How to reduce the risk of surgical site infection

Surgical site infections (SSIs) are an important cause of healthcare-associated infections. In the most recent prevalence survey, SSIs were the third most common type of HCAI after pneumonia and urinary tract infections, accounting for just over 15% of all infections (Public Health England, 2012) (Fig 1). However, these figures underestimate the true burden of SSI, as shorter lengths of stay mean patients are often discharged before the infections become apparent. In addition, only patients who undergo surgery can acquire an SSI, and for this group it is the most common HCAI, with an estimated prevalence of at least 5% (Smythe et al, 2008).

Most SSIs only affect the superficial subcutaneous layers of skin (Fig 2) but, less commonly, they involve the muscle and fascial layers – deep SSI (Fig 3) or the organs and other sites manipulated during the operation (organ/space SSI) (PHE, 2011). Most infections are acquired during surgical procedures, as the surface of the skin seals rapidly once the wound is closed, and is protected from infection unless an external drain is present. The three main sources of pathogens causing SSI are:

- Microbial flora on the skin and in the body of patients;
- Microbial flora (skin or mucous membranes) of operating personnel;
- The operating room environment, including airborne particles and instruments and tools used during the procedure.

Occasionally, micro-organisms released into the bloodstream from a distant infection at another site in the body, such as the urinary tract, can establish post-operative SSI by attaching to a prosthesis or other implant that has been left in the site (David and Vrahas, 2000).

Risk factors for SSI
Patients’ risk of SSI depends on a combination of factors including:

- How many micro-organisms are introduced into the surgical site;
- The number that remain when the wound is closed;
- The ability of the micro-organisms to multiply and invade tissues in the surgical site;
- The efficacy of the patient’s immune system.

(National Institute for Health and Care Excellence, 2008a).

The position of the surgical site is a key factor, as it determines the number of micro-organisms that are present and...
available to establish infection. The risk of SSI is therefore much greater for procedures on the intestines – which are already heavily colonised with bacteria, than those performed on bone – where the tissue is sterile. Table 1 illustrates the risk of SSI associated with different types of surgery: in large bowel surgery SSI is detected in 10% of patients, compared with just 0.7% in orthopaedic surgery such as hip replacement (PHE, 2014).

This difference in risk of microbial contamination is often described by a wound classification system that distinguishes clean wounds from those that involve a body tract (clean-contaminated) or have increased contamination due to traumatic injury, gastrointestinal spillage or pre-existing infection (contaminated or dirty) (PHE, 2011). Factors that are intrinsic to the patient also influence the risk of developing an SSI (Box 1).

**Morbidity and mortality**

SSIs are associated with considerable morbidity and mortality. The most common measure of adverse effects is the impact on length of hospital stay.

In the UK, Coello et al (2005) analysed a large set of data captured as part of the national SSI surveillance system and compared the length of stay for patients who developed an SSI with those who did not. They demonstrated that SSIs, regardless of severity, doubled the length of post-operative hospital stay with attributable increased costs of £1,000-6,000 per infection, depending on the type of surgery.

Other studies have confirmed the effect of SSI on length of hospital stay, and therefore costs, (Jenks et al, 2014) and also accounted for additional post-discharge costs. For example, a case-control study of patients undergoing proximal femoral fracture repair found that when repeat admissions to hospital, re-operations and other treatments are taken into account, severe SSI can quadruple the costs of care and decrease patients’ quality of life (Whitehouse et al, 2002).

SSIs also have an important, but often overlooked, impact on mortality; they have a case fatality rate of 4.5%, and 38% of these deaths are directly attributable to the SSI (Astagneau et al, 2001). In their study, Coello et al (2005) found a significant increase in in-hospital mortality associated with deep or organ-space SSI for three major categories of surgery:

» Hip prosthesis;
» Large bowel surgery;
» Vascular surgery.
Preventing SSI

While it may be difficult to reduce patients’ intrinsic risk of SSI, peri-operative practice is critical to reduce the extrinsic risk and is aimed at minimising the number of micro-organisms introduced into the surgical site. This includes:

- Removing micro-organisms that normally colonise the skin before making the incision;
- Preventing the introduction and multiplication of micro-organisms at the surgical site;
- Enhancing patients’ defences against infection;
- Preventing access of micro-organisms into the incision post-operatively (Wilson, 2013a; NICE, 2008a).

“Custom and practice” dominates surgical procedures and, while huge emphasis is often placed on ritualistic practices, many of those aimed at preventing SSIs are not underpinned by robust evidence. Some key aspects of practice to prevent SSI are outlined below.

Minimising airborne contamination

Airborne bacteria are considered to be the most important route by which micro-organisms enter a wound during surgery (Chow and Yang, 2004). The main source of airborne particles is theatre personnel, who continuously shed skin scales and fabric lint from their clothing.

The number of particles released is increased by movement and the number of people present. These particles can enter the surgical site either by falling directly into the wound or by first settling onto exposed instruments, equipment or surgeons’ hands (Hoffman et al, 2002).

Theatre ventilation systems are intended to prevent airborne particles that are carrying micro-organisms from entering the surgical wound by:

- Filtering out particles from the supplied air;
- Diluting contaminated air in the theatre (by changing the air at least 25 times per hour);
- Preventing the entry of contaminated air from outside the theatre.

The air flows from the cleanest areas (room used to lay up instruments and then the theatre itself) to the dirtiest areas (disposal room and corridors). This is achieved by creating pressure differentials, supplying air at a greater rate to clean areas and extracting it from the disposal room (Department of Health, 2007a; 2007b; Hoffman et al, 2002).

Ultra clean air (UCA) systems are often used for orthopaedic procedures, where microbial contamination of the joint and subsequent SSI can have devastating effects. These use filtered linear airflow at high pressure to reduce the concentration of airborne bacteria directly over the surgical site, although the reduction in contamination can be highly variable (Chow and Yang, 2004). Although the use of UCA for orthopaedic surgery is strongly supported in the UK, it is not considered a requirement in other countries. In addition, recent studies suggest that it actually increases the risk of SSI in orthopaedic surgery and is not cost-effective (Zheng et al, 2014; Hooper et al, 2011).

While theatre ventilation systems contribute to eliminating airborne particles, theatre staff have a key role to play in minimising contaminated airborne particles introduced to the wound by ensuring that:

- Instruments are prepared in a clean area as close to start of surgery as possible;
- Equipment brought into theatre is cleaned and free from dust;
- The number of people present in the theatre is kept to a minimum;
- Movement in and out of theatre is kept to a minimum from the time instruments are laid out until the wound is closed.

Agodi et al (2015) demonstrated that high levels of airborne bacterial contamination in operating theatres occurred during most procedures (even when UCA was used); these were correlated with the number of personnel present in the theatre and the number of times the doors were opened.

Skin preparation

Patients’ skin is an important source of microbial flora that could cause SSI, including transient micro-organisms acquired by touch that are easily removed by washing with soap, and resident flora that normally live in the skin. There is evidence that patients showering before surgery reduces the risk of SSI (NICE, 2013, 2008a; Kamel et al, 2012).

Resident flora are not removed by washing with soap but can be reduced by antiseptics. Iodine or chlorhexidine-antiseptic solutions are recommended to remove resident flora from the incision site (NICE, 2008a).

There is some evidence that alcohol-based solutions are more effective in preventing SSI than aqueous solutions and that 2% chlorhexidine-alcohol is superior to povidone-iodine (NICE, 2013; Dumville et al, 2012; Darouiche et al, 2010). Skin preparation solutions are best delivered as single-use items, because there are risks of both contamination and misuse associated with multi-use containers (NHS England, 2015).

The presence of hair at the surgical site does not increase the risk of SSI, but shaving can increase the risk of infection by causing micro-abrasions of the skin that harbor micro-organisms. Hair at the surgical site should therefore not be routinely removed; if removal is necessary to visualise the site, it should be removed on the day of the procedure using hair clippers (NICE, 2013; NICE 2008a).

Theatre clothing

Clothing worn by theatre staff has been designed to:

- Minimise the transfer of micro-organisms from the skin or mucous membranes into the wound;

MRSA is a relatively common feature of many surgical site infections.
Protect the surgical team from exposure to blood and body fluids (Health and Safety Executive, 2013). Closely woven materials, such as those used for disposable gowns and drapes, minimise the extent to which microorganisms are dispersed from the skin (Al-Hashemi et al, 2013).

Surgical masks are often the source of controversy. Their primary purpose is to prevent blood or body fluid containing the mucous membranes of the wearer’s nose and mouth; they do not protect against inhalation of airborne particles and are not classified as respiratory protective equipment. Specialist respirator masks are required for protection against the inhalation of aerosols (Coia et al, 2013). The risk of micro-organisms from the respiratory tract of staff entering the surgical site is minimal and a systematic review of randomised and quasi-randomised controlled trials comparing rates of SSI with and without the use of surgical masks found no evidence that they reduce the risk of SSI (NICE, 2013; Lipp and Edwards, 2012).

The resident flora on hands could be transferred into the wound, so the surgical team must prepare their hands with an antiseptic solution before donning sterile gowns and gloves. Alcohol-based antiseptic solutions are particularly effective at inhibiting microbial growth for several hours after application, and chlorhexidine is effective for longer periods than solutions without alcohol (WHO, 2009).

The use of two pairs of gloves significantly reduces the number of perforations to the inner glove; double-gloving has been associated with a reduced risk of SSI (Misteli et al, 2009; Tanner and Parkinson, 2006).

**Peri-operative warming**

Hypothermia is an important adverse effect of anaesthesia caused by vasodilatation and reduced thermoregulation. Evidence suggests that inadvertently reducing the body temperature to <36°C during operations is associated with increased intraoperative blood loss, morbid cardiac events and SSI (NICE, 2008b). Maintaining normothermia during surgery is, therefore, recommended and patients undergoing surgery lasting longer than 30 minutes should be actively warmed. Those at particular risk of developing hypothermia should be identified so that warming can be commenced before transfer to theatre.

Patients with at least two of the following risk factors are considered to require active warming pre-operatively:

- A score of >1 using the American Society of Anaesthesiologists’ Physical Status Classification System;
- Undergoing combined general and regional anaesthesia;
- Having intermediate or major surgery;
- At risk of cardiovascular complications;
- Pre-operative temperature of <36°C (NICE, 2008b).

Patients’ temperature should be monitored throughout surgery and when they are in recovery, and maintained >36°C; both intravenous and intracavity fluids should be warmed before use (NICE, 2008b). Active warming may be achieved through use of devices that deliver forced air or conductive heat. Although some concerns have been raised about an increase in airborne particles when forced-air warming is used in combination with UCA (Wood et al, 2014), the majority of studies have significant methodological flaws and no convincing evidence of an increased risk of SSI has been identified (Kellam et al, 2013).

**Surveillance**

Surveillance is defined as the systematic capture, reporting and dissemination of data on rates of infection. National systems that enable hospitals to benchmark their rates against a national average have been found to be associated with significant reductions in rates of SSI (Riouxf et al, 2007; Gastmeier et al, 2005).

In the UK, however, participation in surveillance of SSI focuses on mandatory requirements; in England these focus only on orthopaedic surgery. This means no data is captured for the majority of surgical procedures to inform either patients or surgical teams about the risk of SSI or quality of infection prevention.

The shorter post-operative stays for many procedures mean robust but cost-effective systems to measure SSIs occurring after discharge are required (Wilson, 2013a). The results of surveillance indicate that there is considerable variation in rates of SSI between hospitals; while some of this may be explained by differences in case mix, it also points to the fact that differences in the quality of care affect the risk of SSI (Wilson, 2013b).

Involving theatre staff in the feedback of data on rates of SSI is essential if they are to use the information to drive improvements in practice.

**The future**

Campbell et al (2008) showed that hospitals with low rates of SSI were more likely to have efficient systems that achieved 15% shorter surgery times, as well as policies to minimise traffic in the operating theatre. They were also found to have a positive safety culture, strong leadership for quality improvement, and an environment that fostered communication.

A recent UK initiative, OneTogether (joinonetogether.org), has brought together key professional groups – including the Infection Prevention Society, Association of Perioperative Practitioners, College of Operating Department Practitioners and the Royal College of Nursing in collaboration with 3M Healthcare – with

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**Table 1. Incidence of Surgical Site Infection by Surgical Category**

<table>
<thead>
<tr>
<th>Category of procedure</th>
<th>Operations (n)</th>
<th>Surgical site infection (n)</th>
<th>Infected (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal hysterectomy</td>
<td>4,512</td>
<td>65</td>
<td>1.4</td>
</tr>
<tr>
<td>Breast surgery</td>
<td>7,634</td>
<td>71</td>
<td>0.9</td>
</tr>
<tr>
<td>Cholecystectomy</td>
<td>957</td>
<td>45</td>
<td>4.7</td>
</tr>
<tr>
<td>Coronary artery bypass graft</td>
<td>30,838</td>
<td>1,400</td>
<td>4.5</td>
</tr>
<tr>
<td>Cardiac surgery</td>
<td>9,465</td>
<td>116</td>
<td>1.2</td>
</tr>
<tr>
<td>Cranial surgery</td>
<td>4,963</td>
<td>72</td>
<td>1.5</td>
</tr>
<tr>
<td>Hip prosthesis</td>
<td>180,852</td>
<td>1,246</td>
<td>0.7</td>
</tr>
<tr>
<td>Knee prosthesis</td>
<td>188,974</td>
<td>1,145</td>
<td>0.5</td>
</tr>
<tr>
<td>Large bowel surgery</td>
<td>17,924</td>
<td>1,824</td>
<td>10.2</td>
</tr>
<tr>
<td>Small bowel surgery</td>
<td>4,105</td>
<td>275</td>
<td>6.7</td>
</tr>
<tr>
<td>Spinal surgery</td>
<td>33,053</td>
<td>378</td>
<td>11</td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>7,249</td>
<td>204</td>
<td>2.8</td>
</tr>
</tbody>
</table>

the aim of supporting the implementation of best practice to prevent SSIs (Wilson et al., 2015). The partnership has demonstrated how staff have difficulties in translating evidence-based guidance into everyday practice; there is a lack of local policies and poor compliance with some aspects of guidance, fuelled by a lack of information or training, leadership and ownership (Wilson et al., 2015). This highlights the need for an increased focus on delivering high-quality care in operating theatres; OneTogether aims to support this through the development of readily accessible resources to inform and educate those staff who are working across the entire surgical pathway.

**References**


