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REVIEW

The role of other stakeholders than the surgeon in relation to surgical site infections following total joint replacement

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In contemporary orthopaedics, surgical site infections (SSIs) can have significant negative consequences for both patients and the healthcare system overall. To date, most efforts at combating the risk of SSIs have focused on the role of the surgeon, yet recent data suggest that a more expansive approach is warranted. The current review offers an overview of the most-relevant factors associated with SSIs in orthopaedic surgery, and the crucial role that the full surgical staff can play in addressing them.

Keywords :

INTRODUCTION

Joint arthroplasty is widely considered to be one of the safest and most cost-effective procedures in contemporary surgery (*15*). Despite decades of improved outcomes, the long-term success of these procedures is threatened by the onset of surgical site infections (SSIs) that can lead to increased patient morbidity and mortality (*37,59,69*).

The rate of SSIs within the first year following joint arthroplasty has been reported to be between 2.0% (*84*) and 2.8% (*74*). In total knee arthroplasty (TKA) in particular, intercountry rates range between 0.2% and 3.2% (*39*). Treating these hospital-acquired infections places additional economic strains on an already overburdened healthcare system (*37,39*). This problem is compounded by the global rise in difficult-to-treat resistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) and Gram negatives, which often require additional surgical procedures and increased hospital stays that collectively contribute to ballooning costs (*18*).

The rise in SSIs and their associated costs has created a clear impetus among the surgical community to improve perioperative care for patients undergoing joint arthroplasty. This has led to the creation of comprehensive guidelines to aid in the prevention of SSIs (*40,44*). As the etiology of these infections is decidedly multifaceted (*62*), these guidelines recommend a strategy for preventing SSIs using so-called "bundling" activities that target a variety of risk factors together (*58,71,82*).

The implementation of these bundling techniques is often thought to be chiefly the responsibility of

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the surgeon (22). However, this overlooks the critical role (both direct and indirect) that the broader surgical team have in performing these procedures and interventions. Recent data have further illuminated the influence these medical personnel can have on the risk of infection. In order for preventative strategies to have a maximum impact, they must therefore utilize a team approach that both educates these medical professionals in the potential causes of SSI and enables them to take a more-robust role in combating their occurrence.

The current review summarises the most recent and relevant data on SSIs in adult inpatients undergoing joint arthroplasty. Unlike previous reviews on this topic, it focuses on those risk factors that typically are, completely or in part, beyond the direct control of the orthopaedic surgeon.

THE ROLE OF THE SURGICAL TEAM

Behavioural aspects

Behavioural factors are generally believed to play an important role in the risk of SSIs. However, perhaps due to the inherent difficulties in studying behaviour, the literature on this topic is currently limited to two studies. Beldi *et al* reported an association between intangible aspects of operating room staff behaviour during surgery and the risk of SSI (6). After randomly allocating 1,032 patients to standard versus extensive antiseptic measures, the authors sought to document the "discipline factors" most relevant to developing an SSI (6). They observed that change within surgical team member (odds ratio [OR], 2.84 ; 95% confidence interval [CI], 1.97-4.08), hectic movement (OR, 1.82 ; 95% CI, 1.10-3.01), loud noise in the operating room (OR, 1.87 ; 95% CI, 1.34-2.60), and the presence of one or more visitors during surgery (OR, 1.79, CI, 1.26-1.53) were the strongest independent risk factors for SSI. Additionally, a small study of 35 patients by Kurmann *et al* found that median sound level during surgery was 4 decibels higher in patient that had developed an SSI infection ($p = 0.029$), and talking about non-surgery related topics was associated with a higher sound level ($p = 0.024$) (36).

Door opening

Door opening acts as a risk factor for SSI through two mechanisms : the opening of the operating room door disrupts laminar airflow, thereby allowing pathogens to enter the space surrounding the site of the operation (10,17,62), and increased operating room traffic itself raises infection risk (10,62,65).

Mean door-opening frequency during arthroplasty procedures has been reported at a rate of 0.6-0.7 openings per minute for primary operations and 0.84 for revisions, with 63% of traffic occurring after incision (4,62), a rate which was deemed "alarmingly high" (4). Door openings were attributed primarily to nursing staff (52.2% of total door openings), followed by anaesthesia (23.9%) and orthopaedic staff (12.7%), for reasons ranging from justifiable, such as retrieving necessary instruments or implants and rotating out for breaks, to those less so, such as speaking with colleagues in the corridor (4).

Electronic devices in the operating room

People rely more on portable electronic devices such as tablets and cell phones than ever before, and healthcare workers are no exception. In the operating room, however, such devices can pose substantial contamination risks, with the number of devices carrying resistant microorganisms (gram-negative rods and *S aureus*) thought to range from 44% to 98% (12). It is therefore recommended that such devices be left out of the operating room if possible. However, as portable electronic technology plays a greater role in the diagnosis and care of patients, it is possible that there presence will someday be considered essential. In such instances, the devices should undergo a comprehensive cleanse with an alcohol-related solution prior to their admittance into the operating theatre (1,12).

Sterility breaks

There are tremendous demands placed upon the circulating nurse and scrub person in establishing and ensuring sterile operating conditions in terms of volume (e.g., number of rooms and hours spent sterilizing daily), which in turn makes this area vulnerable to lapses and errors. Throughout the process of pre-operative sterilization, setting up and opening of instruments, and during surgery, it is not uncommon that contamination can occur by unsterile staff by reaching over a sterile field or allowing unsterile items to enter the field, or when the scrub person improperly moves a table with gloved hand (*30*).

Additional risks are posed by the reuse of single-use items. Adverse events related to device contamination or damage do occur, but there is limited reporting in the literature on the risk incidence (*72*). Cost savings related to reprocessing of single-use devices can easily be offset by costs related to adverse events (*72*). A noteworthy case described in the literature is provided with multiple-dosing in multiple patients of single-use vials of propofol, which may lead to contamination and outbreaks of severe sepsis (*57,73*).

Surgical skill and procedure volume

A surgeon's ability to gently handle tissue is considered imperative for minimising trauma and preventing necrosis and its resultant infection risk (*48*). The overall importance of these skills in limiting SSIs is considered undervalued by some (*44,52*). Mishriki *et al* found the surgeon to be the strongest risk factor of SSI in general surgical patients (*53*). However, others consider this factor to be overstated, with a recently published study reporting no differences in periprosthetic joint infection rates regardless of whether a patient was operated upon by a staff surgeon versus a trainee (*59,85*). A clearer association is perhaps found in the number of cases surgical teams perform, as greater familiarity will likely reduce error rates and surgical times (*59*), with the latter having a direct correlation with decreased infection risk (*85*). Several studies in total joint arthroplasty have found that higher infection rates occur at lower-volume institutions and amongst low-volume surgeons (*23,59*). Another possible explanation for this discrepancy may be that high-volume institutions have organised SSI control departments and more-stringent prevention and early detection measures.

Preoperative hair removal

Although numerous randomised clinical studies have investigated the association between preoperative hair removal and SSI, the results in this area have been somewhat contradictory (*44*). Most studies recommended against preoperative shaving of the surgical site, citing a higher infection risk when compared with either no removal or the use of clippers (*43,80*). It is hypothesised that this increased risk is due to microscopic cuts of the skin made during shaving, which in turn serve as foci for bacterial multiplication after surgery (*14,44*). This risk appears to be reduced when clipping or shaving is performed in the immediate preoperative period rather than night before (*44*). Other studies have concluded that not removing hair lowers the postoperative SSI risk (*53,55*).

Surgical attire

The use of disposable caps and masks in operating theatres for scrubbed and non-scrubbed staff is a hallmark of modern surgery, yet recent studies have challenged its effectiveness. Humphreys *et al* reported that wearing surgical headgear was not associated with bacterial air count reductions, and recommended against its routine use among non-scrubbed staff not directly involved in high-risk surgical procedure (e.g., arthroplasty), as effective ventilation counteracts any increased bacterial shedding (*33*). A study of bacterial air counts at head and waste level also observed no consistent benefit to headgear used in conventional (plenum ventilated) airflow theatres, yet did find 22 times the number of organisms when operating staff did not wear surgical headgear in ultraclean (enclosed vertical laminar-flow) theatres (*32*).

Other studies have observed increased bacterial shedding when no facemask is worn, including an analysis by Berger *et al* of 30 cardiac catheterisation procedures where the number of bacterial colonies recoverable was significantly higher than that detected when a full mask was worn ($p < 0.002$) (*7*). A significant reduction in bacterial colonies with face masks was also noted in an analysis of blood agar plates placed 30 cm directly below the lips of 20 volunteers (*49*).

Preoperative hand / forearm antisepsis

The unintended transfer of microorganisms from surgeons and surgical staff to the patient is a key area of concern. Although the use of sterile gloves is the accepted means for protecting against pathogenic transfer, it is not without complication. Their use must be accompanied by meticulous sterile techniques, and even then, perforations in the gloves sustained during surgery can undue their utility (*16,26*). Glove perforations are far from rare, with one study observing their occurrence in 10% of 6,540 procedures (*54*).

A literature review on the topic confirmed that the addition of a second pair of surgical gloves significantly reduced perforations to innermost gloves, as did a third pair of gloves, knitted outer gloves, and glove liners. Despite this, there was no direct evidence that the use of additional glove protection reduced SSIs, though the review was insufficiently powered to confirm such an association (*77*).

There are additional antiseptic options for the hands and forearms prior to entering the operating room theatre. Water-based aqueous solutions typically contain chlorhexidine or povidone iodine (PI), and require a surgical scrub of 3- to 5-minutes duration (*70*). Newer alcohol rubs that contain concentrated ethanol, iso-propanol, or *n*-propanol, require simple hand washing at the beginning of the day and then, if the hands are relatively clean, a presurgery application of the alcohol solution. Additional bactericidal impact can be obtained by adding chlorhexidine, iodine, and various other active ingredients to these alcohol rubs (*70*).

Removal of nail polish and finger rings

It is standard practice in most hospitals for the operating team not to wear hand jewellery, nail polish, or nail extensions during surgical procedures, although a Cochrane review found no randomized clinical studies assessing the impact of these cosmetic features on the postoperative infection rate (*2*). The United Kingdom's National Institute for Health and Care Excellence (NICE) guidelines state that in certain circumstances artificial nails, nail polish, and jewellery may conceal underlying soiling and impair hand decontamination. Because of this inherent risk, NICE recommends that the operating team should remove hand jewellery before operations (*61*).

MODIFIABLE PATIENT-SPECIFIC RISKS

As arthroplasty patients typically undergo conservative treatments prior to surgery, often over several years, physicians have ample time to target modifiable risk factors for infection, which a recent study estimated to be present in approximately 80% of patients (*64*). Addressing these modifiable risk factors must fall to both the surgeon as well as the anesthesiologist in the run-up to surgery. Following appropriate treatment protocols that allow for monitoring and, where possible, correcting these risk factors is an essential part of the preoperative treatment process in total joint arthroplasty. Key modifiable patient risk factors to consider include obesity, immunodeficiency virus, diabetes, smoking, anaemia, risk for MRSA colonization, urinary tract infection, malnutrition, a history local or remote orthopaedic infection, and poor dental hygiene (*56*).

THE ROLE OF THE ANESTHESIOLOGIST

Type of anaesthesia

Recent data suggests that the choice of regional versus general anaesthesia may have a considerable impact on infection risk in orthopaedic patients via the beneficial effects of neuraxial anesthesia on tissue perfusion, immune function, and blood loss (*42, 66*). Currently though, this effect is more established on short-term rather than long-term outcomes.

Intraoperative high inspired oxygen fraction (FIO2) has been effective at preventing SSI in the general surgery population (*31*), though its value in elective orthopaedic surgery requires further research (*79*). In addition, vasodilatation induced through controlled epidural hypotension is known to significantly reduce blood loss and improve tissue perfusion (*79*), and hypotension may be beneficial for addressing the hematoma formation and blood transfusion requirements linked to increased infection risk. Caution should be exercised in equating hypotension with hypo perfusion, as the risk of hypo perfusion is significantly increased during hypovolemic episodes due to blood loss or general anaesthetic effects (*79*).

Antibiotic prophylaxis

Proper timing is essential when administering preoperative antibiotics for knee surgery. This is due to several factors, including the relatively abbreviated half-lives of certain antibiotics and the possibility that the tourniquet often employed during this surgery will prevent an effective antibiotic concentration building up in the tissues. A study conducted in Sweden found that 57% of patients had antibiotic prophylaxis outside of the required 45 to 15 minute preoperative time frame (*76*). However, Soriano *et al* found no significant difference in postoperative infection rate between patients randomized to standard antibiotic prophylaxis or to administration of prophylactic antibiotics just before release of the tourniquet (*75*). A pharmacokinetic analysis by Bicanic *et al* hypothesized that cefazolin should be provided no longer than 30 minutes before incision (tourniquet inflation) and not less than 10 minutes before tourniquet inflation (*8*).

The practice of avoiding cefazolin administration in penicillin-allergic patients is without solid rationale, given the relative lack of cross-reactivity observed between these agents. Rates of cross reactivity have been reported to be as low as 1% and 2.55% in those with reported and confirmed penicillin allergies, respectively (*11*).

Opioid therapy and immunosuppression

Modern anaesthesia aims to reduce the perioperative use of morphine and other opioid-like substances (*25*). There is some evidence in the literature of opioid-mediated suppression of immune responses that can in turn decrease otherwise natural processes of infection resistance (*81*).

Hypothermia

The induction of general anaesthesia impairs thermoregulatory mechanisms and redistributes core body heat to the periphery (*45*), with temperature losses of up 1.6°C observed in the first hour of anaesthesia alone (*19*). When perioperative hypothermia occurs, it can cause a cascade involving adrenalin release, peripheral vasoconstriction and hypertension, and increasing myocardial ischemia risk (*20*). Myocardial infarction, SSI, and resultant increases in recovery time and length of hospital stay can occur with even mild hypothermia (*28,38, 50,68*). Conversely, preventing perioperative hypothermia has been shown to reduce blood loss and transfusion requirements (*68*), as well as the incidence of SSIs (*13,38,50,79*). Some studies have noted that forced air warming (FAW) and heating blankets appear effective in maintaining perioperative normothermia during arthroplasty surgery (*35,60*). This is complicated by another analysis that found that FAW devices have an increased movement of non-sterile airflow over the surgical site, an effect that was not found for conduct fabric warming (*47*). However, the validity of these findings have been questioned by others (*63*) and more research is needed to clarify the issue (*83*).

Hyperoxia

The role hyperoxia plays in the prevention of SSIs remains debated (*19*). In vitro studies have demonstrated the impact of tissue oxygen tension on the effect of oxidative killing of neutrophils (*3*). Clinical studies have also observed a significantly lower subcutaneous tissue oxygen tension in those with SSI than in this without SSI, with no infections documented in patients with tissue oxygen tension levels larger then 90 mmHg (*24,29*). However, such differences may only be apparent when measuring saturation levels at locations remote from the operative site, with no association between oxygen saturation and SSI at the surgical site itself (*24*).

Of the five other randomised trials assessing this topic (*5,9,21,46,51*), all but one (*5*) reported equivalence. A meta-analysis of randomised trials, with 2,7278 patients in total, also yielded comparable results (*67*). Subgroup analysis among these patients did indicate that certain cohorts (e.g., those undergoing colorectal surgery) were less likely to develop an SSI after receiving hyperoxia, signalling a possible role for specific populations, though the utility of hyperoxia across all surgical cases continues to remain unclear.

DISCUSSION

SSIs pose a considerable risk to contemporary orthopaedics, in the form of elevated costs, increased recovery times, and, in the most severe cases, patient mortality. Though the proposed causes for SSIs range in term of supporting evidence, there is a consensus that the room for improved outcomes is considerable. By understanding the potential causes of SSIs, surgical staff can make necessary, and in some instances simple, changes to reduce their potential occurrence.

In the United States, the Surgical Care Improvement Project (SCIP) was created in August 2005 with the aim of reducing surgical infection, venous thromboembolism, and cardiac events (*27,58*). For the specific aim of preventing perioperative infection, SCIP recommends initiatives such as correct antibiotic selection for probable microbial contaminants and managing their use from the prophylactic to postsurgical periods, careful surgical site hair removal, and perioperative normothermia.

Similar initiatives have been undertaken in Europe. The United Kingdom's NICE recommendation encompasses all surgical phases, from the preoperative (e.g., antibiotic prophylaxis and treatment), intraoperative (e.g., maintaining patient homeostasis), and postoperative (e.g., cleansing and dressing) (*40*).

Although several studies have shown that implementing such bundles can lead to a significant reduction in the incidence of SSI (*58,71,82*), this has not translated into a decrease in their overall occurrence rate (*41*). These disappointing results are perhaps due to the wide variability in compliance (20-60%) reported with these programs (*41*).

For these bundles to be implemented successfully, there will need to be a shift in individual, cultural, and institutional support systems (*41*). This process begins with the recognition of the potential impact of operating ward behaviour and practices, and is followed by the enforcement of mandated clinical practices. These must be multidisciplinary efforts that incorporates all staff involved in the surgical process ; not just surgeons, but also anesthetists, operating room heads, and infection control personnel (*34*). Although the roles and responsibilities differ for each individual team member, the common objective is the prevention of SSI. Checklists can provide a simple but effective means for improving compliance (*41*).

The orthopaedic surgeon remains the ultimate person responsible for the patient's well- being, but SSI prevention must without a doubt be considered a shared responsibility if it is to be effective. This requires that all other team members in addition to the surgeon are aware of their roles and responsibilities in the occurrence and the prevention of infection, as well as the impact of infection on the patient's health (*78*). A joint responsibility releases the orthopaedic surgeon from the cumbersome burden of acting as the police officer for the team who is constantly having to show people when they are in conflict with the rules (*78*). This multidisciplinary team must also be responsible for phasing out obsolete practices now known to have little impact on overall SSI risk, and instead moving towards bundles based on the best available evidence. When reliably implemented and enforced, validated protocols can effectively reduce the risk of SSIs (*58,71,82*).

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