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Review

Prevention of surgical site infections in orthopaedic surgery and bone trauma: state-of-the-art update

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S U M M A R Y

Prevention of surgical site infection in orthopaedic surgery and bone trauma has some hallmarks not shared with other surgical disciplines: low inoculum for implant infections; pathogenicity of coagulase-negative staphylococci and other skin commensals; possible haematogenous origin; and long post-discharge surveillance periods. Only some of the many measures to prevent orthopaedic surgical site infection are based on strong evidence and there is insufficient evidence to show which element is superior over any other. This highlights the need for multimodal approaches involving active post-discharge surveillance, as well as preventive measures at every step of the care process. These range from preoperative care to surgery and postoperative care at the individual patient level, including department-wide interventions targeting all healthcare-associated infections and improving antibiotic stewardship. Although theoretically reducible to zero, the maximum realistic extent to decrease surgical site infection in elective orthopaedic surgery remains unknown.

Introduction

Healthcare-associated infections (HCAIs) are relatively rare in orthopaedic and trauma surgery compared with other surgical wards. The current lifelong infection risk for primary hip and knee arthroplasties is around 1% and increases to 2–5% for revision arthroplasties, shoulder arthroplasties, and fracture fixation devices (Table I). By contrast, the risk for surgical site infection (SSI) following colon surgery can be as high as 20%.[1] According to a large French prevalence study, the relative risk of SSI following genitourinary, cardiovascular, gynaecological, and gastrointestinal surgery compared with orthopaedic surgery was 2.1, 2.4, 2.6, 3.4, and 4.8, respectively.[1] SSIs are often associated with a high burden on patients and hospitals in terms of morbidity, mortality, and additional costs.[2] Osteo-articular infections are also difficult to treat and associated with lifelong recurrence risks of around 10–20%, particularly in the case of multi-resistant pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA).[3]

Prevention remains of the utmost importance. SSI prevention in orthopaedic surgery has certain specificities unknown to general surgery: low inocula for implant-related foreign body infections; pathogenicity of skin commensals; a possible haematogenous origin for some infections; and the necessity for a prolonged, post-discharge surveillance period with a minimal follow-up of one year for implant-related surgery.[4–7] The aim of this review was to focus on specific aspects of SSI prevention in adult orthopaedic and trauma patients and highlight important epidemiological features.

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Table I
Surgical site infection in orthopaedic and bone trauma surgery (selected series)[a]

Type of orthopaedic surgery	Risk of surgical site infection
Primary hip and knee arthroplasties	0.8% Norwegian Register (73,000 arthroplasties)
	0.9% Finnish Register (4628 arthroplasties)
	0.9% Geneva Register (6101 arthroplasties)
Elbow arthroplasties	3.6% (2458 arthroplasties)
Femoral osteosynthesis	3.9% (541 operations)
Pin track care	7.0% (170 procedures)
Foot and ankle surgery	1.6% (555 operations)
Hallux valgus (Lapidus procedure)	1.3% (61 operations)
Arthroscopies	0.1–0.4% (552, 258 procedures)
Open fractures Gustilo grade I	0.9%
Open fractures Gustilo grade II	1.9%
Open fractures Gustilo grade III	12–53%
Amputation stump	5–22%

[a] Adapted from Uçkay *et al.*[4]

Methods

Literature review

We conducted a literature search including search engines such as Google and electronic resources such as PubMed to identify English, French, and German language publications published before 31 December 2011 using the MeSH terms 'infection', 'orthopaedic' or 'orthopedic', and 'prevention' alone and in different combinations. PubMed yielded 1712 reports, and almost a million hits were displayed on Google. Results retrieved by PubMed were screened for pertinence and the presence of redundant information with an emphasis on original evidence-based literature published during the last five years. Older landmark papers were retained when the content was considered still valid. The internet search was restricted to the first 400 Google Scholar hits for every MeSH term.

Review articles were included only if they summarized specific aspects of SSI prevention. Publications related to general surgery or multiple surgical disciplines were included only if they contained at least a subgroup of orthopaedic patients and patients undergoing clean surgery. Reference lists of identified articles were hand-searched to retrieve additional evidence-based literature. We excluded animal studies, studies with an outcome other than SSI, *in vitro* studies, and paediatric reports. Sterilization techniques of surgical instruments and issues related to prion diseases were not included as these were outside the scope of this review.

Changing epidemiology – more resistant pathogens

MRSA and meticillin-resistant coagulase-negative staphylococci infections (meticillin-resistant *Staphylococcus epidermidis*: MRSE) are a feared complication of implant-related surgery. Similar to MRSA, MRSE are reportedly increasing as nosocomial pathogens on orthopaedic wards.[5] According to the latest United States National Nosocomial Infections Surveillance report, 65% of coagulase-negative staphylococci have become resistant to meticillin during the past two decades.[8] However, this rise in frequency is not necessarily ubiquitous. For example, we evaluated the epidemiology of osteo-articular infections due to MRSE and meticillin-susceptible coagulase-negative staphylococci at our institution over a 13-year observation period and found no increase in the proportion of MRSE infection.[9] Hospitals and communities are also facing an increase in resistant Gram-negative colonization and infection.[4]

Pathogenesis of surgical site infections and risk factors

Most SSIs are believed to be acquired during surgery.[10] This is supported by the success of SSI prevention measures directed towards activities in the operating theatre and by reports demonstrating matching strains of pathogens from the surgeon's fingers and postoperative infection.[4] To our knowledge, there are currently no data on the actual proportion of SSI acquired in the operating theatre versus postoperative care on wards. Risk factors for orthopaedic, implant-related SSI have been identified through epidemiological studies. Approximately half are endogenous and thus difficult to modify in the immediate pre- and postoperative phase.[4] Systemic patient-related factors, such as malnutrition, diabetes mellitus, elevated serum glucose level, anticoagulation, smoking, or iatrogenic immune suppression (steroid therapy or the use of tumour necrosis factor-α inhibitors), play a role in wound-healing and infection risk for surgery in general, and probably also for orthopaedic surgery.[4] Some factors can be influenced in the immediate pre- and postoperative period. For example, if possible, preoperative, high-dose corticosteroid therapy should be tapered before elective orthopaedic surgery, and glycaemia and anticoagulation optimized. Smoking cessation before and even after surgery is beneficial in terms of post-surgical complications potentially leading to healthcare-associated infection.[4]

Evidence-based preventive measures

Several preventive measures are currently considered as very effective with a high level of evidence (grade IA) according to guidelines.[7,11] These include surgical hand preparation, antibiotic prophylaxis, multimodal interventions and, with some limitations, the surgeon's skill, and postponing an elective operation in the case of active remote infection.[4,7,12–14] These items are often combined as multimodal intervention bundles (Table II).

Surgical hand preparation

Surgical hand preparation is probably the most important strategy for the prevention of orthopaedic SSI infections.[12] For obvious ethical reasons, no randomized, controlled study has been conducted to compare surgery with and without previous surgical hand preparation *sensu stricto* and hygiene remains its counterpart on the wards. A cluster-randomized, cross-over

Table II
Main measures to prevent orthopaedic surgical site infection[a]

Measure	Relative surgical site infection reduction	Evidence grading
High impact		
Active post-discharge surveillance	33%, France	IA
Multimodal intervention	87%, The Netherlands	IA
	65%, Houston, TX, USA	
	10%, Madrid, Spain	
Adequate antibiotic prophylaxis	73%, among orthopaedic patients in the USA	IA
	81%, review of the literature	
Promising impact, needs further studies		
Nasal mupirocin, *S. aureus* decolonization	43%, Pittsburgh, PA, USA	IB

[a] Adapted from Uçkay *et al*.[4] and Mangram *et al*.[7]

trial reported the equivalence of surgical hand preparation with non-medicated soap and water versus alcohol-based hand rub on postoperative SSI rates.[15] Hand-rubbing with an alcohol-based formulation is considered as effective as scrubbing, for which the ideal duration remains unknown, although it is probable that the minimum duration is 2–3 min for both techniques.[12,16] In resource-poor areas, the rapid antimicrobial action, wider spectrum of activity, lower side-effects, and the absence of the risk of hand contamination by rinsing water might favour alcohol-based formulations.[12]

Antibiotic perioperative prophylaxis

The effectiveness of preoperative antibiotic agents is taken for granted for most orthopaedic interventions, including bone trauma.[13,17,18] Eventual exceptions are the removal of implant material where the number needed to prevent one SSI episode might be too small to justify routine administration. Antimicrobial prophylaxis for orthopaedic implant surgery helps to reduce SSI rates to 1–3% compared with 4–8% without antibiotics. Successful surgical antibiotic prophylaxis depends on a number of key principles.[4]

(i) The individual patient history of (pseudo)allergy must be considered.
(ii) First- or second-generation parenteral cephalosporins are sufficient; in the case of skin colonization with meticillin-resistant staphylococci, a glycopeptide antibiotic is recommended.[4,7,14] However, during the current epidemic of virulent *Clostridium difficile* strains in some parts of the world (e.g. North America or the UK) or local outbreaks due to vancomycin-resistant enterococci, some centres are moving away from cephalosporins that are thought to maintain the epidemic more than other antimicrobials. These are exceptional situations. In our opinion, this approach is certainly not valid for institutions without *C. difficile* problems.
(iii) Timing is of the utmost importance and prophylaxis should be given ideally within 30 min to 1 h before incision.[17]
(iv) One dose is sufficient. Redosing may be justified for operating procedures longer than 4 h or in the case of significant blood loss, but it remains unknown whether a repeated administration should use the same or reduced dosage. Some older studies have advocated an improved outcome with duration of antibiotic prophylaxis up to 48 h. For example, Gatell *et al*. performed a randomized, double-blind trial to compare the efficacy of five doses of cefemandole (335 orthopaedic implant patients) with a single perioperative dose of cefemandole (382 implant patients). These were patients with orthopaedic foreign bodies, but elective arthroplasties were excluded. Fewer infections were observed in the group receiving five doses.[18] However, the implants were different across study groups and the benefit of antibiotic prolongation beyond one dose has not been determined in recent trials or meta-analyses.[19] It remains unknown whether standard doses should be routinely enhanced for obese patients, i.e. a body mass index >30 kg/m^2.[20] Different experts recommend a higher dose for obese patients, but this is an empirical opinion.

Use of glycopeptide antibiotics in routine prophylaxis

From an epidemiological standpoint, there is no evidence that a general glycopeptide prophylaxis would be superior to cephalosporins for patients without MRSA carriage.[4,14] A review of four randomized trials comparing the prophylactic use of teicoplanin versus a cephalosporin in settings with a high prevalence of meticillin-resistance among *S. epidermidis* showed similar infection rates in both groups.[21] Another review and economic model of switching from non-glycopeptide to glycopeptide antibiotic prophylaxis for surgery in endemic MRSA settings failed to show an increased efficacy for the prevention of SSI due to meticillin-resistant staphylococci.[22]

Need for Gram-negative prophylaxis?

By contrast with mass casualty situations and penetrating bone trauma, orthopaedic surgery is more concerned by patient skin pathogens and less by internal colonization with extended-spectrum beta-lactamase (ESBL)-producing Gram-negative rods, vancomycin-resistant enterococci (VRE), or multi-resistant non-fermenting rods (*Pseudomonas aeruginosa*, *Acinetobacter* spp.) compared with urological or visceral surgery.[23] Gram-negative infections in clean orthopaedic surgery are rare and the majority appear to be caused by non-fermenting rods, which are by nature resistant to most beta-lactam antibiotics.[24] To our knowledge, there are no solid data to support a change of routine antibiotic prophylaxis for orthopaedic surgery in the case of colonization by these pathogens.[4,25,26] The future may reveal an increasing transplant recipient population undergoing arthroplasty surgery.

Preliminary data suggest that SSI with Gram-negative pathogens may be more frequent in these highly immunocompromised patients than immunocompetent individuals.[26] However, this is an emerging field of epidemiological research and needs more confirmation of preliminary findings.

Antibiotic-containing cement for prophylaxis

Engesaeter *et al.* reviewed the revision rates for 56,000 cemented and uncemented primary total hip replacements.[27] Prostheses with antibiotic cement were associated with an overall lower revision risk. The benefit of antibiotic-loaded cement was further confirmed in the Finnish arthroplasty register and in large retrospective studies where cost-effective antibiotic cementing was reported to reduce SSI by up to 50%.[28,29] Josefsson *et al.* studied the prophylactic effect of gentamicin-containing bone cement in a prospective multicentre study of infected total hip prostheses. A total of 812 episodes were randomly assigned to a systemic antibiotic group and 821 to local therapy with gentamicin-loaded cement. Follow-up of one to two years showed fewer infections (three versus 13) in the gentamicin-cement group.[30] Chiu *et al.* conducted a prospective, randomized trial including 340 primary arthroplasties; one group was treated with simple cement and the other with cefuroxime-impregnated cement. Both groups received systemic antibiotic prophylaxis. The study showed fewer infections in the cefuroxime-cement group, but a comparison of cement-related antibiotic release versus systemic antibiotic administration failed to show a superiority of either regimen.[31]

Open fractures

Open fractures harbour a high risk of infection ranging from 10% to 50%, particularly Gustilo grade IIIc.[32] By contrast with the duration of preoperative antibiotic prophylaxis where a single parenteral dose is sufficient, almost no evaluation has been attempted for the ideal or minimal duration for open fractures. Most of the available literature relies on historical controls or is underpowered. To our knowledge, no study has attempted to distinguish between infection due to self-inoculation and potential hospital-acquired pathogens due to surgical interventions and prolonged length of hospital stay. Since surgery takes place in a contaminated site, most clinicians consider antibiotic use as pre-emptive therapy, not as mere prophylaxis.[4] It is generally accepted that antibiotic medication should not be administered for more than 24 h for grade I and II fractures.[32] The minimum duration for grade III fractures ranges between one day and several weeks, but guidelines based on expert opinion and common sense recommend a maximum of 48 h or 72 h.[33,34] In a case–control study of 1500 patients conducted at our institution, empirical antibiotic therapy and its duration were not related to infection. The infection risk was dominated by the extent of tissue damage according to the Gustilo grade. When compared with less than three days of a pre-emptive course of antibiotic therapy, more than three days did not show any tendency for protection against infection. Results were similar when stratified separately for grade I–III tibial fractures.[35] Dellinger *et al.* found no benefit of five days of prophylaxis with cefonicid or cefamandole compared with one day of cefonicid in open extremity fractures.[36] However, the ideal duration of antibiotic administration or the systematic use of negative pressure wound therapy in open fractures needs further research.[37] It is likely that the future will show an equivalence of shorter prophylactic therapies for open fractures.

A second controversial issue is the choice of antibiotic agents for pre-emptive therapy in open fractures, especially in the presence of contamination with soil and debris. Most authors maintain the usual recommendations for second-generation cephalosporins. Although some combine these with aminoglycosides, quinolones, or regimens targeting anaerobic pathogens, it remains uncertain whether even a maximum antibiotic coverage may prevent infection, especially in tissues with debris and an inadequate blood supply.[38] Open fractures are contaminated by a panoply of antibiotic-susceptible pathogens, including *Pseudomonas aeruginosa* and *S. aureus*.[24,35] The major challenge is that the clinician never knows which pathogen (known or hidden) will emerge as the one selected by ongoing antibiotic therapy, independent of the initial choice of the agent. Moreover, certain non-fermenting rods, such as *Pseudomonas* spp., may develop resistance to a single agent during therapy. To circumvent this danger, a hypothetical, broad, antibiotic coverage including glycopeptides and carbapenems is not feasible and would be very costly when applied to every grade III fracture. A retrospective study investigated the congruence of pre-infection microbiological samples of the first surgical exploration with the pathogen of infection and found very little concordance.[39] We confirmed these results by conducting a similar study and found zero concordance.[35] In other studies, the proportion of positive pre-infectious cultures ranges from 60% to 83%.[40] One report advocated a repeat culture one day after debridement and observed that persistence of the same organism predicted a very high risk for future infection.[40] However, a largely accepted confirmation of this approach is still lacking. Similar to the entire surgical field, the completeness of the surgical excision of contaminated tissue in open fractures is of the utmost importance and certainly more important than any considerations related to antibiotic administration.

Prophylaxis before dental interventions

Antibiotic prophylaxis for arthroplasty patients before dental or gingival interventions is a subject of debate among orthopaedic surgeons, doctors, and dentists. Indeed, several opinion leaders, scientific reviews, and cohort studies regularly deny any objective rationale for routine prophylaxis.[41] Berbari *et al.* performed a prospective study including 339 arthroplasty patients undergoing a high- or low-risk dental procedure without antibiotic prophylaxis compared with 339 arthroplasty controls not undergoing a dental procedure. They showed that antibiotic prophylaxis in high-risk or low-risk dental procedures did not decrease the risk of subsequent total hip or knee joint prosthesis infection.[42] Infections of total hip or knee replacement due to haematogenous seeding following dental intervention are probably very rare.

Surgeon's expertise

Although subjective and difficult to analyse, the surgeon's expertise and surgical technique is certainly very important, but it is almost impossible to perform a randomized trial on this topic.[4] However, differences in outcome between low- and high-volume surgeons have been observed after hip fractures: there is a lower mortality risk, lower rates of pneumonia, decubitus, and transfusion requirements in patients operated by experienced surgeons in the same setting.[43] An excellent surgical technique is believed to reduce SSI by maintaining effective haemostasis while preserving adequate blood supply, gentle handling of tissue, removal of devitalized tissue, eradication of dead space, and appropriate management of the postoperative incision.[4] Finally, the duration of surgery is a strong predictor of SSI – the longer the duration, the higher the risk.[4,17,44]

Other measures with high efficacy

Active surveillance and multimodal interventions

Multimodal strategies targeted at SSI prevention are associated with the highest impact. These interventions, sometimes in the form of so-called 'bundles' or safety checklists, do not need to cover all potential risk factors. For example, De Lucas-Villarubia *et al.* implemented admission screening for MRSA carriage, preoperative decolonization, improvement of antibiotic prophylaxis, and post-discharge surveillance.[45] With these simple measures and an institution-wide awareness of the facility's MRSA problem, the baseline SSI rate of 10% was reduced to almost zero for 12 months.[46]

Screening for *S. aureus* carriage with subsequent decolonization

Screening and subsequent decolonization of patients before and after surgery remain controversial for general surgery.[4] If the orthopaedic literature is considered separately, available data suggest that this may be cost-saving specifically in this group of patients and may allow the eradication of MRSA or meticillin-susceptible *S. aureus* carriage.[17,47,46] It is possible that the lower inoculum needed for implant infections might be one reason for more convincing results compared with other surgical disciplines. Kalmeijer *et al.* identified nasal carriage of *S. aureus* as a major risk factor for SSI among orthopaedic patients.[48] Wilcox *et al.* decreased the incidence of MRSA SSI from 2.3% to 0.3% after the introduction of intranasal mupirocin and triclosan showers before orthopaedic surgery.[49] The same experience was repeated by others with nasal mupirocin use alone without concomitant body decolonization.[50] Kim *et al.* observed that nasal mupirocin and chlorhexidine showers significantly reduced the SSI risk among identified MRSA carriers hospitalized for elective orthopaedic surgery.[51] Rao *et al.* reported that a preoperative decolonization protocol translated to an adjusted economic gain of US $230,000 to the facility.[47] In practice, various institutional recommendations reflect different opinions. The more the recommendation is based on expert opinion, the more it favours screening, decolonization, or preoperative bathing.

Widespread measures with low evidence

Preoperative bathing or showering

There is little evidence that preoperative showering with an antiseptic agent reduces SSI rates, although it has been shown to reduce skin colonization.[7] The US Centers for Disease Control and Prevention (CDC) recommend that patients shower or bathe with an antiseptic agent prior to surgery.[7] A Cochrane review including six trials with 10,000 participants found no evidence for the superiority of preoperative bathing and showering versus placebo.[52]

Preoperative skin preparation

Preoperative skin preparation in the operating theatre immediately before surgery is routinely implemented worldwide based on expert opinion.[7] To our knowledge, there is no consensus on the best antiseptic agent to be used.[4,53,54] Indeed, even with optimal preparation, true sterilization of the skin is impossible. A prospective, randomized, non-blinded study revealed a superiority of 2% chlorhexidine combined with 70% isopropyl alcohol versus 10% povidone-iodine for the prevention of SSI after clean-contaminated surgery, while another group found the contrary in a before–after study.[55,56] For several decades, povidone–iodine or chlorhexidine have been generally used for skin antisepsis. The development of bacterial resistance (mainly among staphylococci and *P. aeruginosa*) to mupirocin or chlorhexidine has been recognized and its clinical impact is the subject of ongoing studies.[55,57,58] At present, many centres have raised the chlorhexidine concentration to 4%. In theory, the recolonization of skin bacteria over time needs to be respected, particularly during long operative procedures. Again, no data are available regarding an eventual re-preparation during ongoing surgery, although this could prove difficult as most patients and adjacent skin areas are under drapes.

Gloves, gowns, drapes and masks

Sterile gloves and adhesive drapes are usually used in the operating theatre, but many gloves reveal tiny punctures after use that mostly go unnoticed by the operating team.[12] Double-gloving or regular glove-changing might reduce the risk of punctures, but it does not guarantee their absence. A Cochrane review of 26 trials conducted on the practice of double-gloving as a barrier precaution was inconclusive in terms of SSI reduction.[59] Routine changing of the outer gloves during lengthy surgery is supported by expert opinion, but is not evidence-based.

Hair removal

Hair removal had its firm place in the 1999 CDC guidelines, but it has been questioned in a recent meta-analysis.[7,60] If hair removal is performed, it should be done with clippers, not razors, immediately before surgery and not the previous evening.[4,60,61]

Laminar airflow and ultraviolet light in the operating theatre

Earlier studies and expert opinion in the 1970s suggested reduced SSI rates in orthopaedic implant surgery performed in ultraclean air facilities.[62,63] Many hospitals in resource-rich countries are equipped with relatively expensive, vertical, horizontal, or mixed laminar airflow systems that reduce the bacterial burden in the air.[64] Actual costs today range from US $60,000–90,000 for the installation of an airflow system into a new operating theatre.[65] Expert opinion considers vertical airflows as superior over horizontal ones regarding air turnover at and away from the surgical wound.[65] Conventional plenum ventilation theatres have air exchange rates of 30 times/h. By contrast, laminar flow theatres exchange the volume >300 times/h at a continuous positive pressure, resulting in a maximum of 10 colony-forming units (cfu)/m^3, but with values as low as 1 cfu/m^3.[66] Few countries have set bacterial threshold limits for conventionally ventilated operating rooms, although most recommend 20 room air changes/h to obtain 50–150 cfu/m^3 of air.[65] Strict attention to laminar airflow protocol is essential to avoid any paradoxical increases in infection rates if these concepts are disregarded.[66,67]

In 1982, Lidwell *et al.* evaluated the effect of laminar airflow during 6781 hip arthroplasties and 1274 knee arthroplasties in a multicentre, prospective, randomized clinical trial.[62] Infection occurred in 1.5% of the control group compared with 0.6% in the ultraclean-air group. Although these results seemed to provide irrefutable evidence for the efficacy of laminar airflow systems, the study design had flaws that included randomization irregularities and lack of patient stratification. Furthermore, there was no control over the use of prophylactic antibiotics. In the presence of prophylactic antibiotics, the independent effect of laminar airflow was a non-significant reduction of SSI prevalence from 0.8% in the control group to 0.3% in the ultraclean-air group.[62] Recent clinical studies have already questioned its use in terms of SSI reduction. There is an inconsistent relationship between surface and air bacterial counts, indicating that the measurement of air contamination represents an unhelpful method for the assessment of surgical site contamination in laminar airflow units, including a failure to consider the effect of occlusive clothing. Retrospective nationwide analyses from Germany and New Zealand confirmed the absence of SSI reduction with laminar airflow versus no laminar airflow.[67,68] However, absence of scientific proof does not necessarily translate as absence of evidence and further studies are needed.

Ultraviolet light (UVL) works by killing bacteria in the operative field rather than simply decreasing bacterial counts. Its efficacy has been shown in some studies, but not in others. Studies to date have been retrospective with a comparison of clinical experiences and historical controls.[65] SSI rates of hip arthroplasty fell from 3.1% to 0.53% with the use of UVL at intensities of 25 to 30 μW/s/cm^2.[68] Initial levels of UVL used were based on health and safety concerns, but more recent studies have used intensities of up to 300 μW/s/cm^2 without reporting side-effects.[69] UVL technology is considerably less expensive and easier to install and run than laminar airflow systems.[65] Thus, it may achieve the same objectives at much lower cost. In relation to its benefit, the CDC attribute a potentially unacceptable health risk for staff coupled with high costs and do not recommend its use.[65] In particular, all exposed skin should be protected and it is recommended that the operating team wear two caps, visors, and occlusive clothing.[65]

Other measures

There are several SSI preventive measures with promising results for visceral surgery, which have not yet been investigated formally in orthopaedic patients.[4] These include supplemented oxygen during surgery, avoidance of intraoperative hypothermia, and hyperglycaemia, although the evidence for the latter is mixed.[4,70] Nevertheless, glycaemic control is used as a cornerstone of SSI prevention in many trials or settings.[4] For example, Karunakar *et al.* showed that patients with mean serum glucose levels >220 mg/L carried a seven-fold increase for the risk of SSI following orthopaedic trauma than patients below this threshold.[71] By contrast, insulin should not be given routinely to reduce the SSI risk.[4]

Behavioural aspects

An emerging field of research is the change of routine and behavioural aspects in the operating theatre, often in collaboration with nurses.[72,73] Epidemiological studies have identified noise provoked by the operating staff as an independent risk factor for SSI, and the first interventional studies equally incorporate behavioural aspects in their multimodal interventions.[74] To our knowledge, this research concerns general surgery so far and it has not been fully extended yet to orthopaedic surgery with one exception.[74] Douglas *et al.* experienced a 30% drop in SSI rates by implementing a multimodal programme consisting of a dedicated hospital hygiene team, elaboration of guidelines, staff education, avoidance of urinary catheter, active post-discharge surveillance, and limitation of traffic flow in the operating theatre.[75]

Post-surgical wound care

There is a paucity of literature on surgical wound care and SSI prevention. Most importantly, the proportion of SSI acquired postoperatively on the ward by direct inoculation remains unknown. Experts suggest that this proportion may be as high as 10%, but there are no studies to support this at present. More than contributing to a mere decrease of SSI, dressings might influence the avoidance of blistering.[76] A Cochrane review assessed the effectiveness of various dressings and topical agents on surgical wound healing and infection and concluded that the quality of the trials was insufficient to determine any superiority of one protocol or one topical agent over another.[77] Other randomized studies comparing occlusive versus gauze dressings failed equally to detect superiority in terms of SSI reduction or wound-healing.[78–80] To our knowledge, the potential preventive role of silver-coated antimicrobial barrier dressings for non-infected surgical wounds is currently unknown.

Conclusion

All healthcare-associated infections must be targeted to reduce their incidence. This requires multidisciplinary commitment, dedicated teams, surveillance networks, and an optimum policy concerning the reduction of antimicrobial use to actual evidence-based levels. From an academic standpoint, we still lack a complete understanding of exactly when the surgical site starts to develop infection and the premises that drive microbial colonization to infection. There is certainly a need to improve the work-up of the pathogenesis, material development, and search for hidden risk factors inside large databases, including the implementation of well-designed and conducted randomized studies to help improve patient safety.

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