Does glove use increase the risk of infection?

Surgical site infection: the size of the problem and strategies to prevent them

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Summary

Surgical site infections (SSI) are an important cause of healthcare associated infection (HCAI) and are associated with considerable morbidity and mortality. Although intrinsic factors in the patient, such as age, underlying illness and site of the procedure increase the risk, the quality of care delivered during the perioperative period is critical to preventing SSI. This paper explores what is known about the epidemiology and pathogenesis, and practices that are effective in reducing the risk of SSI.

The epidemiology and pathogenesis of SSI

Surgical site infections are an important cause of HCAI. In the most recent prevalence survey undertaken in the UK, they were the third most common type of HCAI after pneumonia and UTI and accounted for 15% of all infections (PHE 2012) (Figure 1). These results will underestimate the true burden, as for many types of surgery the length of time the patient spends in hospital after the procedure is very short and the patient will have already been discharged home before the SSI has become apparent. In addition, only those patients in hospital who undergo surgery can acquire an SSI, and for this subset of patients it is the most common HCAI they are at risk of and the prevalence of SSI in this group is estimated as at least 5% (Smythe et al 2006).

Surgical site infections can affect only the superficial subcutaneous layers of skin or, less commonly, involve the muscle and fascial layers (or deep SSI) or even affect the organs and other sites manipulated during the operation, (these are called organ/space SSI) (PHE 2011). Most SSI will be acquired during the operative procedure as once the wound is closed the surface of the skin seals rapidly and is protected from infection unless an external drain is present. The three main sources of pathogens that cause SSI are:

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

Occasionally, micro-organisms released into the blood stream from a distant infection at another site in the body e.g. urinary tract, can establish an SSI after the procedure by attaching to a prosthesis or other implant left in the operative site (David & Vrahas, 2000).

Risk factors for SSI

However, the risk that a patient will develop an infection depends on a combination of factors which influence how many micro-organisms are introduced into the operative site, the number that remain when the wound is closed, the ability of the micro-organisms to multiply and invade tissues in the operative site, and the efficacy of the host's immune defences against them (NICE, 2008a). The site of the body where the operation is performed is a key factor as this determines the number of microorganisms already present and available to establish infection. Thus, the risk of SSI is much greater for procedures on the intestines, which are already heavily colonised with bacteria, than

those performed on bone where the tissue is sterile. Figure 1 illustrates the risk of SSI associated with different types of surgery and is derived from data collected as part of the national SSI surveillance system in England. This shows that in large bowel surgery an SSI is detected in 10% of patients whilst in orthopaedic surgery such as hip replacement an SSI is identified in only 0.7% (Table 1). This difference in risk of microbial contamination is often described by a wound classification system which distinguishes clean wounds from those that involve a body tract (clean-contaminated), have increased contamination due to traumatic injury, gastrointestinal spillage or pre-existing infection (contaminated or dirty) (PHE 2011). Other factors intrinsic to the patient also influence the risk that they subsequently develop an SSI. Age is once of the most important factors, with many studies demonstrating that the risk of SSI steadily increases with age across different types of surgery (NICE 2008a, Mu et al 2011, PHE 2014). A study on risk factors for SSI following hip replacement demonstrated that patients over 75 years were more than 1.5 times more likely to develop SSI than those under 65 years (Ridgway et al 2005). Underlying illnesses also have a very important effect on the risk of SSI and a simple way of measuring this is by the ASA score (American Society of Anesthesiologist classification of physical status score). A score of 3 or more indicates that patients have a severe underlying disease process and this group are consistently shown to have a significantly higher risk of SSI than those with a score of 1 or 2 (Mu et al 2011, PHE 2014, Ridgeway et al 2005, NICE 2008a). Whilst other specific conditions such as diabetes also significantly increase the risk of SSI (Zhang et al 2015), the presence of these underlying conditions is also captured in the increased ASA score.

Morbidity and mortality associated with SSI

Surgical site infections are associated with considerable morbidity and mortality. The most common measure of adverse effect 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 those patient who developed an SSI with those that did not. This demonstrated that an SSI, regardless of whether it was superficial or more severe, doubled the length of post-operative hospital stay with attributable increased costs of between £1000 and £6000 per SSI depending on the type of surgery. Other studies have confirmed the effect of SSI on length of hospital stay and significant impact on 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 the quality of life of affected patients (Whitehouse et al, 2002).

SSI has an important, but often overlooked impact on mortality with a case fatality rate of 4.5% and 38% of these deaths being directly attributable to SSI (Astagneau et al, 2001). 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 (OR 2.5; 95%CL 1.3-4.5), large bowel surgery (OR 1.8; 95%CL 1.1-3.2) and vascular surgery (OR 6.8; 95%CL 3.0-15.4).

Evidence for practice to prevent SSI

Whilst it may be difficult to affect the intrinsic risk of SSI perioperative practice is critical to reduce the extrinsic risk and is aimed at minimising the number of micro-organisms introduced into the operative site. This includes practices directed at removing micro-organisms that normally colonise

the skin prior to making the incision; preventing the introduction and multiplication of micro-organisms at the operative site; enhancing the patients' defences against infection; and preventing access of micro-organisms into the incision postoperatively (NICE, 2008a, Wilson 2013a). 'Custom and practice' dominates theatre procedures and whilst huge emphasis is often placed on ritualistic practices, many of them are not underpinned on any robust evidence to demonstrate their efficacy in terms of prevention of SSI (Woodhead et al 2002). 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 microorganisms enter a wound during an operation (Chow & Yang 2004). The main source of airborne particles are theatre personnel who continuously shed skin scales and fabric lint from their clothing, with the number of particles released increased by movement and the number of people present. These particles can enter the operative site by either falling directly into the wound or by first settling onto exposed instruments equipment or surgeons hands and then being carried into the wound (Hoffman et al 2002). Theatre ventilation systems are intended to prevent airborne particles carrying micro-organisms from entering the surgical wound. This is achieved by filtering out particles from the supplied air, diluting contaminated air in the theatre (by changing the air volume in the room at least 25 times per hour) and by preventing the entry of contaminated air from outside the theatres. The flow of air is directed to ensure that it moves from the cleanest (room used to lay-up instruments and then the operating 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 (Hoffman et al 2002, Department of Health 2007). 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 operative site, although the reduction in contamination can be highly variable depending on local configuration and factors that might deflect the air flow (Chow & Yang 2004). A multicentre randomised controlled trial in the 1980s demonstrated a more than two-fold reduction in risk of deep sepsis following hip and knee replacement associated with UCA (Lidwell et al 1982). However, this study did not control for risk factors, or the use of prophylactic antibiotics, which also appeared to have a significant protective effect. Although the use of UCA for orthopaedic surgery is strongly supported in the UK, it is not considered a requirement in other countries (Miner et al 2005). Recent studies suggest that UCA actually increases rather than reduces the risk of SSI in orthopaedic surgery and their use is not cost-effective (Hooper et al 2011; Zheng et al 2014).

Whilst theatre ventilation systems contribute to eliminating airborne particles, theatre staff have a key role to play in minimising the amount of contaminated airborne particles introduced to the wound. Several aspects of 'theatre discipline' are key to this, including ensuring that instruments layed up in a clean area as close to the start of surgery as possible, that equipment brought into theatre is cleaned and free from dust, and restricting the number of people present in the theatre, and movement in and out of theatre to a minimum from the time instrument lay up start to when the wound is closed. A recent study by Agodi et al (2015) demonstrated that high levels of airborne bacterial contamination in operating theatres occurred during most procedures (even when UCA

was used), and these were correlated with the number of personnel present in the operating room and the number of times the doors were opened.

Preparation of the patients' skin

The patients' skin is an important source of microbial flora that could cause SSI including both transient microorganisms acquired by touch that are easily removed by washing with soap, and resident flora that normally live in the skin, are not removed by washing with soap but can be reduced by antiseptics. Patients should therefore shower prior to a procedure and there is some evidence that this reduces the risk of SSI (NICE 2008a, NICE 2013, Kamel et al 2012). The presence of hair at the operative site does not increase the risk of SSI and removing it can increase the risk of infection by causing micro-abrasions of the skin that harbor microorganisms. Hair at the operative site should therefore not be routinely removed, and if removal is necessary in order to visualise the site, it should be removed on the day of the procedure using hair clippers (NICE 2008a, NICE 2013). Antiseptic solutions, formulated using iodine or chlorhexidine, are recommended for preparation of the incision site in order to remove resident flora (NICE 2008a). There is some evidence that alcohol-based solutions are more effective in preventing SSI and that 2% chlorhexidine-alcohol is superior to povidone-iodine (NICE 2013, Dumville 2012, Dariouche 2010). Skin preparation solutions are best delivered as single-use items, as there are risks of both contamination and misuse associated with multi-use containers (NHS England 2015, Woodhead 2002).

Theatre personnel and clothing

Clothing worn by theatre staff is designed to minimise the transfer of micro-organisms from the skin or mucous membranes into the wound but in addition to protect the surgical team from exposure to blood and body fluids (HSE 2013). Closely woven materials such as disposable gowns and drapes minimise the extent to which micro-organisms are dispersed from the skin of the wearer (Woodhead et al 2002, Al-Hashemi et al 2013).

Surgical masks are often the source of considerable controversy, however, their primary purpose is to prevent blood or body fluid contaminating 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 to offer protection against inhalation of aerosols e.g. laser plume (Coia *et al* 2013). The risk of micro-organisms from the respiratory tract of staff entering the operative site is minimal and a recent 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 (Lipp & Edwards 2012, NICE 2013).

The resident flora on hands could be transferred into the wound, therefore the surgical team prepare their hands with an antiseptic solution prior to donning sterile gowns and gloves in order to remove this resident flora. Alcohol-based antiseptic solutions are particularly effective and chlorhexidine has the advantage of persisting on the skin over prolonged periods (WHO 2009). The use of two pairs of gloves significantly reduces the number of gloves perforations to the inner glove and double-gloving has been associated with a reduced risk of SSI (Tanner & Parkinson 2006, Mistelli et al 2009).

Perioperative warming

An important adverse effect of anaesthesia is hypothermia due to vasodilation and loss of body responses to thermoregulation. Evidence suggests that inadvertently reducing the body temperature below 36^{o}C during the operation is associated with increased intraoperative blood loss, morbid cardiac events and SSI (NICE 2008b). Maintaining normothermia perioperatively is therefore recommended in order to minimise these adverse effects. This requires that all patients who undergo a procedure lasting longer than 30 minutes should be actively warmed and those at particular risk of developing hypothermia should be identified so that warming can be commenced prior to transfer to theatre. In addition, the patients temperature should be monitored throughout the procedure and in recovery and maintained above 36^{o}C throughout the perioperative period and both IV and intra-cavity fluids 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 (Kellam et al 2013).

Surveillance of rates of SSI

Surveillance is defined as the systematic capture, reporting and dissemination of data on rates of infection and evidence for its impact on reducing rates of SSI was first published in the 1970s and comprehensively demonstrated by a large study conducted by the Centers for Disease Control in the USA (Cruse and Foord 1973, Haley et al 1980, Wilson 2013a). Rates of SSI were found to be up to 38% lower in hospitals that conducted comprehensive SSI surveillance including feedback of rates to the surgical team and involvement of an epidemiologist in generating and interpreting the rates (Haley et al 1980). National systems that enable hospitals to benchmark their rates against a national average have also been found to be associated with significant reductions in rates of SSI (Gastmeier et al 2005; Rioux et al 2007). However, in the UK participation in surveillance of SSI is largely focused on mandatory requirements, which in England are focused only on orthopaedic surgery. This means that for the majority of surgical procedures performed there is no data captured to inform either the patient or the surgical team about the risk of SSI or quality of practice to prevent infection. In addition, the length of post-operative stay is now short for many procedures and therefore robust but cost-effective systems that can measure SSI that occur after discharge are required to more accurately measure and take action in response to rates of SSI (Wilson et al 2013a). The results of surveillance indicate that there is considerable variation in rates of SSI between hospitals and whilst some of this may be explained by differences in case-mix, it also points to differences in quality of care that 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.

Conclusions

The impact of delivering high quality care in operating theatres that is directed at prevention of SSI is signposted by a study conducted in the USA on 117 hospitals contributing data to a national system conducting surveillance on post-operative complications (Campbell et al 2008). This showed that those hospitals with low rates of SSI were more likely to have efficient systems that achieved 15% shorter operation times and policies on minimising traffic in the operating room, but also a positive safety culture, strong leadership for quality improvement, and environment that fostered

communication. A recent initiative started in the UK called OneTogether has brought together key professional groups including the Infection Prevention Society, Association of Perioperative Practitioner, College of Operating Department Practitioners and Royal College of Nursing in collaboration with 3M Healthcare, with the aim of supporting the implementation of best practice to prevent SSI (Wilson et al 2015). The work of this partnership has demonstrated how staff have difficulties in translating evidence-based guidance into everyday practice, with a lack of local policies and poor compliance with some aspects of gudiance fuelled by lack of information or training, leadership and ownership (Wilson et al 2015). This highlights the clear need for an increased focus on delivering high quality care in operating theatres and OneTogether will be working to support this through the development of readily accessible resources to inform and educate staff working across the entire surgical pathway.

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Figure 1: The frequency distribution of the six most common healthcare associated infections

Source: Public Health England 2012

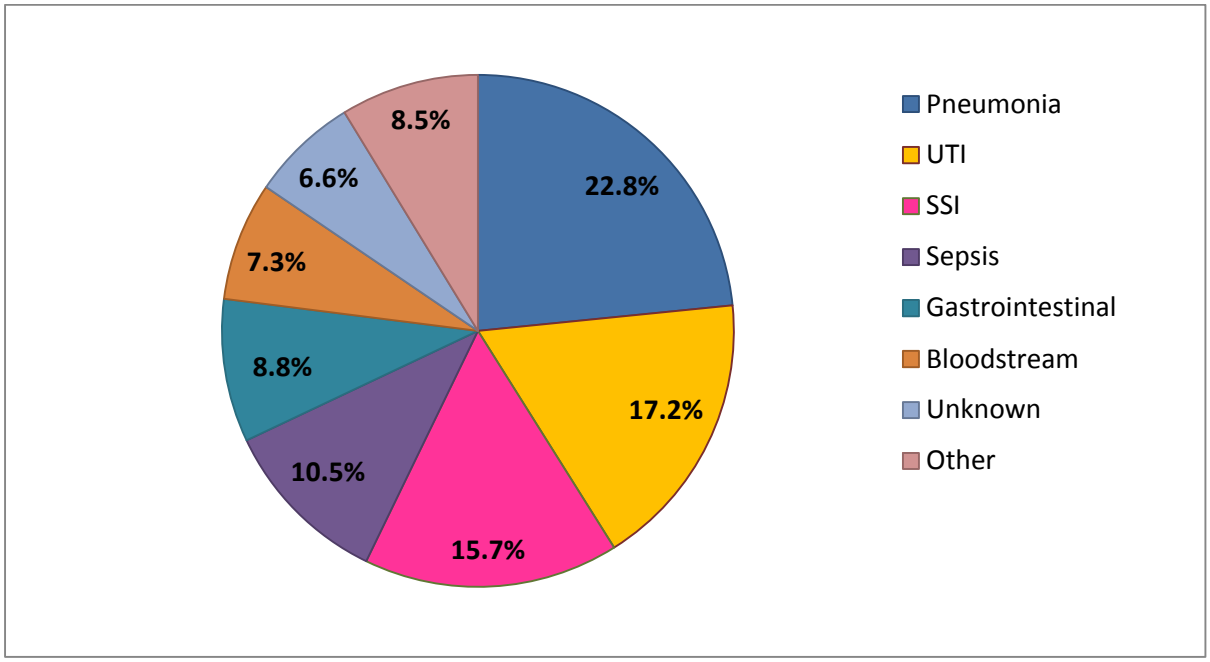

Table 1: Incidence of surgical site infection by surgical category

Source: Public Health England (2014)

Based on data captured by the Surgical Site Infection Surveillance Service in England between April 2009 and March 2014.

Category of procedure	No. operations	No. SSI*	% infected
Abdominal hysterectomy	4512	65	1.4%
Breast surgery	7634	71	0.9%
Cholecystectomy	957	45	4.7%
Coronary artery bypass graft	30,838	1400	4.5%
Cardiac surgery	9465	116	1.2%
Cranial surgery	4963	72	1.5%
Hip prosthesis	180,852	1246	0.7%
Knee prosthesis	188,974	1145	0.5%
Large bowel surgery	17,924	1824	10.2%
Small bowel surgery	4105	275	6.7%
Spinal surgery	33.053	378	1.1%
Vascular surgery	7249	204	2.8%

* Includes SSI detected during the inpatient stay or on readmission to hospital