Preventing surgical site infection. Where now?

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Summary  Surgical site infection (SSI) is increasingly recognised as a measure of the quality of patient care by surgeons, infection control practitioners, health planners and the public. There is increasing pressure to compare SSI rates between surgeons, institutions and countries. For this to be meaningful, data must be standardised and must include post-discharge surveillance (PDS) as many superficial SSIs do not present to the original institution. Further work is required to determine the best method of conducting PDS. In 2008 two important documents on SSI were published from the Society for Healthcare Epidemiology of America/The Infectious Disease Society of America and the National Institute for Health and Clinical Excellence, UK. Both emphasise key aspects during the preoperative, operative and postoperative phases of patient care. In addition to effective interventions known to be important for some time, e.g. not shaving the surgical site until the day of the procedure, there is increasing emphasis on physiological parameters, e.g. blood glucose concentrations, oxygen tensions and body temperature. Laparoscopic procedures are increasingly associated with reduced SSI rates, and the screening and decontamination of meticillin-resistant Staphylococcus aureus carriers is effective for certain surgical procedures but has to be balanced by cost and the risk of mupirocin resistance. Finally, there is a need to convert theory into practice by the rigorous application of SSI healthcare bundles. Recent studies suggest that, with a multidisciplinary approach, simple measures can be effective in reducing SSI rates.

Introduction  Recent years have seen an increasing emphasis on the importance of surgical site infection (SSI)
from the perspective of the surgeon, infection prevention and control practitioners, health administrators, managers and patients. While some healthcare-associated infections (HCAIs) such as bloodstream infections are more likely to be associated with life-threatening illness or even death, SSI remains among the commonest infections occurring in acute hospitals.

In a survey of 75694 patients in England, Wales, Northern Ireland and the Republic of Ireland, the overall prevalence of HCAI was 7.59%, with SSI accounting for 14.5% of these infections. The surveillance of some or all SSIs is conducted in many hospitals as part of routine surveillance and as a measure of patient safety. For a period of 15 years from 1982 to 1997, 59335 surgical sites were surveyed in a 600-bed hospital with an overall SSI rate of 4.5%, and for clean surgery 2.4%, with little change in rates during that period.

The significance of SSI and its prevention to surgeons carrying out procedures has increased as they realise that this is a measure of their effectiveness. Many surgeons rightly consider that the most critical factor in the prevention of SSI, although difficult to scientifically quantify, is the sound judgement and proper technique of the surgeon and his/her team, as well as the general health of the patient. It is important to ensure that the actual surgical procedure is successful, e.g. complete removal of a tumour, and that preventible adverse consequences arising from not adequately addressing infection prevention are addressed.

Quality initiatives taken by surgeons in collaboration with others are bearing fruit in highlighting the issues and possible interventions. As part of the American College of Surgeons Standard National Surgical Quality Improvement Programme (NSQIP), a survey of 117 private sector hospitals was undertaken to identify low and high outliers in terms of SSI prevention. High outliers (increased infection rates) were associated with higher numbers of trainees, longer operations, and low haemoglobin levels in operated patients; low outliers had a policy of minimising operating-room traffic.

Apart from the obvious morbidity and sometimes mortality that follows SSI, it is increasingly recognised that there is a significant cost to the healthcare system such as prolonged hospital stay as well as the cost to society in disability payments while out of work and loss of income tax revenue. An example of the healthcare costs is described in a case-control study of SSI following coronary artery bypass surgery in Australia between 1996 and 1998 in which 125 patients developed SSI; the mean excess healthcare cost attributable to SSI was $AU12,419 per case.

SSI rates are increasingly seen as an example of a performance indicator of the quality of healthcare. Changes are taking place in some countries leading to the public reporting of HCAI, including SSI rates. Although there are some logistical difficulties in ensuring that rates are truly comparable, it is likely that the future will see patients having access to the SSI rate of their local hospital before admission for elective surgery. In North America, this aspect of what could be described as ‘healthcare consumerism’ has led to major initiatives involving healthcare professionals, patient groups and others, to try to significantly improve the quality of care by focusing on those aspects that are amenable to prevention, thus aiming to reduce infection rates and produce better patient care. In this review, some aspects of surveillance and recent issues in SSI prevention are discussed.

Measuring the SSI rate

The details of techniques used for the surveillance of SSI are beyond the scope of this review, nevertheless it is essential that standardised definitions are used, e.g. classifying infections into superficial, incisional, deep incisional and organ/space, and that allowance is made for risk factors, especially when infection rates are likely to be compared between one surgeon or one institution and another. This must be done accurately and allow for changes in healthcare such as those resulting in shorter acute hospital stay, leading to many infections being diagnosed either in the outpatient or in the community. This emphasises the importance of post-discharge surveillance (PDS).

Whitby and colleagues in Queensland, Australia attempted to improve the reliability of PDS through patient self-determination and a programme of educating patients on SSI. The positive predictive value for a correct diagnosis was 65.2% for the educated group compared with 83.3% for the non-educated patient group, and the authors concluded that pre-discharge education resulted in patients overdiagnosing SSI. PDS is particularly important for superficial incisional SSI, which may not be serious enough to warrant re-admission to hospital. For example, in a survey in Finland of orthopaedic SSI, 86% of SSIs detected after hospital discharge were superficial.
Scotland yielded a statistically higher SSI rate when PDS was performed (6.34% compared with 2.61%) and the authors concluded that a procedure-specific approach was required with direct observation of patients.\textsuperscript{15} In The Netherlands, a national nosocomial surveillance network has been collecting data on HCAI for some years. SSI rates were determined according to different PDS methods for surgical procedures performed in 62 hospitals.\textsuperscript{16} Recommended PDS methods, e.g. direct observation by the surgeon, were compared with passive surveillance, e.g. patients re-presenting to the hospital. Recommended compared with passive surveillance methods detected a higher SSI rate, 3.7% compared with 3.1%.\textsuperscript{16}

It is universally acknowledged that PDS is essential in accurately determining the SSI rate, but there is a need for consensus as to how best this can be achieved while taking into account limited resources.

\textbf{Preventing SSI}

Approaches to the prevention and control of SSI have evolved over many years and traditionally have been classified into those interventions before surgery, during surgery and after surgery. However, prevention must be underpinned by a knowledge and understanding of the microbial pathogenesis, and the importance of surveillance. Much of the advice from the Hospital Infection Control Practices Advisory Committee (HICPAC) from North America on SSI prevention is derived from practice and custom, rather than rigorous scientific studies such as randomised controlled trials, but practice, custom and even ritual, continue to influence approaches to prevention.\textsuperscript{17}

In 2008 two important documents were published that synthesised and presented clearly many of the important issues pertaining to the prevention of SSI. The Society for Healthcare Epidemiology of America and the Infectious Diseases Society of America produced recommendations on HCAI including SSI, addressing surveillance methods, interventions to actively prevent SSI and approaches to monitoring the implementation of those strategies.\textsuperscript{11} In the UK, the National Institute for Health and Clinical Excellence published a document on the prevention and treatment of SSI which emerged after an extensive review of the literature and a wide consultation exercise.\textsuperscript{10} Both documents represent an impressive body of literature on SSI but combine this with practical and feasible advice about prevention; both emphasise the importance of education and the identification of risk factors for SSI. Some of the issues from both documents are outlined in Table I. Some are discussed below in terms of the evidence and what should be incorporated into current practice.

\textbf{Hand hygiene and the surgical scrub}

Hand hygiene is regarded as one of the key components in any infection prevention strategy. For many years, the traditional surgical scrub where the surgeon ensures that hands, nails and parts of the forearm are lathered and scrubbed has been standard practice. However, surgeons themselves accept that their practice, both in the operating theatre and outside, has often been suboptimal; 90% compliance is not sufficient.\textsuperscript{18} Recent evidence suggests that the traditional ritual of scrubbing can be replaced by a less lengthy and less ritualistic procedure. In a study involving six surgical services and 4387 consecutive patients who underwent clean and clean-contaminated surgery earlier this decade, there was no difference in the SSI rate, whether the surgeon used the hand-rubbing protocol with 75% aqueous alcohol or a hand-scrubbing protocol with povidone-iodine or chlorhexidine.\textsuperscript{19} Furthermore, the alcohol solution was better tolerated and associated with improved compliance.

\textbf{Physiological parameters}

Tissue hypoxia leads to necrosis and is often followed by infection. High blood glucose levels, such as occur in patients with diabetes mellitus for example, are also associated with increased risks of infection. It is logical to assume that normalising these will assist in the prevention of SSI, and recent studies have supported this. Gottrup has emphasised that the decisive period for the development of SSI is during surgery and the first few hours thereafter; consequently, the physiological status of the patient at that time is crucial.\textsuperscript{20} A higher fraction of inspired oxygen (80% compared with 30%) was associated with a 39% lower risk of SSI in a randomised controlled trial of 300 patients.\textsuperscript{21} It is believed that the mechanism of action is by more effective neutrophil killing of potential pathogens.\textsuperscript{22}

In a case-controlled study of 260 patients undergoing mastectomy, variables associated with SSI included high blood glucose levels.\textsuperscript{23} Similarly, in an assessment of risk factors for SSI after surgery for hepato-biliary pancreatic cancer, poor blood glucose levels were associated with an odds ratio of 6.6 for the development of SSI.\textsuperscript{24} Physiological homeostasis is therefore important in maintaining body defences, and inspired oxygen, controlled
blood glucose concentrations and normothermia, among other things, are important.

**Surgical practice**

Appropriate use of antimicrobial prophylaxis, i.e. during induction to ensure adequate tissue levels at the time of the first incision, is associated with reduced SSI rates, particularly with surgical procedures at high risk of infection, such as those involving the gastrointestinal tract. However, it has taken some time before best practice has been incorporated into routine protocols by surgeons and others. Recently, a statement for urological surgery incorporated important principles of appropriate surgical prophylaxis and offered sensible options in terms of the choice of antibiotics for a variety of urological procedures.25 Indications for prophylaxis are likely to increase with the complexity of surgical procedures performed, and with the increasing longevity of the patient population. For example, antibiotic prophylaxis is not usually recommended for elective clean surgical procedures such as those involving the breast. However, prophylaxis has been recommended for patients undergoing breast cancer surgery if they have had previous chemotherapy, or if the surgery involves reconstruction.26 Therefore surgeons need to liaise with others, e.g. anaesthetists, microbiologists, infectious disease physicians and others, to ensure that the correct agent is given at the right time and for the appropriate duration.

One of the major advances in surgical practice in recent decades has been the development of laparoscopic or minimally invasive surgery. This offers the potential for reducing infection as the incision site is much smaller, but it is unclear whether all other practices and the environment setting associated with open surgery should be replicated. In a survey of 150 hospitals in the UK and Ireland, 3.9–5.6% of minimally invasive surgical procedures associated with urology, e.g. transurethral prosthetic surgery, uretheric stent insertion, etc. took place in a non-ventilated room or in a treatment room with some form of ventilation, but outside a conventionally ventilated theatre.27

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**Table I** Major headings and some factors in preventing surgical site infection from recent UK and North American guidelines

<table>
<thead>
<tr>
<th>NICEa</th>
<th>SHEA/IDSAb</th>
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<tbody>
<tr>
<td><strong>Preoperative phase</strong></td>
<td>Surgical Care Improvement Project</td>
</tr>
<tr>
<td>Patient showering and hair removal</td>
<td>Proper hair removal</td>
</tr>
<tr>
<td>Patient and staff theatre wear</td>
<td>Controlling blood glucose</td>
</tr>
<tr>
<td>Movement to and from theatre area</td>
<td>Maintain normothermia</td>
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<tr>
<td>Nasal decontamination (do not use mupirocin routinely)</td>
<td>Infrastructure</td>
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<tr>
<td>Mechanical bowel preparation (not routine)</td>
<td>Trained personnel</td>
</tr>
<tr>
<td>Patient and staff jewellery</td>
<td>Education</td>
</tr>
<tr>
<td>Antibiotic prophylaxis (which patients, when and number of doses)</td>
<td>Computer-assisted decision support and automated reminders</td>
</tr>
<tr>
<td><strong>Intraoperative phase</strong></td>
<td>Antimicrobial prophylaxis</td>
</tr>
<tr>
<td>Hand decontamination</td>
<td>Measure and provide feedback on process measures, e.g. hair removal</td>
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<tr>
<td>Incise drapes</td>
<td>Accountability</td>
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<tr>
<td>Gowns and gloves</td>
<td>Chief executive responsible for support</td>
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<tr>
<td>Antiseptic skin preparation and diathermy</td>
<td>Senior management ensures adequate personnel and perform job responsibilities</td>
</tr>
<tr>
<td>Patient homeostasis (oxygenation, normothermia, etc.)</td>
<td>Healthcare workers responsible for their practices</td>
</tr>
<tr>
<td>Wound irrigation and dressings</td>
<td>Non-routine approaches</td>
</tr>
<tr>
<td>Antisepsics before closure</td>
<td>Vancomycin not routine for antimicrobial prophylaxis</td>
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<tr>
<td><strong>Postoperative phase</strong></td>
<td>Don’t delay surgery for parenteral nutrition</td>
</tr>
<tr>
<td>Dressings</td>
<td>Unresolved issues</td>
</tr>
<tr>
<td>Postoperative cleansing of surgical site</td>
<td>Preoperative bathing with chlorhexidine</td>
</tr>
<tr>
<td>Topical agents (not indicated)</td>
<td>Positive screening for, and decolonisation of, MRSA</td>
</tr>
<tr>
<td>Antibiotic treatment and debridement for SSI</td>
<td>Supplemental oxygenation for colorectal procedures</td>
</tr>
<tr>
<td>Specialist wound care services</td>
<td>Maintaining normothermia after colorectal surgery</td>
</tr>
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MRSA, meticillin-resistant *Staphylococcus aureus*; SSI, surgical site infection.

a Adapted from reference 10.
b Society for Healthcare Epidemiology of America/Infectious Diseases Society of America (adapted from reference 11).
Meta-analysis of laparoscopic compared with open repair of a perforated peptic ulcer suggests that the risk of postoperative SSI is reduced when carried out laparoscopically, and similar findings have been associated with colon surgery.28–30 Most of these procedures currently take place in a full operating theatre, but it may be that some procedures may not require the conventional ventilated theatre with appropriate air changes, air pressures and filters. Surgical factors, e.g. the necessity to convert from a laparoscopic to an open procedure if the procedure is complicated, may demand that all laparoscopic procedures are carried out in operating theatres, yet the benefits for patients from laparoscopic surgery — irrespective of where it takes place — in terms of reduced morbidity are increasingly clear.

Surgical site infection and \textit{Staphylococcus aureus}

\textit{Staphylococcus aureus} is the commonest cause of SSI and increasingly meticillin-resistant \textit{S. aureus} (MRSA) accounts for a greater proportion of infections in many hospitals throughout the world. Recommended measures to prevent MRSA will also assist in the reduction of SSI and these include screening, decontamination and glycopeptide prophylaxis.31

The role of pre-emptive mupirocin prophylaxis to the anterior nares to reduce MRSA carriage and its impact on postoperative infection has been studied in detail in recent years. This has to be balanced by the cost of mupirocin, the risk of resistance — particularly with repeated courses — and the impact on postoperative SSI. However, two recent systematic reviews and meta-analyses strongly suggest that prophylactic intranasal mupirocin significantly reduces the rate of postoperative infections including that caused by MRSA and meticillin-susceptible \textit{S. aureus} (MSSA).32,33 Nonetheless, there is a reluctance to use mupirocin in all patients but to identify those patients most at risk, i.e. those carrying \textit{S. aureus} or those undergoing certain types of surgery such as orthopaedic and cardiovascular surgery, where the consequences of postoperative infection are great.

The rapid detection of \textit{S. aureus} might potentially assist in achieving this, as only patients carrying \textit{S. aureus} would receive mupirocin prophylaxis. However, a prospective interventional cohort study on twelve surgical ward patients using PCR to detect MRSA did not lead to a reduction overall in HCAI;34 the failure of this study to demonstrate a benefit may be partly related to the local setting, where MRSA was not endemic. Alternatively, there may have been a failure of one intervention, i.e. rapid MRSA detection, to impact on what is a multifactorial process.

Converting theory to practice

Despite the scientific literature, and the publication of recommended best practice by many professional bodies, compliance with preventative measures is often suboptimal. A survey of almost 590 surgeons in Canada revealed that 63% were not in compliance with recommended guidelines on preoperative bathing, hair removal, antimicrobial prophylaxis or intraoperative skin preparation.35 The absence of full compliance indicates that infection prevention and its importance is not yet embedded in all routine surgical practice. However, studies increasingly show the potential impact of collective efforts to minimise SSI.

Enhancing compliance with best practice requires a multidisciplinary approach and ownership from all concerned. In a survey of antimicrobial prophylaxis, each surgical service was internally monitored for 30 consecutive surgical procedures with considerable educational and communication efforts to improve practice.36 Compliance on ensuring that prophylactic antibiotics were started within 60 min of surgical incision was increased from 72.25% in the first six-month period to 83.78% during the conduct of the survey.36 Nonetheless, the authors were disappointed that they did not achieve their objective of 90% compliance.

Fifty-six hospitals participated in a project to implement a quality improvement approach to decrease SSI that involved appropriate prophylactic antibiotic practice, preventing hyperglycaemia, maintaining normothermia, optimising oxygen tension and avoiding the shaving of the surgical site.37 Improvements in process measurements ranged from 3% to 27% and, during the first three months of the programme, SSI rates fell from 2.28% to 1.65%.37 Improving compliance with best practice is also possible locally.38

The introduction of healthcare bundles, incorporating validated methods and measures to prevent infection, which are rigorously policed and audited, is the way forward to decreasing SSI and other HCAIs. Such bundles can be combined with other measures to ensure the quality and safety of patient care. Eight hospitals in eight cities around the world implemented a surgical safety list that reduced mortality and inpatient complications.39 There is likely to be increasing pressure in the years ahead from patients/consumers and healthcare management/funding agencies to comply
with best practice and to demonstrate improvements in outcomes.

Discussion

SSI s are one of the commonest HCAIs and are increasingly recognised as a measure of the quality of healthcare. When benchmarking one surgeon with another or between institutions, it is important to ensure that data collected are accurate, adjusted for risk, and incorporate PDS. There is now a wealth of scientific literature and consensus recommendations regarding those measures that are important before, during and after surgery. When these are implemented in the form of healthcare bundles and involve multidisciplinary input, significant improvements can be achieved. Such improvements will be expected by patients and members of the public as part of the increasing consumerisation of healthcare. The years ahead will see better surveillance of SSI, particularly PDS. New products or devices used in patient care, e.g. application of shock wave therapy to the surgical site, are likely to be widely evaluated and some may be incorporated into routine practice. Ultimately, while there has been some progress to date, more can be done to prevent SSI by the systematic application of best practice before, during and after all surgical procedures.

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