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Surgical site infections: a scoping review on current intraoperative prevention measures

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ABSTRACT

Introduction Surgical site infections (SSIs) remain a significant cause of morbidity for surgical patients worldwide and with growing rates of antibiotic resistance, the development of new nonantimicrobial techniques to target SSI reduction is crucial. This review aimed to explore available nonantibiotic intraoperative interventions to reduce the risk of SSI.

Methods A literature search was undertaken using Medline, Web of Science, Embase, and Cochrane Library databases. Any study published from 1 January 1980 to 1 September 2021 that described any nonantibiotic intraoperative physical technique aiming to reduce SSI rates, with a primary or secondary outcome of SSI rates, was included.

Findings A total of 45 articles were included in the final scoping review. The current nonantibiotic intraoperative interventions advised for use include chlorhexidine skin preparation with alcohol, pressurised wound irrigation, Triclosan-coated sutures for skin closure, and negative pressure wound therapy. Many other widely used surgical practices do not have the supporting evidence to validate their routine use in clinical practice to reduce SSI rates.

Conclusions We identified several techniques that can be used in the operating theatre to provide additional opportunities to reduce SSI rates. However, strict adherence to current established SSI prevention guidelines remains the mainstay of ensuring SSI rates remain low.

KEYWORDS
Surgical site infection – Prevention – Surgery – Intraoperative

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Introduction

Surgical site infections (SSIs) are a significant cause of morbidity in the surgical population. Around one-fifth of all hospital-acquired infections are SSIs,[1,2] and current SSI rates in Europe are reported between 5% and 18%,[3] with even higher levels in lower income countries.[4] SSIs place sizeable financial strains on healthcare systems worldwide,[5] resulting in approximately 1 million additional inpatient days per year in the US alone, costing an additional US$1.6 billion.[6] SSIs also have a profound impact on patient outcomes; patients with an SSI postoperatively have a risk of death between 2 and 11 times higher than those without an SSI,[7–10] alongside longer hospital stays,[5,11,12] increased rates of complications,[13] increased rates of hospital readmission,[5,14] and an overall reduction in quality of life.[15]

SSI prevention is perhaps an overlooked area for many practising surgeons, however a recent international Delphi survey identified that the prevention of SSIs after abdominal surgery should be placed as the highest priority topic for guideline development.[16] Indeed, all aspects of the pre-, intra-, and postoperative risks can be targeted at every step of the perioperative pathway by all members of the surgical team. SSI care bundles are employed by many surgical departments to ensure a multifaceted risk factor reduction approach occurs, and these have been shown to reduce SSI rates by up to 40%,[17] as well as reducing hospital costs and length of hospital stay.[18]

Surgeons arguably have the most influence on the intraoperative SSI reduction strategies, however outside of prophylactic antibiotics at induction,[19–22] many intraoperative interventions trialled have shown limited benefit.[23,24] In this scoping review, we present the current evidence around key nonantibiotic interventions available for use intraoperatively, across all surgical specialties, outwith conventional SSI bundle checklists.

Methods

To identify current literature on the main physical nonantibiotic intraoperative measures available, a literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) guidelines.[25] An agreed study plan was devised before undertaking the review. A literature search was undertaken using Medline, Web of Science, Embase, and Cochrane Library databases, with grey literature search results subsequently added using the Open Grey database. Additional studies not included in the database

search were identified by searching the reference lists of retained articles.

Any study that described a nonantibiotic intraoperative mechanical technique aiming to reduce SSI rates, with a primary or secondary outcome of SSI rates, was included. We defined 'intraoperative' as the time between the patient being moved onto and off from the operating table. The search terms employed were based upon a previous Cochrane review on wound irrigation techniques[26]; the search terms were: ('Surgical Wound Infection' OR 'Surgical Wound Dehiscence' OR 'wound complication' OR 'SSI') AND ('Prevention' OR 'Primary Prevention' OR 'Prophylaxis') AND ('Intra-Operative' OR 'Operative Techniques' OR 'Operative Surgical Procedures').

The search included all articles from 1 January 1980 to 1 September 2021, with any duplicates subsequently removed. The search was performed independently by two of the authors (MB and RS), with any discrepancies resolved by discussion and consensus. All article types reporting primary data or secondary data analysis (e.g., meta-analyses) were included. Due to the descriptive nature of the review, no formal data charting process was performed. Any study reporting on nonhuman data was excluded, as were those not published in the English language.

Overall, 608 articles were identified from the literature search for the scoping review, with an additional 30 records identified through other sources. Following screening, 43 articles were included in the final literature review (Figure 1). The articles identified were then categorised into subsections of Skin Preparation, Wound Irrigation, and Closure Techniques and Devices.

Results

Skin preparation

Although historically performed preoperatively as routine for all surgical patients, it is now commonplace for hair removal to be performed intraoperatively, before the initial incision. Clearly, hair removal has its own benefits by reducing interference at wound closure, however its impact on SSI rates is of greater interest. High-quality systematic reviews have been performed on this topic, demonstrating minimal benefit in elective hair removal at the surgical site to improve SSI rates, both in technique (clipping relative risk (RR) 0.95 (confidence interval (CI) 0.65–1.39) versus shaving RR 1.82 (CI 1.05–3.14)) and in timing (RR 0.83, CI 0.54–1.30),[27] and the overall quality of trial data available on this topic is poor.[28]

More sizeable benefits, however, are seen with the use of preoperative skin preparations, of which the most commonly used are chlorhexidine and povidone-iodine.[29] Both skin preparations are used widely across the globe, and, whereas previous data had suggested no sizeable differences in efficacy,[30] more recent evidence suggests that chlorhexidine is likely superior in its antimicrobial action, especially when used in alcohol. A large randomised controlled trial (RCT) published in the *New England Journal of Medicine* demonstrated that overall SSI rates were significantly lower with use of chlorhexidine than with povidone-iodine (9.5% vs 16.1%, p=0.004).[31] A subsequent network meta-analysis concurred with these findings, with chlorhexidine halving the risk of infection following any clean operation compared with povidone-iodine.[32]

Adhesive drapes can be applied to the skin before starting the procedure, through which the initial surgical incision can then be made (eg, OpSite, Smith and Nephew). While often also impregnated with antimicrobial agents such as iodine, the use of adhesive drapes of any kind have shown no benefit in reducing overall SSI rates (RR 1.03 (CI 0.06–1.66)).[33] The same is true for the use of wound protectors during the procedure; it was previously theorised that wound protectors would prevent both endogenous- and exogenous-derived pathogens coming into contact with the subcutaneous tissues during the procedure,[34] and initial data were indeed promising towards their use.[35–38] Yet, whereas there may be a small benefit in a select subset of patients,[39] high quality data from a well-referenced RCT of 760 patients undergoing abdominal surgery has shown no benefit with their use, reporting no difference in SSI rates compared with the control groups (24.7% vs 25.4%, p=0.85).[40]

Wound irrigation

The presence of necrotic tissue in a wound both impedes wound closure and provides the optimal environment for pathogens to grow.[41,42] Perioperative wound irrigation aims to reduce both infectious agents and necrotic debris from the wound surface,[43] and is used by the vast majority of surgeons in various forms,[44] povidone-iodine solution proving the most widely used by general surgeons.[45] Povidone-iodine solution is known to be effective against a broad spectrum of pathogens,[46] across a range of concentrations, and indeed is superior in its efficacy over saline irrigation in abdominal surgery.[47] However, povidone-iodine is accompanied by the theoretical risks of local toxicity and delayed wound healing.[48,49]

The most recent Cochrane review on wound irrigation and SSI rates was published in 2017, amassing data from 14 studies and including over 6,000 patients, across multiple subspecialities.[26] The authors concluded no discernible differences were present in the incidence of SSIs in those who receive any form of wound irrigation versus those who do not (RR 0.87, 95% CI 0.68–1.11).[26] A similar systematic review, commissioned by the World Health Organisation (WHO) on the same topic and published in the same year, reported comparable results.[50]

However, in the same Cochrane review, a subanalysis on the use of pressurised irrigation identified a statistically significant reduction in SSI rates. When pressurised irrigation was undertaken, an absolute risk difference of 109 fewer SSIs per 1,000 participants was observed when compared with standard irrigation

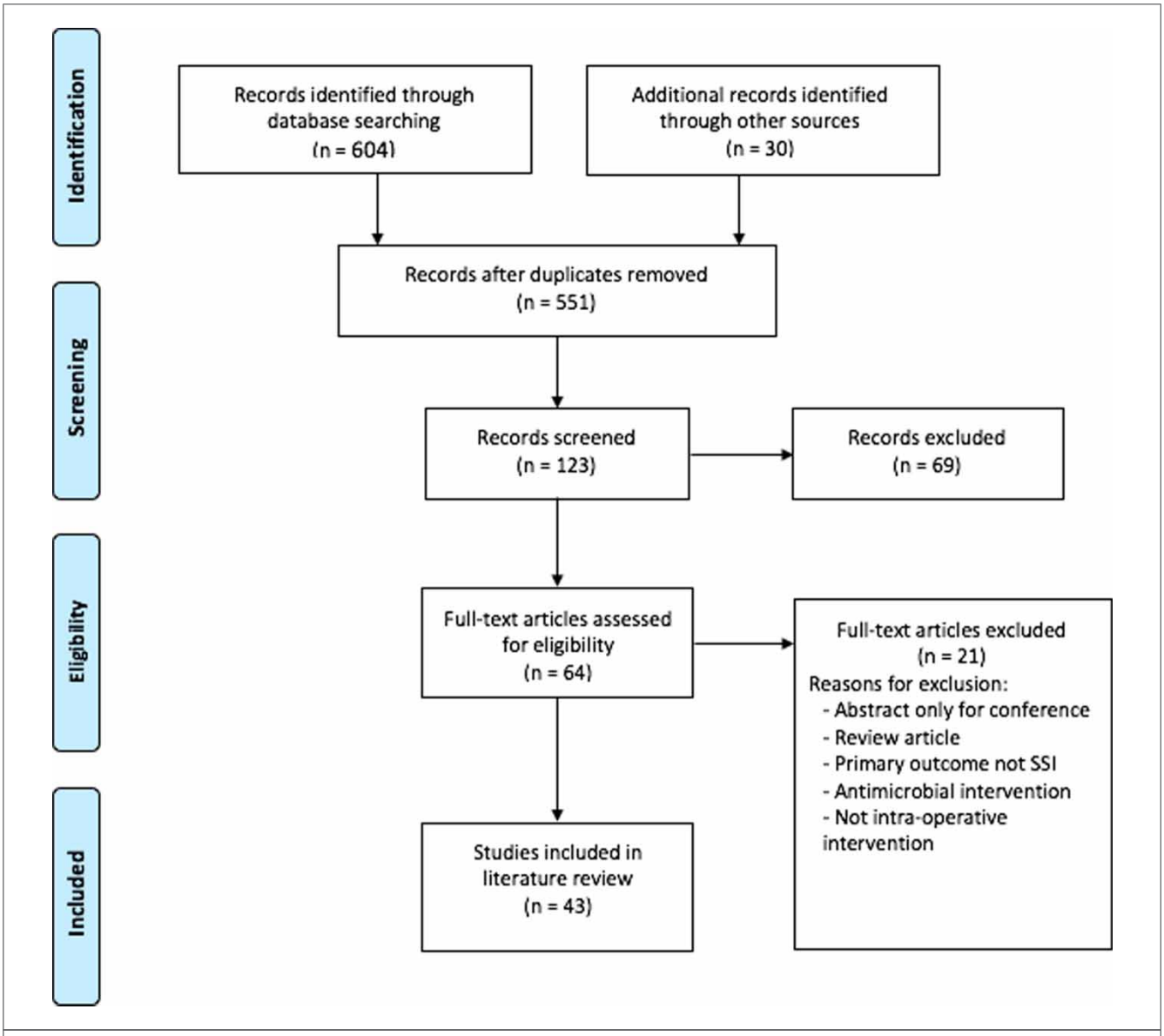

Figure 1 PRISMA flowchart. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

methods.[26] The use of pressurised irrigation, often termed 'Pulsed Lavage' (Figure 2), is used widely in orthopaedic surgery,[51] but less so in other specialities; the use of pressurised irrigation in general surgery has shown some promise in reducing SSI rates (odds ratio 0.39 (CI 0.25–.62),[52] although the majority of studies published thus far are small or retrospective.

Closure techniques and devices

Choice of suture material for closure has been shown to impact rates of SSIs. Multiple suture types are available, varying in both composition and size, for closing both the deep fascial layers and superficial adipose and skin layers. Reducing pathogens harbouring in wounds is known to reduce the risk of SSIs,[53] and it is with this rationale that monofilament sutures are classically chosen for closure, providing less surface area for pathogens to survive.

However, a recent network meta-analyses has disproven this widely held dogma, showing that no specific suture type (including Polyglactin, Polydioxanone (PDS), Polypropylene and Nylon) should be considered the 'best treatment' for the prevention of SSI,[54] with similar conclusions with the use of skin glue too.[55] Nevertheless, triclosan-coated sutures (an antimicrobial agent) have begun to show promise, with a meta-analysis of RCT data performed by

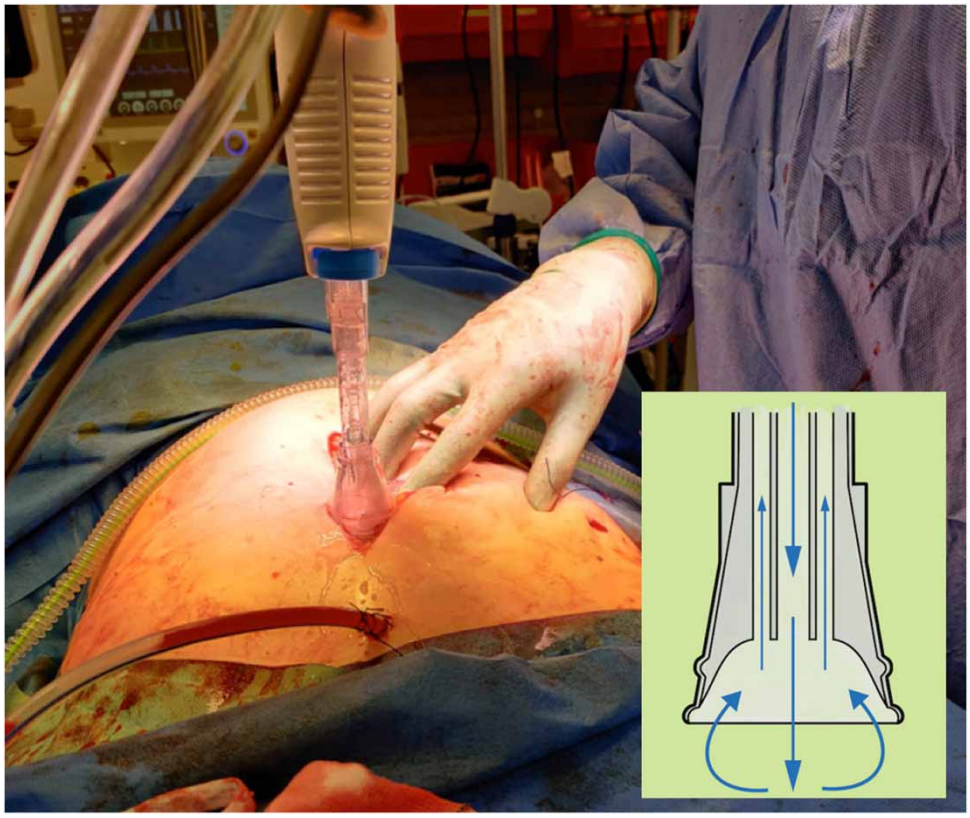

Figure 2 Use of pulsed lavage at the closure of a laparotomy; inset, direction of flow for fluid irrigation.

the National Institute for Health and Care Excellence (NICE) reporting a RR 0.71 (85% CI 0.59–0.85) for the development of a SSI with their use.[56] The report suggested use of triclosan-coated sutures will save £13.62 per patient through SSI reduction alone, compared with standard absorbable sutures.[56]

Current evidence suggests no clear benefit of any one wound dressing type in reducing SSI risk over another,[57] apart from perhaps with the use of negative pressure wound therapy (NPWT). NPWT provides a continuous delivery of negative pressure to a wound through the use of a vacuum-device, with the goal of removing excess tissue oedema and promoting granulation tissue formation.[58] Although historically used solely for open wounds, the use of NPWT has been extended to include closed surgical incisions too, and its benefit in reducing SSI rates in orthopaedic, cardiothoracic and general surgical procedures has been widely described.[59–62] More importantly, NPWT has been shown to be potentially cost-effective for multiple indications and is a promising area of development.[63] This differs, however, to the placement of prophylactic negative pressure suction drains in the subcutaneous tissue, which have shown no benefit in reducing SSI rates in the vast majority of surgical procedures.[64]

Discussion

The WHO has stated that antibiotic resistance remains 'one of the biggest threats to global health, food security, and development today' and has become a leading cause of death around the world,[65] especially in low-resource settings.[66] Antibiotic resistance is as applicable to surgical spheres as to any other, and limiting the prevalence of SSIs should be seen as a priority to every surgeon worldwide. Implementation of the nonantibiotic intraoperative interventions described in this review (Table 1) should be considered by all surgeons if SSI rates are to be curtailed.

Use of chlorhexidine skin preparation with alcohol, pressurised wound irrigation, Triclosan-coated sutures for skin closure and negative pressure wound therapy NPWT are nonantibiotic measures that can be feasibly incorporated into many surgeons routine surgical practice. We do not suggest that this should detract away from other aspects of the perioperative pathway, where key modifiable risk factors for SSIs, such as optimising nutrition or smoking cessation, can be targeted. Indeed, ensuring a multifaceted risk factor reduction across the perioperative period, typically through use of SSI care bundles, can produce a greater

Table 1 Recommendations of intraoperative interventions to reduce SSI rates, with key references included

Chlorhexidine with alcohol as skin preparation – Chlorhexidine produces a significantly lower rate of SSIs than with povidone-iodine (9.5% vs 16.1%)[31]
Pressurised irrigation to the subcutaneous tissue at closure – Use of pressurised irrigation results in 109 fewer SSIs per 1,000 participants than standard irrigation methods[26]
Use of Triclosan-coated sutures for skin closure – Triclosan-coated sutures result in significantly fewer SSIs. Can save £13.62 per patient through SSI reduction alone[56]
Application of NPWT – Use of NPWT has been shown to reduce SSI rates across multiple specialties in closed surgical incisions, from orthopaedics to cardiothoracics to general surgery[59–62]

NPWT = negative pressure wound therapy; SSI = surgical site infection

impact on SSI rates than any intraoperative intervention. However, this review provides an evidence-based assessment to practising surgeons on the current intraoperative techniques available to further reduce their SSI rates, outside of current standard SSI bundles.

There are a wide range of effective pre- and postoperative interventions that successfully influence SSI rates that are not covered in this review, as other systematic reviews have previously explored this data more extensively. Moreover, while we aimed to cover all surgical subspeciality techniques in this review, the majority of published research on this topic was in abdominal surgery. Although we did not undertake a formal cost-effectiveness analysis on the interventions reported, the key messages remain that nonantibiotic techniques to reduce SSI rates intraoperatively are available and should be adopted by all surgeons wherever feasible.

In 1958, famed Professor of Surgery and President of the American Surgical Association, Dr. William A. Altemeier, stated that 'antibiotic therapy cannot be depended upon to prevent the development of local infection if established surgical principles or important technical details have been ignored'.[67] With growing rates of antibiotic resistance worldwide, this statement remains as pertinent now as it ever did.

Author contribution

All authors were involved equally in the conception, design, process and write-up of the study.

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