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Meeting Report

New non-pharmaceutical Ways to reduce surgical site infections
Reykjavík, Iceland, 21–22 June 2007

Meeting report prepared by
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International symposium, Reykjavík, Iceland, 21–22 June 2007.

Surgical site infections (SSIs) are common postoperative complications that impose a high – and largely avoidable – burden of morbidity and mortality. SSIs lead to increased hospital stays or readmissions, and more hospital stays within high dependency or intensive care units (ICUs). In addition to the adverse consequences for patients' well-being, quality of life and loss of earnings, this adds substantially to healthcare costs, with increased bed occupancy the leading component cost. In current healthcare systems, where resources are often fixed or limited, the increased demand on resources by SSIs leaves fewer resources for other clinical needs.

This brief report summarizes the proceedings of a symposium on *New non-pharmaceutical ways to reduce surgical site infections*, which took place in Reykjavík, Iceland, in June 2007. This meeting brought together an international group of clinicians and researchers to review current and emerging strategies for the prevention of SSIs. Specific attention was devoted to two new approaches to help reduce SSIs:

- InteguSeal® microbial sealant; a fast-drying film-forming liquid that, when applied after typical preoperative skin preparations, forms a barrier that protects against migration of skin microbial flora into the incision
- the Kimberly-Clark Patient Warming System; an active warming system that uses water-perfused conductive thermal pads to prevent perioperative hypothermia.

Within a comprehensive programme of presentations and workshop sessions, the symposium provided a forum for detailed discussion of the current status of and future approaches to SSI, from which some important points of consensus emerged regarding:

- the definition of SSI in terms of occurrence relative to the surgical procedure
- target SSI rates that are both realistic and achievable
- Validated and discussed approaches of SSI prevention
- the process and consequences of basing assessment of surgical performance on SSI outcomes

The symposium emphasised that, despite the complexity of SSI as a pathophysiological process, there are clear opportunities to control some risk factors in order to reduce the impact of this continuing clinical problem. New effective strategies to reduce SSI are required, while some older, ritualistic aspects of surgery and surgeons should be reassessed.

SSI: a current overview

To illustrate the substantial burden of morbidity and mortality due to SSIs **Kathy Stoessel**, RN, (Clinical Education Group, Kimberly-Clark Healthcare) cited data from a comprehensive study in the USA which showed that patients with SSIs were:

- 60% more likely to enter ICU
- more than five times more likely to be rehospitalised than patients who do not develop such infections
- twice as likely to die[1]

Among current trends in surgery and healthcare, two in particular – the global increase in early discharge after surgery and the increasing use of minimally invasive surgical techniques – are affecting our ability to detect SSI, said **Dr Charlotte Owens** MD, FACOG (Global Clinical Affairs, Kimberly-Clark Healthcare). Infection can occur several weeks after surgery, often once a patient has been discharged from hospital. For patients undergoing prosthetic orthopaedic surgery, for example, infections that occur within 12 months of surgery should be considered a potential SSI. Falling SSI detection rates are reported by many hospitals, but with postoperative hospitalisation decreasing, this at least partially reflects the fact that SSIs are not occurring in the hospital. Monitoring SSIs in hospitalised patients alone thus leads to underestimation of infection rates; post-discharge surveillance should be included for valid estimation and comparison of SSI rates. Furthermore, procedures for identifying emergent SSIs after hospital discharge vary markedly. The trend for increasing use of minimally invasive surgical techniques, such as laparoscopy, not only reduce the direct risk to patients but also lead to shorter hospitalizations, and hence to a potentially decreased risk of SSI. In cholecystectomy, for example, laparoscopic procedures are associated with an SSI rate of 1.1% compared with 4% for open surgery.

Published literature has identified many factors that contribute to an increased risk of SSI. Such risk factors can be classified as endogenous (those inherent to the patient) or exogenous (those associated with surgery and the clinical setting), explained Ms Stoessel (Table 1). Because SSIs can occur following any surgical intervention, predicting who is at risk is complex. Several systems have been developed to assist in forecasting infections, one of which is the Centers for Disease Control and Prevention National Nosocomial Infections Surveillance (NNIS) system risk index.[2] The NNIS risk index scores a patient's risk according to the duration of surgery, wound characteristics and physical status. Patients at higher risk include those with severe systemic disease or who require the surgery in order to secure survival, those undergoing contaminated or dirty/infected wound surgery, and those who undergo a longer than accepted duration of operation.

Table 1. Risk factors associated with patients and surgery that influence the occurrence of SSI.

Endogenous (patient-related) risk factors	Exogenous (surgery-related) risk factors
■ Extremes of age (the elderly and neonates) ■ Alcoholism ■ Altered immune response – disease, e.g. HIV, or medication, e.g. chronic corticosteroid use ■ Previous colonisation with microorganisms ■ Concurrent disease status – renal failure, diabetes mellitus ■ Hypoglycaemia ■ Hypothermia ■ Length of preoperative stay ■ Obesity ■ Poor nutrition or physical status ■ Previous radiotherapy or chemotherapy ■ Remote site infection ■ Skin disease ■ Smoking and use of tobacco products	■ Contaminated/dirty surgical procedure or poor surgical instrument processing ■ Duration of operation ■ Duration of surgical scrub ■ Excessive movement of staff ■ Foreign material in surgical site ■ Inadequate staffing levels ■ Staff with skin infections ■ Surgical classification ■ Surgical drains ■ Surgical technique ■ Transplant or implant operations

Current strategies to reduce risk

Current strategies for the prevention of SSIs include measures aimed at pathogen control and improving the patient's defences against infection. Some endogenous risk factors for SSIs, such as diabetes and renal failure, are manageable, whereas others may be more problematic. In some cases, for example, it may be feasible to defer surgery in obese patients until an adequate weight loss has been achieved. However, lifestyle modifications such as weight loss or smoking cessation are difficult for many patients. Most, if not all, exogenous risk factors for SSIs are controllable.

The ability to control intraoperative risk factors depends largely on the duration of the procedure, and hence on surgical technique. Some studies have shown evidence that one of the most important intraoperative risk factors for SSIs is the individual surgeon.[3-5] [References to be confirmed] Risk factors that are particularly important intraoperatively include temperature, glycaemia and the degree of oxygenation. A number of temperature management systems are available, while the degree of oxygenation can be controlled by the anaesthetist. There is evidence that mortality related to SSIs decreases when glycaemia is adequately controlled during surgery, and the use of insulin in non-diabetic patients, such as transplant recipients, may be beneficial under certain circumstances. Risk factors such as glycaemia, oxygenation, temperature and bleeding also operate after surgery, and again are readily controllable.

Prevention of SSIs is complex and effective risk reduction will require a multimodal approach, emphasised Ms Stoessel, with attention to multiple patient-related and exogenous risk factors. A number of studies have reported significant reductions in SSI rates during periods of up to 2 years following implementation of such approaches.[6-12]

Guidelines for the prevention of SSIs have been published by the US Center for Disease Control (CDC)[2] noted Dr Owens. These address patient-related risk factors such as diabetes, tobacco use and malnutrition, procedure-related risk factors in the preoperative, intraoperative and postoperative settings, and SSI surveillance (Table 2). They include category 1A recommendations (i.e. strong recommendations based on well designed experimental, clinical or epidemiological studies) for the following interventions:

- identification and treatment of all infections remote to the surgical site prior to elective surgery
- removal of hair around the incision site (preferably with electric clippers) only if it is likely to interfere with the operation
- the use of prophylactic intravenous antimicrobial treatment, the choice of agent being based on the most common pathogens implicated in SSIs for a specific operation and published recommendations
- adherence to principles of asepsis when placing intravascular devices such as central venous catheters
- Other recommendations based on limited experimental evidence and a sound theoretical rationale include:
- control of blood glucose, and avoidance of perioperative hyperglycaemia, in diabetic patients
- requiring patients to shower or bathe with an antiseptic agent on at least the night before surgery
- thorough washing and cleaning around the incision site to remove gross contamination before applying an appropriate antiseptic skin preparation
- educating surgical personnel to report signs or symptoms of infectious disease promptly, and development of appropriate policies to manage such personnel
- attention to good surgical technique and appropriate postoperative wound care

Table 2. CDC guidelines for SSI risk reduction.[2]

Preoperative	**Intraoperative**
■ Patient preparation ■ showering ■ hair removal (clipping) if necessary ■ skin preparation ■ hand/arm antisepsis for surgical team members ■ Management of infected or colonized surgical personnel ■ Antimicrobial prophylaxis	■ Operating theatre ventilation ■ Cleaning of environmental surfaces ■ Full sterilization of surgical instruments (flash sterilization should be used only in emergencies) ■ Use of scrub suits, masks and gloves ■ Use of surgical drapes ■ Rigorous adherence to asepsis principles ■ Attention to good surgical technique ■ Prevention of hypothermia
Postoperative	**Intraoperative**
■ Incision care ■ Discharge planning	■ Surveillance ■ Record variables known to be associated with increased SSI risk (e.g. surgical wound class, duration of operation, etc.) ■ Report operation-specific SSI rates to surgical team members

Reducing bacterial contamination with InteguSeal®

InteguSeal® is a cyanoacrylate-based skin sealant that forms a film and bonds to the skin, sealing off micro-spaces to immobilize surviving bacteria and hence preventing their migration into the incision, explained **Casey Dusenbery** BSc (Research & Development, Kimberly-Clark Healthcare). Importantly, InteguSeal® flows into irregular surfaces in the skin to mechanically trap bacteria. In addition it is a breathable barrier, thereby preventing the 'greenhouse' effect that results in bacterial regrowth in micro-spaces (Figure 1). Thus, InteguSeal® reduces the risk of wound bacterial contamination of the wound during surgery.

Figure 1. The sealing effect of InteguSeal® traps surviving bacteria to prevent its migration into the wound. Because it is breathable, it prevents the 'greenhouse' effect that can result in bacterial regrowth in microspaces.

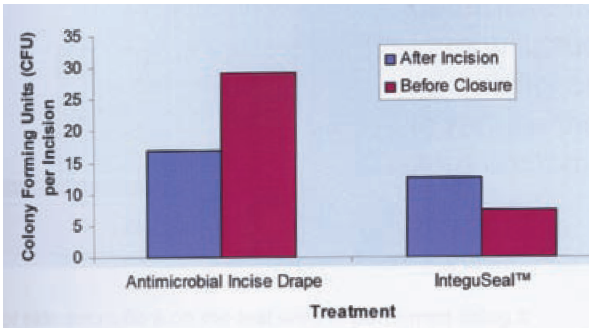

Figure 2. Bacterial recovery of the wound in vivo was significantly lower with InteguSeal® than with an antimicrobial incise drape.

Initial in *vitro* studies showed that InteguSeal® significantly reduced the recovery of potential pathogens such as *S. epidermidis*, MRSA, and *Escherichia coli*. This finding was confirmed in a subsequent in *vivo* study, which compared the effect of InteguSeal® and an antimicrobial incise drape on bacterial recovery in a porcine model following incision and prolonged manipulation to simulate surgical procedures. The number of colony forming units isolated from the wound was significantly lower with InteguSeal® than with the antimicrobial drape, both following the initial incision and immediately prior to wound closure, said **Professor Samuel Wilson** (University of California, USA) (Figure 2). A further in *vivo* study, using a cup scrub technique, compared the ability of InteguSeal® and aqueous povidone iodine to reduce bacterial contamination of human skin. InteguSeal® produced significantly greater reductions in bacterial counts than povidone iodine at both 4 and 24 hours after application; concomitant application of InteguSeal® and povidone iodine resulted in a greater decrease at 24 hours than either agent alone. Importantly, in in *vitro* studies InteguSeal® had no significant effect on water vapour transmission rate, in contrast to either antimicrobial or non-antimicrobial incise drapes. Thus, InteguSeal® allows normal skin transpiration.

The importance of controlling likely pathogens

Large numbers of commensal organisms – chiefly micrococci (Staphylococcus epidermidis and Micrococcus spp.) and corynebacteria – inhabit the skin and play an important role in preventing colonization by potential pathogens. Skin-borne bacteria are also, however, an important factor in the pathogenesis of SSIs, said **Professor John Fairclough**, Llandough Hospital, Cardiff, UK. Even with optimal preparation of the surgical site, not all of the patient's endogenous bacteria are removed from the skin and recolonisation of the skin occurs within 30 minutes, irrespective of how the skin is prepared.[13] Many of the remaining bacteria will be sufficiently deep in the pores that they pose little risk of infection; however, a significant proportion will migrate to the surface and contaminate the wound. Indeed, most surgical wounds show some evidence of contamination. It is therefore important to use a non-occlusive cover wherever possible that will allow evaporation of moisture but prevent bacteria from multiplying, said Professor Fairclough. New technologies, such as microbial sealants should also be evaluated and used as appropriate.

Clinical experience with InteguSeal®

Presenting the results of a clinical trial with InteguSeal® involving 177 patients who were undergoing open inguinal hernia repair, Professor Wilson explained that this procedure was chosen because hernia repair is one of the most commonly performed operations, the inguinal area is more difficult to prepare for sterility, application of an adhesive drape is difficult because of the inguinal skin fold and hernia repair is associated with a small but clinically significant number of SSIs. The primary objective of the study was to compare the effect of InteguSeal® and control treatment (10% povidone iodine) on wound contamination (defined as bacterial counts > 0). The proportion of patients with wound contamination was significantly lower in the InteguSeal® group than in the control group (16% difference, P=0.04). InteguSeal® microbial sealant significantly reduces surgical wound bacterial contamination when used in conjunction with 10% povidone iodine skin preparation, compared to povidone iodine alone. This reduction in contamination is evident at the start of surgery and persists through the length of the operation, noted Professor Wilson. Furthermore, reductions in wound contamination were seen with InteguSeal® irrespective of the use of prophylactic antibiotics and hair removal by clipping. The operating surgeons rated InteguSeal® highly with respect to:

- ease of application
- ability to incise, suture or staple through it
- visualization of surgical markers
- visualization of InteguSeal®

InteguSeal® offers a number of advantages in clinical practice (Table 3). Marketing feedback from 44 surgeons in seven countries has been highly positive:

- 95% stated that cost is not an issue
- 75% believed that the current lack of clinical data is not a concern
- 66% found InteguSeal® easy to use

Table 3. Key clinical benefits of InteguSeal®.

Safety	Ease of use
■ Non-irritant ■ Non-cytotoxic ■ Does not sensitize skin ■ Does not induce local toxic effects following 4 weeks of implantation ■ Non-clastogenic ■ Non-mutagenic ■ No acute systemic toxicity	■ Easy to apply ■ Can be used with a variety of surgical preparation solutions ■ Dries quickly ■ Works with electrocautery, defibrillation, sutures, staples, and wound closure adhesives such as Dermabond® ■ No need to remove InteguSeal®, even for wound closure

Improved patient outcomes through better perioperative temperature control

Mild hypothermia, defined as a decrease in core body temperature of up to 2°C below normal, is common and occurs in 45%–60% of patients undergoing surgery, irrespective of the type or duration of procedure, said **Dr Dheeraj Mehta** (University Hospital of Wales, Cardiff). Before describing his experience of intraoperative temperature control in off-pump coronary artery bypass (OPCAB) surgery, Dr Mehta reviewed the range of adverse consequences of non-intentional perioperative hypothermia, which include:

- increased blood loss due to impairment of platelet function and decreased activation of coagulation[14]
- increased cardiac events, including myocardial ischaemia15 and early post-operative cardiac complications[16]
- prolongation of action of anaesthetic agents, leading to reduced drug clearance[17,18] and delayed postanaesthetic recovery[19]
- increased risk of wound infection[20] due to impairment of cell- and antibody-mediated immune responses, including:
    - decreased migration of polymorphonuclear cells, reduced superoxide production and reduced oxidative bacterial killing by neutrophils[21,22]
    - reduced NK-cell activity and production of cell-mediated antibodies and immunity-promoting cytokines[23,24]
    - reduced subcutaneous oxygen tension due thermoregulatory vasoconstriction impairs oxidative killing by neutrophils and inhibits oxygen and nitroso free radical production[25]
    - impaired collagen synthesis[26]

The induction of anaesthesia is the key factor responsible for the initial drop in temperature in surgical patients, with inhalational and intravenous anaesthetic agents producing a dose-dependent inhibition of thermoregulation. Peripheral vasodilatation follows induction, and the net effect of anaesthesia is a redistribution of body heat from core to periphery. Further heat loss to the environment follows, with patients losing heat through convection, conduction, evaporation and evaporation throughout the surgical procedure. The same basic processes can be used to transfer energy back to the patient and are exploited in variety of invasive and non-invasive approaches to patient warming (Figure 3). Immersing the patient in warm water is probably the most efficient of these approaches, although clearly impractical as part of surgical practice. The choice of transfer medium is important; water is able to carry 3300 times more heat than the same volume of air and is 1500-fold more thermally conductive than that of air.

The Kimberly-Clark Patient Warming System One is a water-based system that uses thermal pads placed in contact with the patient. The innermost layer of direct conduction hydrogel is most important part of the 3-layer pad (Figure 4). The biocompatible 'skin-friendly' hydrogel is 50% water, which results in efficient energy transfer from the overlying layer of circulating warm water. In cardiac surgery patients, there is limited body surface available for conventional forced air warming devices. An important advantage of this system is that the thermal pads are applied to the dorsum of the thorax and do not interfere with the operative field.

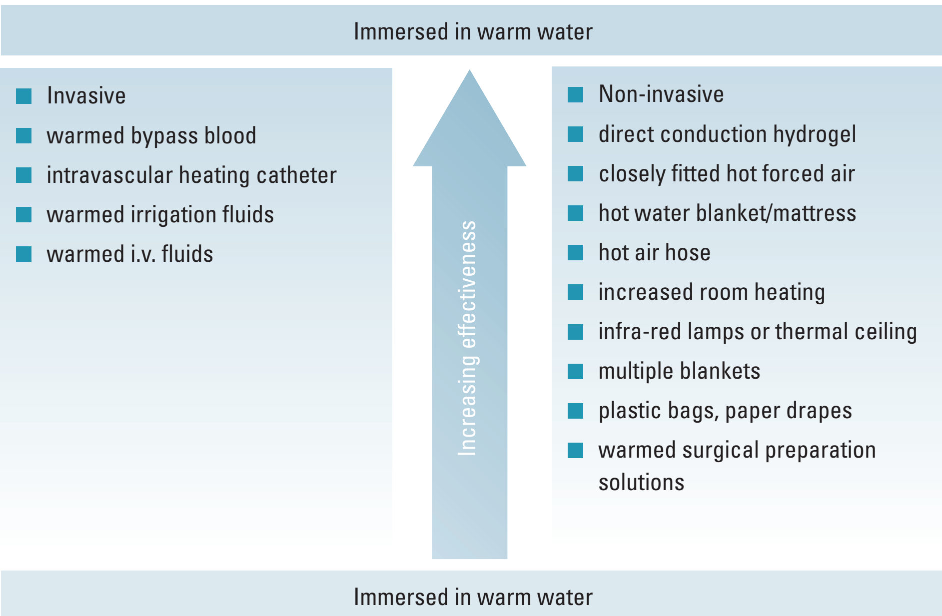

Figure 3. A variety of approaches, both invasive and non-invasive and of differing effectiveness, are available for perioperative patient warming.

Maintaining normothermia has been shown to have several beneficial effects, including:

- lower plasma troponin I and risk of myocardial injury[27,28]
- improved cardiac function[29]
- lower inflammatory response[28]
- less perioperative blood loss and transfusion requirement[30-32]
- reduced intubation time[32]
- less risk of post-operative wound infection[26]
- shorter ICU and hospital stays[32]
- less postoperative mortality[30]

Adding to the extensive data from completed clinical trials of the Kimberly-Clark Patient Warming System (which was previously known as the Artic Sun™ patient warming system in the USA), the University Hospital of Wales recently evaluated this system in OPCAB surgery. All patients studied were normothermic when assessed in the ICU, noted Dr Mehta. In contrast, all those patients using a conventional forced-air warming system were hypothermic on entering the ICU (Figure 5). In OPCAB surgery, normothermia is thus an achievable objective and has demonstrable benefits in outcome.

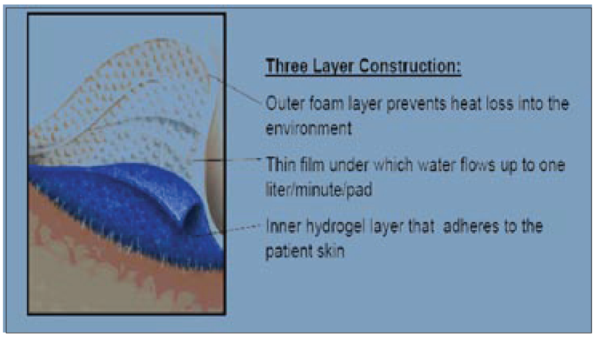

Figure 4. The three-layer composition of the thermal pads in the Kimberly-Clark Patient Warming System achieves efficient energy transfer with high patient comfort and skin compatibility.

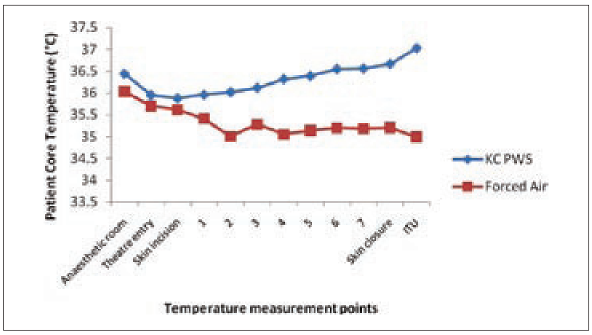

Figure 5. Mean core temperature of patients undergoing off-pump coronary artery bypass graft surgery who received active warming with the Kimberly-Clark Patient Warming System (K-C PWS) or a conventional forced-air system from induction of anaesthesia through to extubation.

Tackling SSI: unmet needs and what should change

The development of SSI is a complex pathophysiological process, dependent on many factors related to the patient, clinical setting, and type and site of surgical procedure. All delegates agreed that, while the goal for SSI rate should ideally be zero, confounding factors such as age, disease status and type of surgery mean this may not be a realistic target. Similarly, defining one figure across all surgery was considered to be misleading and potentially unhelpful. Overall, across a range of surgery types delegates believed that an SSI rate of 0.7% to 1% should be realistic. The increasing use of minimally invasive and day-care surgery is leading to shorter hospitalizations, and hence to a potentially decreased risk of SSI, but procedures for identifying emergent SSIs after hospital discharge vary markedly. As a result, in many countries there is a need to improve follow-up procedures, and a wider need for standardisation of protocols for patient evaluation, risk assessment, and data collection.

Most delegates accepted that SSI can occur days or weeks after surgery, and that in prosthetic surgery the possibility of an SSI should be considered up to one year after surgery. Defining an SSI as an infection that occurs within the first few weeks post-surgery was recognised as arbitrary, but delegates recognised the need for such a definition as part of a comprehensive risk assessment programme.

Delegates agreed strongly that there were factors they could control in order to reduce SSI and that surgical performance was important with respect to SSI, but measures of this could only be meaningful once data collection and audit mechanisms within units, regions and countries are synchronized and controlled. Once standards can be drawn on a national level, individual units, even individual surgeons, can gauge their performance against these standards. The National Surgical Quality Improvement Program, instigated by the US Department for Veterans Affairs over 15 years ago, provides a working example of such a system.

Delegates felt that basing performance on SSI outcomes would be damaging to patients because surgeons would then tend to avoid patients and/or procedures with a higher risk of SSI that would be more likely to detract from their perceived performance and consequent reduction in their performance-related reward. Participants from several countries commented that as a result of media coverage patients' expectations are often unrealistically high, and hence the occurrence of a SSI is perceived as a surgical or institutional failure. A further unmet need is for improved education of both healthcare administrators and patients about the multiple causes of SSIs and what can realistically be expected in terms of preventing such infections.

With SSI continuing to present a significant burden for patients and healthcare services, there is a need to implement new effective risk reduction strategies. New technologies should be adopted once these have been evaluated. Cost considerations need not inhibit such developments, because the cost savings resulting from preventing one SSI will almost certainly outweigh the costs of any new technology. Ritualistic aspects of surgery and surgeons should be reviewed and questioned, although the concept of eliminating the clinical problem of SSI altogether remains ambitious.

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