplasty. J Bone Joint Surg Br 2005 Apr;87:556—9.
[66] Shek KMY, Chau JPC. Surgical glove perforation among nurses in ophthalmic surgery: a case-control study. Int J Nurs Pract 2014 Apr;20:179—86.
[67] Jahangiri M, Choobineh A, Malakoutikhah M, Hassanipour S, Zare A. The global incidence and associated factors of surgical gloves perforation: A systematic review and meta-analysis. Work Read Mass 2022;71:859—69.
[68] Kang MS, Lee YR, Hwang JH, Jeong ET, Son IS, Lee SH, et al. A cross-sectional study of surgical glove perforation during the posterior lumbar interbody spinal fusion surgery: Its frequency, location, and risk factors. Medicine (Baltimore) 2018 June;97:e10895.
[69] Bekele A, Makonnen N, Tesfaye L, Taye M. Incidence and patterns of surgical glove perforations: experience from Addis Ababa, Ethiopia. BMC Surg 2017 Mar 20;17:26.
[70] Kumar D, Shantanu K, Kumar M, Kumar A, Sharma V. A Cross-sectional Analysis of Glove Perforation in Primary and Revision Total Hip Arthroplasty. Malays Orthop J 2016 Nov;10:31—5.
[71] Manjunath AP, Shepherd JH, Barton DPJ, Bridges JE, Ind TEJ. Glove perforations during open surgery for gynaecological malignancies. BJOG Int J Obstet Gynaecol 2008 July;115:1015—9.
[72] Yinusa W, Li YH, Chow W, Ho WY, Leong JCY. Glove punctures in orthopaedic surgery. Int Orthop 2004 Feb;28:36—9.
[73] Green SE, Gompertz RH. Glove perforation during surgery: what are the risks? Ann R Coll Surg Engl 1992 Sept;74:306—8.
[74] Godin MS, Lavernia CJ, Harris JP. Occult surgical glove perforations in otolaryngology-head and neck surgery. Arch Otolaryngol Head Neck Surg 1991 Aug;117:910—3.
[75] Kralj N, Beie M, Hofmann F. [Surgical gloves-how well do the protect against infections?]. Gesundheitswesen Bundesverb Arzte Offentlichen Gesundheitsdienstes Ger 1999;61:398—403.
[76] Jazinidorcheh S. Associated Factors of Surgical Glove Damages in Orthopedic Surgeries. Asian J Pharmaceutics (AJP) 2018 Aug 18;12(02):S609—14.
[77] Witzke H, Fuchs S, Schmitz E, Wittmann A, Kralj N, Vetter H. Surgical glove perforation — Raising the bar for safety during cardiac surgery. Thorac Cardiovasc Surg 2012 Feb;60:s-0031—1297912.
[78] Lancaster C, Duff P. Single versus double-gloving for obstetric and gynecologic procedures. Am J Obstet Gynecol 2007 May;196:e36—7.
[79] Kralj N, Whittmann A, Hofmann F. Optimierter infektionsschutz in der chirurgie durch doppelhandschuhsysteme - Record details - Embase. Arbeitsmedizin Sozialmedizin Umweltmed 2004;39:472—6.
[80] Wong PS, Young VK, Youhana A, Wright JE. Surgical glove punctures during cardiac operations. Ann Thorac Surg 1993 July;56:108—10.

[81] König M, Bruha M, Hirsch HA. [Perforation of surgical gloves in gynecologic operations and abdominal Cesarean section]. Geburtshilfe Frauenheilkd 1992 Feb;52:109—12.
[82] Prendiville P, McDonnell PJ, Lee PP. Glove perforations in ophthalmic surgery. Am J Ophthalmol 1992 Oct 15;114:397—404.
[83] Li X, Li M, Li J, Gong W, Sun Y, Tang J, et al. Glove perforation and contamination in fracture fixation surgeries. Am J Infect Control 2017 Apr 1;45:458—60.
[84] Carter AH, Casper DS, Parvizi J, Austin MS. A prospective analysis of glove perforation in primary and revision total hip and total knee arthroplasty. J Arthroplasty 2012 Aug;27:1271—5.
[85] Beldame J, Lagrave B, Lievain L, Lefebvre B, Frebourg N, Dujardin F. Surgical glove bacterial contamination and perforation during total hip arthroplasty implantation: when gloves should be changed. Orthop Traumatol Surg Res OTSR 2012 June;98:432—40.
[86] Liew SM, Stoney JD, Falkenberg MP, Leitl SM. A comparative study of two types of latex surgical gloves in elective orthopaedic surgery. Aust N Z J Surg 1995 June;65:406—8.
[87] Karakus O, Sarı AS. At what point during total knee arthroplasty operations are gloves most frequently torn? J Orthop Surg Hong Kong 2020 Dec;28:2309499020959167.
[88] Han CD, Kim J, Moon SH, Lee BH, Kwon HM, Park KK. A randomized prospective study of glove perforation in orthopaedic surgery: is a thick glove more effective? J Arthroplasty 2013 Dec;28:1878—81.
[89] Wolfhagen N, Boldingh QJJ, Boermeester MA, de Jonge SW. Perioperative care bundles for the prevention of surgical-site infections: meta-analysis. Br J Surg 2022 Sept 9;109:933—42.
[90] Zywot A, Lau CSM, Stephen Fletcher H, Paul S. Bundles Prevent Surgical Site Infections After Colorectal Surgery: Meta-analysis and Systematic Review. J Gastrointest Surg Off J Soc Surg Aliment Tract 2017 Nov;21:1915—30.
[91] Ademuyiwa AO, Adisa AO, Bhangu A, Brocklehurst P, Chakrabortee S, Ghosh D, et al. Routine sterile glove and instrument change at the time of abdominal wound closure to prevent surgical site infection (ChEETAh): a pragmatic, cluster-randomised trial in seven low-income and middle-income countries. The Lancet 2022 Nov 19;400:1767—76.
[92] NIHR Global Research Health Unit on Global Surgery. Reducing surgical site infections in low-income and middle-income countries (FALCON): a pragmatic, multicentre, stratified, randomised controlled trial. Lancet Lond Engl 2021 Nov 6;398:1687—99.
[93] Scrafford JD, Reddy B, Rivard C, Vogel RI. Effect of intraoperative glove changing during cesarean section on postoperative complications: a randomized controlled trial. Arch Gynecol Obstet 2018 June;297:1449—54.
[94] Hartley JE, Ahmed S, Milkins R, Naylor G, Monson JRT, Lee PWR. Randomized trial of blunt-tipped *versus* cutting needles to reduce glove puncture during mass closure of the abdomen. Br J Surg 2005 Dec 6;83:1156—7.
[95] Mingoli A, Sapienza P, Sgarzini G, Luciani G, De Angelis G, Modini C, et al. Influence of blunt needles on surgical glove perforation and safety for the surgeon - PubMed. Am J Surg 1996;172:512—7.
[96] Nordkam RAG, Bluyssen SJM, van Goor H. Randomized Clinical Trial Comparing Blunt Tapered and Standard Needles in Closing Abdominal Fascia. World J Surg 2005 Apr 1;29:441—5.
[97] Chan P, Lewis AA. Influence of suture technique on surgical glove perforation. Br J Surg 1989 Nov;76:1208—9.
[98] Corlett MP, England DW, Kidner NL, Attard AR, Fraser IA. Reduction in incidence of glove perforation during laparotomy wound closure by 'no touch' technique. Ann R Coll Surg Engl 1993 Sept;75:330—2.
[99] Rattanakanokchai S, Eamudomkarn N, Jampathong N, Luong-Thanh BY, Kietpeerakool C. Changing gloves during cesarean section for prevention of postoperative infections: a systematic review and meta-analysis. Sci Rep 2021 Feb 25;11:4592.
[100] Narice BF, Almeida JR, Farrell T, Madhuvrata P. Impact of changing gloves during cesarean section on postoperative infective complications: A systematic review and meta-analysis. Acta Obstet Gynecol Scand 2021;100:1581—94.
[101] Ismail H, Mohamed MF, Abdelmoaty MA. Effect of Intraoperative glove changing during Cesarean on Post-operative Complication (Clinical Trial). Al-Azhar Int Med J 2022 Aug 31;3:68—72.
[102] Malhotra M, Sharma JB, Wadhwa L, Arora R. Prospective study of glove perforation in obstetrical and gynecological operations: are we safe enough? J Obstet Gynaecol Res 2004 Aug;30:319—22.
[103] Glowicz JB, Landon E, Sickbert-Bennett EE, Aiello AE, deKay K, Hoffmann KK, et al. SHEA/IDSA/APIC Practice Recommendation: Strategies to prevent healthcare-associated infections through hand hygiene: 2022 Update. Infect Control Hosp Epidemiol 2023 Mar;44:355—76.
[104] Thom KA, Rock C, Robinson GL, Reisinger HS, Baloh J, Li S, et al. Direct Gloving vs Hand Hygiene Before Donning Gloves in Adherence to Hospital Infection Control Practices: A Cluster Randomized Clinical Trial. JAMA Netw Open 2023 Oct 26;6. e2336758—e2336758.