Swedish operating room nurses' preventive interventions to reduce bacterial growth and surgical site infections, and to increase comfort in patients undergoing surgery
To

My family
Swedish operating room nurses' preventive interventions to reduce bacterial growth and surgical site infections, and to increase comfort in patients undergoing surgery
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Abstract

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Surgical site infection is a major postoperative complication that causes patient suffering and is costly for society. The general aim of this thesis was to test and describe interventions performed by operating room (OR) nurses to prevent bacterial growth in surgical patients, with the intent to prevent surgical site infections (SSIs) whilst increase patients comfort.

In studies I and II, 220 pacemaker patients were tested to compare preheated skin disinfection with room-temperature skin disinfection regarding bacterial growth, skin temperature and patient experience. Preheated skin disinfection was not less effective compared to room-temperature skin disinfection in reducing bacterial growth after skin disinfection and there were no differences regarding SSIs three month postoperatively. Preheated skin disinfection reduces skin heat loss and was perceived as more pleasant compared to room-temperature skin disinfection.

In study III, 12 OR nurses were examined regarding bacterial growth on their hands and at the sterile glove cuff end after surgical hand disinfection and again after wearing sterile surgical gloves during surgery. They were compared with a control group of 13 non-health care workers. OR nurses’ hands had higher amounts of bacterial growth at two of three culture sites after surgical hand disinfection compared with the control group, and the bacterial growth increased in both groups with time during surgery. There seems to be a risk of bacterial growth at the glove cuff end during surgery, involving the same type of bacteria as isolated from the hands.

In study IV, 890 OR nurses answered an online questionnaire describing OR nurses interventions guided by national guidelines to reduce SSIs, such as preparation of the patient skin, patient temperature, and OR materials used. The proportion of the OR nurses who complied with the national guidelines preventive interventions was high: skin disinfection solution (93.5%), drapes (97.4%) and gowns (83.8%), and double gloves (73%). However, when guidelines were lacking the interventions differed.

Keywords: skin disinfection, patient experience, skin temperature, intra-operative, surgical site infection, bacterial growth, recolonization.

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<td>Bacteria isolated from cultures</td>
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<td>C</td>
<td>Celsius</td>
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<tr>
<td>CI</td>
<td>Confidence interval</td>
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<td>CDC</td>
<td>Centers for Disease Control and Prevention (USA)</td>
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<td>CDS</td>
<td>Cold Discomfort Scale</td>
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<tr>
<td>CFU</td>
<td>Colony-forming units</td>
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<tr>
<td>Commensal bacteria</td>
<td>Symbiotic relationship between two populations without harm to each other</td>
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<td>CoNS</td>
<td>Coagulase-negative staphylococci</td>
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<td>Contamination</td>
<td>Bacterial contamination of otherwise sterile area</td>
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<td>CRT</td>
<td>Cardiac resynchronization therapy</td>
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<td>DDD</td>
<td>Dual chamber rate adaptive pacemaker</td>
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<td>HCW</td>
<td>Health care worker</td>
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<td>HLR</td>
<td>Heart and lung resuscitation</td>
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<td>ICD</td>
<td>Implantable cardioverter–defibrillator</td>
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<td>IQR</td>
<td>Interquartile range</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
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<tr>
<td>NICE</td>
<td>National Institute for Health and Care Excellence (UK)</td>
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<tr>
<td>NRS</td>
<td>Numerical rating scale</td>
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<tr>
<td>OR</td>
<td>Operating room</td>
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<tr>
<td>Recolonization</td>
<td>Bacterial regrowth after skin disinfection</td>
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<tr>
<td>RCT</td>
<td>Randomized controlled trial</td>
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<tr>
<td>Resident bacteria</td>
<td>Bacteria living in a specific area of the body</td>
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<tr>
<td>SSI</td>
<td>Surgical site infection</td>
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<tr>
<td>Transient bacteria</td>
<td>Bacteria temporarily living on the skin surface</td>
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<tr>
<td>VAS</td>
<td>Visual analogue scale</td>
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<tr>
<td>VVI</td>
<td>Single ventricular rate adaptive pacemaker</td>
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List of original papers

This thesis is based on the following original papers, which will be referred to by their Roman numerals:


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Preface

When I began to work as an operating room (OR) nurse, I struggled to keep myself and my surroundings as sterile as possible. It is demanding to maintain a high hygiene standard, especially when bacteria are invisible to the human eye. One of the responsibilities of OR nurses is to provide the best possible care for the patient to prevent suffering and complications. The patient is surrounded with a surgical team, each with their own perspective of what constitutes the best possible outcome for the patient. My perspective and/or work involve many preventive interventions to reduce surgical site infections (SSIs) in the patient. Of these many preventive interventions, one is preparing the skin of the patient. The skin of the patient is routinely disinfected directly prior to surgery. It was when I first performed the skin disinfection on a patient who was awake that I realized that the skin disinfection process felt uncomfortably cold for the patient. The question “why don’t we preheat the solution?” was the starting point for this dissertation, and immediately thereafter, “is it as effective and safe for the patient?”
Background

Patient safety
Patient safety, threatened by health care-associated infections, is of international concern.\textsuperscript{1} With emerging antibiotic resistance, it is important to find safe preventive interventions for the patients undergoing surgery.\textsuperscript{2-5} Compliance with several interventions is needed to provide optimal care and safety for the patient. The evidence-based national guidelines for health care can be found in the online Handbook for Healthcare.\textsuperscript{6} SSI is a patient injury which should be prevented, and a report from the Swedish Association of local Authorities and Regions showed that among nosocomial infections, the third most common infection was SSIs.\textsuperscript{7} Swedish law regarding patient safety (2010:659) states that health care workers (HCWs) should lead and control the activity in such a way that good care is sustained and should also provide needed interventions to prevent patient injury.\textsuperscript{8} There are many strategies to prevent SSIs at the operating departments, such as following care bundles, which provide for correct administration of, for example, antibiotics, and for correct hair removal, preservation of normothermia, and correct skin disinfection.\textsuperscript{9} Moreover, the Handbook for Healthcare guides the HCW to use the right strategies and interventions to minimize bacterial contamination in the surgical patient during surgery, such as employing basic hygiene procedures, controlled OR ventilation, sterile material, and preoperative skin preparation of patients and of hands of the HCWs.\textsuperscript{6}

OR nurses
Internationally, there are differences concerning which profession is responsible for preparing the patient with respect to hygienic procedures such as skin disinfection at the OR. It may be nurses with different educational levels, or it may be the surgeon. In Sweden, it is the OR nurse who prepares the patient for the surgical procedure at the OR. This does not include any part of the patient anaesthesia, which is performed by the team of anaesthesiologists and nurse anaesthetists. In Sweden, OR nurses have a minimum of four years of education, comprising three years to achieve a nursing degree, which includes a bachelor’s degree, followed by one year of postgraduate education at an advanced level directed towards OR care. OR nurses’ procedures are designed to provide a secure environment for the patient, which includes ensuring a hygienic, aseptic
environment; preparing the patient skin; draping; maintaining body
temperature; caring for the instruments; and fulfilling assistance and
circulation roles (i.e. non-sterile person assisting the sterile surgical
team).10, 11

Surgical site infection
SSIs are the third most common among hospital-acquired infections in
Sweden, which is in concordance with data from the United Kingdom7, 12
The probability of acquiring an SSI in general is approximately 10%, with
variations depending on surgical specialties and registration.13, 14 Surgical
wounds are classified by different sources of expected contamination. The
four-graded classification is class I, clean; class II, clean–contaminated;
class III, contaminated; and class IV, dirty–infected.15 The classification is
often associated with the proportion of SSIs.14, 16 Cardiac device
implantation is classified as clean surgery, and the incidence of SSI is
approximately 1%,17, 18 and according to the Swedish pacemaker registry
for 2015, about 0.6%.19 It is difficult to assess additional costs for SSIs.
Depending on the location of the SSI, a severe SSI might be one that
occurs after open heart surgery, where a deep sternal infection can double
or even triple the usual cost of treatment.20-22 For example, the additional
mean cost for treatment of a deep sternal infection in Örebro (Sweden) in
2006 was calculated to be approximately 130,000 SEK (14,481 EUR).23
To produce an accurate description of SSIs, it is crucial to use consistent
criteria for diagnosis of SSIs, and today the definition of SSI most
frequently referred to in the literature is that of the U.S. Centers for
Disease Control (CDC).15 The CDC’s criteria for SSIs are divided into
three main classifications, such as superficial incisional SSI, deep incisional
SSI, and organ/space SSI. A common criterion is that the SSI occur within
30 days, or within one year, if an implant is in place.15

Many SSIs are caused by the commensal skin flora, such as coagulase-
negative staphylococci (CoNS),24-26 which are the microorganisms that are
the most difficult to reduce by skin disinfection; hence, they inhabit the
lower level of the skin such as in the hair follicles and sebaceous glands.13,
27 These microorganisms are often slow growing and are often seen in SSIs
when foreign materials are implanted or when the patient has a depressed
immune defence. If the skin or wound is contaminated by virulent
Staphylococcus aureus, then all individuals are at risk of acquiring an
SSI.4, 13, 18, 28 Other risk factors for SSIs are surgical technique and patient
characteristics. Moreover, the type of surgical procedure influences the
risk for SSI, depending on the use of diathermy, and on drainage, foreign material, surgical classification, and haematoma. During anaesthesia, the timing is crucial regarding antibiotic administration and maintaining patient body temperature. The patient may have risk factors such as diabetes, obesity, high age, malnutrition, smoking, eczema, and so forth.15

**The human skin flora**

The skin is an organ that among other things protects the tissue and organs inside the body from the outside environment. Bacteria inhabiting the skin are involved in protecting and maintaining a healthy skin barrier.29 Bacteria found on the human skin are divided into two groups, transient and resident bacteria. The resident bacteria are present permanently, while the transient bacteria more frequently move between humans. The microorganisms that are transient are more easily removed than the resident ones, which always are present in the host. Under normal circumstances, the transient bacteria are unable to persist on the skin for a longer time due to competition from the resident bacteria.29 The most abundant microorganisms on the human skin are mainly CoNS, Corynebacterium, and Propionibacterium acnes.30, 31 Bacteria can be found at different levels of the skin. Many colonize the skin surface, but bacteria also inhabit deeper layers of the skin, in hair follicles and sebaceous glands.30, 32 The density of microorganisms is higher on sebaceous-rich and moist skin sites, and the total number of aerobic bacteria found on the skin can vary from $10^2$ cells/cm² at the arm site to $10^7$ cells/cm² at the arm pit.33, 34 Anaerobic bacteria are mostly present at sebaceous-rich areas and nearly absent at other more dry areas such as legs and arms.33 The body site that holds the highest microbial density is the axilla, followed by the cranium, sole of foot, forehead, upper back, subclavia, lumbar area, arm, lower back, chest, deltoid area, leg, palm, abdomen, and dorsum of foot.35 Skin with eczema or other diseases has been shown to be heavily colonized with *S. aureus*.36 Looking at the healthy skin flora, there are some differences between genders and individuals. Men tend to have higher counts of microorganisms compared with women.35, 37, 38 Men shed colony-forming units (CFU/m³) up to seven times more compared to women.39 Individuals within each gender also differ, but the flora of the same individuals appears to be constant.31, 38, 40
Bacteria
The human skin is predominately colonized by *Staphylococcus*, *Corynebacterium*, and *Propionibacterium*. The most common microorganisms that cause SSIs in cardiac patients are *S. aureus*, CoNS, and Gram-negative bacteria. Different factors will determine whether particular bacteria will cause an infection, such as how, and how much, bacteria come in contact with the host, and the virulence of the specific bacteria. The virulence of the bacteria is defined by the ability to cause an infection even in low numbers. These two factors together with the host defences are important when calculating the risk of acquiring SSIs. The risk of acquiring an SSI is higher with a large contamination by virulent bacteria together with an immune-compromised host. Some bacteria can multiply every 20 minutes, such that in a favourable environment one bacterium can multiply up to as many as 32,768 after five hours, while others only divide once a day.

Staphylococci
The genus *Staphylococcus* consists of more than 40 different species and about 20 subspecies. The distribution of *Staphylococcus* on the human skin consists mainly of *S. epidermidis* and *S. hominis*, followed by *S. haemolyticus*, *S. capitis*, and *S. aureus*. The distribution of staphylococci is somewhat different. *S. aureus* are mostly found in the nares. Microscopically, staphylococci resemble clusters of grapes and they are Gram-positive cocci. Species identification has been made by colony morphology, coagulase and DNase test, and other biochemical tests, predominantly API kits. Since the introduction of MALDI-TOF MS, this method has replaced all other routine methods at the clinical microbiological laboratories, since it provides a rapid, cheap, and reliable method for determination of staphylococci to species level. On agar plates *S. aureus* appear as yellow opaque colonies, compared with CoNS, which have white to grey colonies. Staphylococci are mainly divided into the two groups coagulase-positive and coagulase-negative staphylococci. This separation is of clinical interest because *S. aureus* (coagulase-positive) is one of the most important and virulent pathogens causing SSIs in humans. *S. aureus* is often a transient bacterium but may also be a resident bacterium that can colonize nares and axillae, and does so, comprising up to 30% of the population. It has been shown that the carriers of *S. aureus* who acquire bacteraemia, mostly is caused by endogenous strains. *S. aureus* causes, in addition to SSIs, a broad
spectrum of infection such as impetigo, endocarditis, scaled skin syndrome, urinary tract infections, toxic shock syndrome, and sepsis.\textsuperscript{48} \textit{S. aureus} protects itself with different toxins and enzymes, together with the ability to form biofilm. \textit{S. aureus} evades the host neutrophil and macrophage responses by using biofilm and avoiding destruction by phagocytosis.\textsuperscript{51, 52} \textit{S. aureus} seem to be able to adhere and hide intracellularly, and thereby be protected from host defence mechanisms.\textsuperscript{47}

Of the human resident staphylococci, the majority is \textit{S. epidermidis}, which exists nearly everywhere on the human skin and is thought to be mutualistic for skin health and protective for colonization of pathogens.\textsuperscript{53} \textit{S. epidermidis} binds to specific receptors that inhibit the adherence of the pathogenic \textit{S. aureus}.\textsuperscript{54} \textit{S. epidermidis} are particularly present at moist areas such as anterior nares, axillae, toe webs, and the inguinal area.\textsuperscript{46} An important virulence factor of CoNS is their ability to produce biofilm.\textsuperscript{55} Other less common \textit{staphylococcus} is \textit{Staphylococcus hominis} which is mostly found at the axillae, head, legs, and arms. \textit{Staphylococcus capitis} are mostly found at the head and arms. \textit{Staphylococcus warneri} that is only occasionally isolated from the skin.\textsuperscript{31}

\textit{Propionibacterium acnes}

\textit{P. acnes} are gram-positive facultative anaerobic rods and are considered to be commensal bacteria and mutualistic bacteria. These bacteria are slow-growing bacteria that can be missed if they are not cultured for a longer time.\textsuperscript{56, 57} Cultured on agar plates, the colonies appears circular, with size 1 to 2 mm in diameter, glistening and opaque.\textsuperscript{56} \textit{P. acnes} release protective fatty acids which inhibit the growth of the pathogenic \textit{Streptococcus pyogenes}.\textsuperscript{41, 56, 58} \textit{P. acnes} are mostly known for causing the skin disease acne vulgaris, but lately these resident bacteria have with improved diagnostics procedures been proven to be pathogen bacteria associated with foreign material or implanted medical devices such as pacemakers, shunts, etc.\textsuperscript{56, 57, 59-65} The major virulence factor of \textit{P. acnes} is believed to be the biofilm formation that protects \textit{P. acnes} from antibiotics and the host immune defence.\textsuperscript{56, 66}

Biofilm

Implanted foreign material is normally covered by non-pathogenic biofilm, usually consisting of plasma, fibrinogen, and collagen, which are employed in the normal functioning of the immune defence system. When a cardiac device such as a pacemaker is implanted, it poses a risk that the
contaminated with possibly bacteria present on the patient skin. This contamination may be the first step towards the formation of a multilayer biofilm incorporating bacteria, covering the implanted foreign surface. The pathogenesis of the bacteria, creating biofilm, is the ability to adhere to surfaces, both on tissue and foreign material.\textsuperscript{67, 68} Biofilm consists mainly of a biochemical matrix of microbial cells and extracellular polymeric substances, mainly polysaccharides attached to the surface.\textsuperscript{69} The biofilm architecture consists of mushroom-shaped bacterial microcolonies, attached to each other. These microcolonies incorporate a myriad of channels that can deliver nutrients and oxygen to the bacteria inside. The matrix protects the bacteria from the hosts’ immune defences, such as antimicrobial peptides and neutrophil phagocytosis.\textsuperscript{70, 71} Moreover, bacteria incorporated into the biofilm are protected from antibiotics by the specific physiology which reduces the antibiotics’ effect (decreased metabolism and aggressiveness), and by limiting the antibiotic ability to reach the bacteria inside the biofilm (reduced diffusion).\textsuperscript{55, 72} Finally, when the biofilm is matured, it detaches colonies of bacteria to the surrounding tissue and the bloodstream. The reason for this action is still unclear, but theories are that the biofilm needs to dispatch colonies to maintain optimal thickness and function, or possibly to colonize elsewhere in the host body.\textsuperscript{55}

**Preventing interventions for the patient undergoing surgery**

**Operating room environment and materials**

To maintain the patient and sterile material free from bacteria from the air, the OR has a controlled ventilation system which cleans the air of bacteria, measured in CFU/m³.\textsuperscript{6, 73} The quality of the air is dependent on the number of persons within the OR. The more persons within the OR, the higher the number of bacteria shed into the air.\textsuperscript{74, 75} The air quality is also strongly dependent on the traffic in and out of the OR, which should be limited.\textsuperscript{74} To prevent cross-infection by exogenous transmission from persons present in the OR, all personnel should wear special work suits and caps, which reduces the spread of bacteria into the air,\textsuperscript{6, 15, 76} and these work suits should be laundered by the employer.\textsuperscript{77} Special clean air suits (single-use) reduce the spread of bacteria more effectively compared to more permeable material such as that found in reusable clothing.\textsuperscript{78} All sterile material that is handled by the sterile team is resterilized if it is reusable, and sterile materials for single use are disposed of. Draping materials should be for
single use and cover the patient entirely, except for the surgical site. Drapes should be non-permeable for fluids and adhere to the patient body, approximately 10 cm into the disinfected area. Patients’ skin needs to dry completely for the drapes to adhere properly. All staff in the OR should wear caps and face masks (depending on local guidelines). Sterile gowns and gloves for single use should be used by all persons within the operating field. The use of surgical gloves is intended to prevent cross-infections between the patient and the surgical team. Double gloves are recommended. It has not yet been proven that use of double gloves reduces SSIs, but there are significantly fewer puncture holes in the inner glove compared to single glove perforations, and using indicator gloves makes it easier to detect puncture holes. The glove perforation sites are mostly found on the non-dominant hand, index finger, long finger, or ring finger. Studies performed on puncture holes in the surgical gloves often recommend a change of gloves, and some recommend glove changes after 90 minutes due to glove puncture rates and because bacterial counts increase with length of surgery. The use of double gloves increases the change of the outer gloves. Changing the outer glove before handling implant material has not been shown to reduce SSIs.

Patient skin disinfection
Skin disinfection is routine prior to surgical procedures. However, there is no consensus regarding which type of skin disinfectant is the most effective. In Sweden, the surgical skin disinfectant should preferably be chlorhexidine 5mg/ml in 70% ethanol and should be applied directly prior to surgery. It is thought that skin disinfection reduces SSIs due to the reduction of bacteria, but skin disinfection has not yet been proven to reduce SSIs. Skin disinfection does not make the skin sterile but reduces the bacterial growth substantially.

Skin disinfection consists of the mechanical rub and the chemical agent. The methods by which the antiseptics are applied vary between countries. The general principle of applying skin disinfection is that the antiseptic applicator should be sterile and should move with friction from the incision site outwards towards the periphery (Figure 1).

There are three main antiseptic compounds: alcohol, iodine/iodophors, and chlorhexidine gluconate. These can occur in different combinations. Which of these antiseptics is the most effective in preventing SSIs is not
clear, but to use any of these antiseptics has been shown to reduce the amount of bacteria on the skin of the patients.88

In Sweden chlorhexidine 5mg/ml in 70% ethanol is widely used, but the choice differs greatly between and within countries.91 The ideal skin disinfection agent should kill all types of bacteria, viruses, fungi, and spores, and have residual activity. The agent should at the same time be patient-friendly, in terms of being non-toxic/allergenic. Skin disinfection agents’ main mode of action is through interfering with the cell wall of different microorganisms.92

Figure 1. Photo of the skin disinfection process prior to a pacemaker implantation.
Photo by Stefan B. Larsson ©
HCWs’ preoperative hand disinfection
With the intention to prevent cross infection during surgery, the surgical team performs preoperative hand disinfection. Preoperative hand disinfection prior to surgery should be performed with hand disinfection agents and methods that comply with the individual skin type. Skin disinfection duration varies, depending on the agent and method used. Preoperative hand disinfection is important due to the risk of puncture of the gloves. The three kinds of methods for preoperative hand disinfection are alcohol rubs, alcohol rubs with active agents, and aqueous scrubs.

An alcohol rub consists of a simple soap wash at the start of the first procedure or when hands are soiled, with an additional rub with alcohol 60% to 90% in strength. Alcohol rubs with an active agent are similar to the alcohol rub, but an active agent such as chlorhexidine is added to the alcohol, with a suggested prolonged inhibition of bacterial regrowth. An aqueous scrub contains of water instead of alcohol, with an active agent as chlorhexidine gluconate or povidone–iodine. The scrub involves repeatedly applying the agent with a sponge, scrubbing hands, nails, and forearms under running water. In the past the norm has been to use a scrub, but the trend has moved toward alcohol rubs. Rubs seem to cause less skin irritation and dryness and are sometimes considered more effective in reducing bacteria.

Maintenance of patient temperature
Perioperative hypothermia is an inadvertent loss of core body temperature to less than 36°C, and is a problem during surgical procedures when patients undergo general anaesthesia. The patient’s body temperature should be maintained by the use of preheated fluids and warming blankets of different types. Hypothermia during surgery may result in several complications, including increased rate of SSIs, impaired coagulation and blood loss. These complications have an association with prolonged hospital stay. Although evidence exists that hypothermia is associated with a series of adverse effects, there is still a lack of high quality evidence for the effects of warming devices to prevent severe complications. Nonetheless, active warming of the patient has shown to significantly shorten time to achieve normothermia and less heat loss and tends to improve thermal comfort if patients are awake. Skin disinfection can enhance heat loss. Different kinds of skin disinfection solutions have different impact on heat loss. If the skin disinfectant used contains alcohol, the heat loss is more enhanced, since
alcohol evaporates more readily than water, resulting in a potentially greater heat loss.107

**Patient experience**

Reports of patients’ experience of skin disinfection are lacking, as well as reports on the effects of increasing the temperature of disinfectant solutions. Most patients are satisfied with the care they receive in the OR.108-111 However, some patients experience the sensation of being cold, especially when undergoing surgery with local anaesthesia.106, 108, 111, 112 In a pilot study by Wistrand and Nilsson (2011),113 preheated and room-temperature skin disinfection was performed on ten healthy volunteers. The study showed that preheated skin disinfectant was experienced as more pleasant and less cold compared to room-temperature disinfectant. Furthermore, there was a significant difference in skin temperature before and after disinfection when using a room-temperature solution, whereas there was no significant difference in skin temperature before and after disinfection with preheated skin disinfectant.113
Rationale

According to Swedish law (SFS: 2017:30), patients should receive health care with good standards and on equal terms. The Swedish National Handbook for Healthcare aims to guide the HCW to maintain safe and high quality care nationally. The clinical work at the OR departments is designed to have a high hygiene standard to prevent bacterial contamination of the wound and thereby prevent SSIs. SSIs are a major problem in terms of both suffering for patients and high costs for society. Surgical complications increase the risk of SSIs, and as a complication due to surgery can never totally be foreseen, SSIs are still therefore unavoidable. One way of reducing SSIs is to reduce the bacterial growth in the surgical patient. SSIs have historically decreased, but despite enhancements, there is much to learn about the different factors involved in the development of SSIs. To improve patient safety alongside comfort and maintain the number of SSIs at a minimum, knowledge about bacterial growth and the interventions performed by OR nurses is essential to enhancing the health care of the surgical patient.
Aims of the thesis

The general aim of this thesis was to test and describe interventions performed by OR nurses to increase patient comfort, prevent bacterial growth, and reduce SSIs.

The specific aims of each study were:

I. To test if preheated (36°C) skin disinfectant was non-inferior to room-temperature (20°C) skin disinfectant regarding skin colonization. The secondary aim was to investigate whether gender had an impact on differences in bacterial colonization in the surgical wound or surgical site infections among patients undergoing surgery;

II. To compare preheated (36°C) with room-temperature (20°C) skin disinfectant solution. Focusing on changes in skin temperature before and after skin disinfection and on patients' experience with the skin disinfection;

III. To investigate if there were differences in bacterial growth and recolonization of hands between operating room nurses and non-health care workers as well as to investigate if bacterial growth existed at the surgical glove cuff and gown interface during surgery; and

IV. To describe the daily clinical interventions guided by national guidelines that Swedish operating room nurses performed to prevent surgical site infections.
Methods

All studies in this thesis are quantitative in design. Variables that are not quantitative have been operationalized into quantitative labels. The studies will be referred to by their Roman numerals as studies I–IV throughout the text (Table 1).

Table 1. Overview of design and method, studies I–IV

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Participants</th>
<th>Outcomes</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Randomized controlled trial, non-inferiority</td>
<td>Pacemaker device surgery patients ( n = 220^* )</td>
<td>Bacterial growth Postoperative surgical site infections</td>
<td>Absolute differences Confidence interval Mann-Whitney U test Descriptive</td>
</tr>
<tr>
<td>II</td>
<td>Randomized controlled trial</td>
<td>Pacemaker device surgery patients ( n = 220^* )</td>
<td>Skin temperature in °C Patients’ thermal comfort</td>
<td>Student’s t-test Mann-Whitney U test Chi-square test Descriptive</td>
</tr>
<tr>
<td>III</td>
<td>Exploratory, comparative, clinical trial</td>
<td>Operating room nurses ( n = 12 ) Non-health care workers ( n = 13 )</td>
<td>Bacterial growth Bacterial species</td>
<td>Mann-Whitney U test Chi-square test Wilcoxon signed rank test Descriptive</td>
</tr>
<tr>
<td>IV</td>
<td>Descriptive Cross sectional survey</td>
<td>Operating room nurses ( n = 890 )</td>
<td>Questionnaire measuring operating room nurses preventive interventions</td>
<td>Descriptive</td>
</tr>
</tbody>
</table>

*Studies I and II were based on the same sample.

Settings

Data for studies I and II were collected at the OR Department of Cardiotoracic and Vascular Surgery, University Hospital in Örebro, Sweden. Data collection for studies I and II took place between January 2013 and November 2014. For study III, data were collected at an OR
department between March 2014 and June 2014 (OR nurses), and between December 2014 and April 2015 (non-HCWs) at the same OR department in Sweden. Study IV data collection was carried out from December 2015 to the end of January 2016.

Participants

Studies I and II
All 220 participants consisted of patients scheduled for pacemaker device surgery under local anaesthesia. The same sample base were used for studies I and II. Inclusion criteria were age 18 years or older and ability to read and understand Swedish. Exclusion criteria were infection in an existing implanted pacemaker device.

Study III
Study III consisted of two groups, one group of 12 OR nurses and another of 13 non-HCWs as a control group. The 13 non-HCWs consisted of healthy volunteers without any recent contact with medical care. Exclusion criteria for both groups were artificial nails, hand eczema, jewellery, or surgical hand disinfectant solution other than that stated as protocol.

Study IV
Email addresses were accessed for 2264 of the approximately 4000 OR nurses in Sweden. Respondents were 967 OR nurses (43%). Inclusion criteria were OR nurses. Exclusion criteria were OR nurses who no longer fulfilled OR nurses’ tasks. Of these 967 OR nurses, 77 were excluded due to having other work positions such as chief of staff, leaving 890 OR nurses.

Intervention and randomization
In studies I and II, patients were included consecutively when arriving at the OR. Patients were randomly allocated to either preheated (36°C) or room-temperature (20°C) skin disinfectant solution (chlorhexidine 5mg/ml in 70% ethanol, Fresenius Kabi AS, Halden, Norway). Allocation took place directly after patients provided informed consent. The randomization was stratified by gender, and an independent statistician
provided the randomization lists. The patient and the laboratory technician who performed the analyses were blinded to the allocation.

Outcomes

**Bacterial growth on patient skin and in the wound**

In study I cultures were obtained at four time points using a nylon-flocked swab (ESwab, COPAN Italia S.p.A., via Perotti 10, Bescia, Italy):

1. Before skin disinfection on the skin surface (Figure 2);
2. After skin disinfection on the skin surface (Figure 2);

![Figure 2. Photo illustrating swabs taken on skin surface for cultures one and two.](Photo by Stefan B. Larsson ©)

Swabs for cultures of the skin (1 and 2) were moistened with two drops of sterile saline, then rubbed for 15 seconds on the skin surface (incision site, approximately 10 mm x 50 mm).
3. Directly after incision, subcutaneously in the wound (Figure 3) and
4. Before closing sutures, subcutaneously in the wound (Figure 3).

![Photo illustrating swabs taken in the wound for cultures 3 and 4. Photo by Stefan B. Larsson ©](image)

Swabs taken in the wounds (3 and 4) were rubbed along the inside of the incision and along the edges for 15 seconds with a dry swab.

**Surgical site infections**
All patients in study I were followed up after three months to detect SSIs, with the help of a nurse who accessed the Swedish ICD (Implantable Cardioverter-Defibrillator) and Pacemaker Registry and provided the data regarding patients diagnosed with SSI. The Swedish pacemaker registry
is a national registry for quality, started in 1989. About 5000 pacemaker implants are performed every year in Sweden, and all implanting hospitals or units report to the registry. The national ICD and Pacemaker Registry compiles and reports annually. These reports contain data with more than 95% of all procedures reported, validated against The National Board of Health and Welfare. The National Board of Health and Welfare is a government agency under the Ministry of Health and Social Affairs.

**Skin temperature**

In study II skin temperature was measured at two time points, before and after skin disinfection, at the planned incision site on the left side below the clavicle, with an infrared (IR) thermometer (CIR 8819; Injector, Stockholm, Sweden) held approximately 10 cm from the skin. The IR thermometer had two IR dots that indicated where on the skin the temperature was being measured (Figure 4).

![Figure 4. Photo of the infrared thermometer used to measure skin temperature.](Photo by Stefan B. Larsson ©)
Experience
In study II patients’ experience of the disinfection process was measured by means of a numeric rating scale (NRS) with anchor words from positive to negative (0, pleasant to 10, unpleasant). The following questions were asked in accordance with a written protocol at the start of the skin disinfection procedure:

- ‘On a scale from 0 to 10, where 0 is pleasant and 10 is unpleasant, how are you experiencing the temperature of the skin disinfectant?’
- ‘Are you cold now?’ Yes or No.
- ‘If you could choose, would you like the skin disinfection solution to be (a) warmer, (b) colder, or (c) as it is?’

Bacterial growth and recolonization on the hands
In study III, skin cultures were taken at two time points, directly after preoperative hand disinfection when the hands were dry, and again after wearing sterile surgical gloves and gowns. The OR nurses were sampled in total at seven sites, and the non-HCWs at six sites. The non-HCWs had six cultures taken, because the culture from the glove cuff and gown interface was excluded. At the first time point both groups were cultured

1. In the right hand palm (Figure 5a);
2. Between the right index finger and middle finger (Figure 5b);
3. At the nail/cuticle of the right index finger (Figure 5c).

Photos 5a to 5c illustrate sampling sites on the hands. Photos by Stefan B. Larsson
After the cultures were taken the participants continued to don the gowns and gloves. When the two groups were finished with their tasks the second time point for cultures began. For the OR nurses’ one culture was obtained before removing the gloves. This culture was obtained at the glove cuff and gown interface (Figure 6).

This swab was rubbed around the interface of the right inner glove and gown sleeve.

Figure 6. Photo illustrating the OR nurses culture site at the glove cuff end. Photo by Stefan B. Larsson ©

Thereafter, the second time point proceeded with both groups being cultured at three sites as above (Figure 5a to 5c), once again. All cultures were taken using a nylon-flocked swab (ESwab, Copan Italia S.p.A.,
Brescia, Italy). The culture area was approximately 5 mm × 15 mm. At the nail site the area was somewhat smaller.

**Preventive interventions to reduce surgical site infections**

In study IV, the study-specific questionnaire was based on an extensive review; on evidence from earlier research produced by the research group regarding skin disinfection effects, both of patient skin and of the hands of the staff; and from existing Swedish guidelines as well as from the research group’s own clinical experiences working in an OR setting as OR nurses and OR anaesthetist. The following guidelines were selected for the study-specific questionnaire:

- Recommended skin disinfection solution, chlorhexidine 5mg/ml in 70% ethanol or similar, with a prolonged effect;
- Duration of the skin disinfection process to be two minutes, and then the site allowed to dry;
- Sterile draping material for single use, which should stay adherent throughout the surgical procedure;
- Two methods for preoperative surgical hand disinfection: method 1, rub – the use of plain soap and water and thereafter rubbing of the hands and forearms fluidly with alcohol; and method 2, scrub – the use of soap, containing 4% chlorhexidine or similar solution, and water;
- Sterile gowns and gloves to be worn by all within the sterile area of surgery, and double gloves recommended;
- Special work suit designed to prevent the spread of bacteria from staff to the surrounding air, that is, a clean air suit;
- Maintenance of patient body temperature perioperatively by the use of warm fluids and blankets; and
- Preoperative shower with a chlorhexidine-containing soap at least twice before surgery, the cleansing to begin the day before surgery at home and be completed the morning of the surgery at the ward or at home by the patient.

The questions were arranged as an online questionnaire by a professional web survey company. The questionnaire addressed the daily activities an OR nurse does to prevent bacterial growth, such as preparing the patient skin (n = 12), maintaining the patient temperature (n = 10), and preparing OR materials (n = 10). The response form included a five-point scale with
the answer options always, often, sometimes, seldom, or never (n = 19); a four-point scale regarding recolonization – large, moderate, small, or none – and puncture of glove, long duration, use of single glove, or open-ended (n = 2); a fixed set of three choices with an open-ended alternative regarding double gloving and reasons for changing outer glove – yes, no, unsure, or open-ended (n = 2); a five-point scale regarding source of information on patient skin disinfection with the answer options educator (university), supervisor (OR nurse), Handbook for Healthcare, colleagues, unsure, or open-ended (n = 1); and finally, eight open-ended questions, for example, Which preoperative hand disinfectant do you use? and Which OR temperature is usually set? The questionnaire also included six sociodemographic variables such as age, type of hospital, work experience, educational level, type of surgical specialty, and in what part of Sweden they worked (Table 2).

Table 2. The response alternatives in the questionnaire

<table>
<thead>
<tr>
<th>Answers using five-point scale, n = 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
</tr>
<tr>
<td>Answers using four-point scale, n = 2</td>
</tr>
<tr>
<td>Large</td>
</tr>
<tr>
<td>Puncture duration</td>
</tr>
<tr>
<td>of gloves</td>
</tr>
<tr>
<td>Answers with a fixed set of three choices with an open-ended alternative, n = 2</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Answers using a five-point scale regarding education, n = 1</td>
</tr>
<tr>
<td>Educator</td>
</tr>
<tr>
<td>Open-ended questions, n = 8</td>
</tr>
</tbody>
</table>

**Procedures**

Patients in studies I and II were undergoing elective surgery and arrived at the hospital on the morning of the surgery. Patients showered twice with Descutan®, a 4% chlorhexidine soap (Fresenius Kabi AB, Uppsala, Sweden), prior to surgery. Patients waited at the ward and were brought to the OR immediately before the procedure. Following standard procedures, intravenously administered antibiotic prophylaxis (cloxacillin 2 g) was given in the ward 15–30 minutes prior to surgery. The patient was placed upon an operating table under a blanket, and wore a gown...
backwards so that the chest could be easily exposed. Data collection was performed in the OR, with a temperature of 19°C with upward displacement ventilation. The patient’s skin was disinfected from the cheek downward over the sternum and toward the left shoulder, which was in accordance with the clinic’s routine. Both groups underwent skin disinfection with the same amount (250 ml) of solution on 10 cotton swabs. The preheated disinfection solution was stored in a warming cupboard and kept at 36°C (Figure 7), while the room-temperature skin disinfection solution was stored at room temperature, and measured to maintain 20°C. The patients were not informed as to whether they received preheated skin disinfection or not. All the surgical procedures were performed by two cardiologists. The main side for surgery was the patients’ left side. Patients either received a pacemaker, an implantable cardioverter–defibrillator, or cardiac resynchronization therapy, or had an existing pacemaker device (battery) changed. All the pacemaker device implantations were performed with the
Seldinger technique. The wound was closed with resorbable monofilament sutures for the subcutaneous tissue and intracutaneous layer. After wound closure, a dressing was applied while sterile conditions were intact. Patients were instructed to leave the dressing on for 10 days before changing it. Patient flow through studies I and II is shown in a flow chart (Figure 8).

Figure 8. Flow chart showing patients’ inclusion in studies I and II.
In study III, 12 OR and 13 non-HCWs performed the preoperative hand disinfection. They performed the preoperative hand disinfection according to clinic routine by washing their hands under running water with soap and cleaning their nails if necessary for one minute, and then drying their hands and forearms properly with paper and rubbing hands and forearms with a fluid alcohol (Dax preop 80, CCS Healthcare AB, Sweden). Both the OR nurses and the non-HCWs wore caps, masks, nonwoven disposable surgical gowns (BARRIER, Mölnlycke Health Care, Gothenburg, Sweden), and double gloves (Biogel PI indicator system, Mölnlycke Health Care, Gothenburg, Sweden). The OR nurses prepared and assisted at a clean surgery procedure until they were either relieved or the surgery was completed. To simulate nearly the same workload as preparing and assisting a patient for surgery, the non-HCWs performed a heart and lung resuscitation (HLR) course while dressed in gowns, caps, and gloves. The course consisted of information and practice, at the end of which the participants were offered lunch. OR nurses were compared with a control group of non-HCWs regarding bacterial growth and outcome variables analysed, shown in a flow chart (Figure 9).

In study IV, the questionnaire was sent to 2264 of a total of approximately 4000 OR nurses’ work email addresses in Sweden. IT departments at the participating hospitals or regions delivered the lists of all email addresses of the OR nurses to the author. The remaining email addresses were not retrieved. The web-based questionnaire was distributed via email together with information about the study. Information about the study was also published in the Swedish journal for OR nurses (Uppdukat) as well as in a closed Facebook group (Operationssjuksköterskor, 1668 members).
Bacterial cultures
All cultures taken were sent to the Department of Laboratory Medicine, Clinical Microbiology, University Hospital, Örebro, and analysed according to specific study protocols.

The swabs were vortexed for a few seconds, and for studies I and III, 50 and 100 μL aliquots, respectively, of the liquid transportation medium were subcultured on haematin agar medium 4.3% (w/v); (Columbia Blood Agar Base, Acumedia Neogen Corporation, Lansing, MI, USA) supplemented with 6% (w/v) chocolatised defibrinated horse blood and
incubated at 36°C under aerobic conditions. Samples were also subcultured on FAA plates (LAB 90 Fastidious Anaerobe Agar 4.6% (w/v; LAB M Ltd., Lancashire, UK), supplemented with 5% (v/v) defibrinated horse blood and incubated under anaerobic conditions (10% H2, 10% CO2, 80% N2) at 37°C. After 24 and 48 hours of aerobic incubation and 5 days of anaerobic incubation, bacterial growth was determined quantitatively (CFU/mL). Culture diagnostics and species verification were performed based on characteristic colony morphology and using routine diagnostic procedures. Additionally, for study III, MALDI-TOF mass spectrometry (MicroflexLT and Biotyper 3.1, Bruker Daltonics, Bremen, Germany) was used.

**Statistical analysis**

Statistical analysis was performed with SPSS, version 22 (SPSS Statistics, IBM, Armonk, NY).

**Study I**

A sample size of 102 participants per group provided 80% power at a one-sided significance level of 5%, with an expected proportion of bacterial growth of 0.09 and the maximal allowable difference of 0.10 non-inferiority limit. Absolute difference and CI were manually calculated. Bacterial counts and other non-normally distributed variables were analysed with the Mann-Whitney U test, and normally distributed variables with an unpaired t-test. Categorical variables were evaluated with chi-square test or Fisher’s exact test, as appropriate. Descriptive statistics are presented as mean, median, number, percentage, confidence interval, and standard deviation. A p-value of <0.05, two tailed, was considered statistically significant.

**Study II**

Study II was a part of study I, and the power calculation was based on the expected proportion of bacterial growth from a pilot study by Wistrand and Nilsson. The pilot study detected differences in both skin temperatures and in experience; thus, we decided that the sample size of 220 was sufficient. Student’s t-test was used for analysis of skin temperature, and the NRS was analysed with Mann-Whitney U test. Categorical variables were evaluated with chi-square test or Fisher’s exact test, as appropriate. Descriptive statistics are presented as mean, median,
number, percentage, confidence interval, and standard deviation. A $p$-value of $<0.05$, two tailed, was considered statistically significant.

**Study III**  
No sample size was calculated; hence, this was a pilot study, which can provide data for future power calculations. The bacterial counts and other non-normally distributed variables were analysed with Mann-Whitney $U$ test and Wilcoxon signed rank test comparing repeated measurements. Categorical variables were evaluated with chi-square test or Fisher’s exact test, as appropriate. Descriptive statistics are presented as mean, median, number, percentage, confidence interval, and standard deviation, and interquartile range (IQR). A $p$-value of $<0.05$, two tailed, was considered statistically significant.

**Study IV**  
No sample size was calculated; hence, the aim was to have as high a response rate as possible of OR nurses in Sweden. Descriptive statistics were presented as mean, median, number, range, percentage, confidence interval, and standard deviation.

**Ethical considerations**  
All studies were conducted in accordance with the Helsinki Declaration regarding ethical principles involving humans.

All participants in studies I, II, and III were given oral and written information about the studies, and all gave written informed consent before the start of data collection.

The Regional Ethical Review Board of Uppsala, Sweden, approved studies I, II, and III (reference number 2012/255 and 2013/283). Registrations were made in ClinicalTrials.gov for studies I and II (NCT02260479) and for study III (NCT02359708).

As study IV did not involve patients or sensitive data, ethical approval was not required according to the Swedish Act concerning the Ethical Review or Research Involving Humans (SFS, 2003:460). No sensitive data means no information was retrieved regarding ethnicity, political opinions, union membership, or religion, or information regarding health and sexual preferences. Written information was given regarding the study, and participation was voluntary. Study IV was conducted with respect for the participants’ integrity, and the data were stored.
depersonalized on data files at the hospital servers, protected with firewalls and private codes. No key codes existed to connect the answers with any individuals, and the results were presented groupwise with no possibility for recognition.
Results

The results in this thesis showed that preheated skin disinfection reduces skin heat loss and increases patient comfort (study II), whilst not being less effective in reducing bacterial growth or SSIs (study I). There was no conclusive difference between OR nurses and non-HCWs regarding bacterial growth on their hands, but there was a possible risk of bacterial contamination at the glove cuff during surgery (study III). The proportion of the OR nurses who complied with the preventive interventions recommended in the national guidelines was high (study IV). The results are presented following the outcomes. An overview of patients’ characteristics for studies I and II is presented in Table 3.

Table 3. Patients’ baseline characteristics between preheated and room-temperature skin disinfectant groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Preheated 36°C</th>
<th>Room temperature 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorhexidine 5 mg/ml in 70% ethanol</td>
<td>Preheated</td>
<td>Room temperature</td>
</tr>
<tr>
<td>Characteristics</td>
<td>n = 108</td>
<td>n = 112</td>
</tr>
<tr>
<td>n = 108</td>
<td>n = 112</td>
<td></td>
</tr>
<tr>
<td>Age (years), mean ± SD</td>
<td>72 ± 11.9</td>
<td>74 ± 12.5</td>
</tr>
<tr>
<td>Body mass index, mean ± SD</td>
<td>27 ± 4.5</td>
<td>27 ± 5.4</td>
</tr>
<tr>
<td>Colony-forming units, median ± IQR</td>
<td>1180 ± 4690</td>
<td>2080 ± 4770</td>
</tr>
<tr>
<td>Skin temperature (°C), mean ± SD</td>
<td>32 ± 1.2</td>
<td>32 ± 1.1</td>
</tr>
<tr>
<td>Length of surgery, minutes, mean ± SD</td>
<td>37 ± 24</td>
<td>39 ± 24</td>
</tr>
<tr>
<td>Men, n (%)</td>
<td>62 (57)</td>
<td>62 (55)</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>46 (43)</td>
<td>50 (45)</td>
</tr>
<tr>
<td>Bacterial growth, %</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>Eczema, %</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Incision site hair shorten, %</td>
<td>31</td>
<td>26</td>
</tr>
<tr>
<td>Diabetes, %</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Type of surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device (battery) change, %</td>
<td>45.4</td>
<td>46.4</td>
</tr>
<tr>
<td>DDD, %</td>
<td>35.2</td>
<td>36.6</td>
</tr>
<tr>
<td>VVI, %</td>
<td>6.5</td>
<td>6.3</td>
</tr>
<tr>
<td>ICD, %</td>
<td>1.9</td>
<td>3.6</td>
</tr>
<tr>
<td>CRT, %</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Other, %</td>
<td>9.2</td>
<td>5.4</td>
</tr>
</tbody>
</table>

SD, standard deviation; IQR, interquartile range; DDD, dual chamber rate adaptive pacemaker; VVI, single ventricular rate adaptive pacemaker; ICD, implantable cardioverter–defibrillator; CRT, cardiac resynchronization therapy. Continuous and dichotomous variables were analysed using t-test and Mann Whitney U test; no significant differences between groups.
**Bacterial growth on patients’ skin and in the wound**

In study I, the absolute difference in bacterial growth between the patient groups was zero (90% CI, -10.1 to 10.1). The bacterial growth was reduced by the skin disinfection process, but recolonization occurred during the surgical procedure. Cultures showed that males had significantly more bacteria at the four time points than females, irrespective of the temperature of the skin disinfectant (Table 4).

<table>
<thead>
<tr>
<th>Chlorhexidine 5 mg/ml in 70% ethanol</th>
<th>All</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>36°C</td>
<td>20°C</td>
<td>Absolute difference</td>
<td>36°C</td>
</tr>
<tr>
<td>n = 106</td>
<td>n = 112</td>
<td>(90% CI)</td>
<td>n = 62</td>
</tr>
<tr>
<td>Before skin disinfection, %</td>
<td>95.3</td>
<td>96.4</td>
<td>100</td>
</tr>
<tr>
<td>After skin disinfection*, %</td>
<td>28.6</td>
<td>28.6</td>
<td>0</td>
</tr>
<tr>
<td>After incision (wound), %</td>
<td>24.5</td>
<td>30.4</td>
<td>-0.059</td>
</tr>
<tr>
<td>Before wound closure (wound), %</td>
<td>53.8</td>
<td>62.5</td>
<td>-0.087</td>
</tr>
</tbody>
</table>

*Primary outcome. No statistical difference between the preheated and room-temperature skin disinfection groups was found. Differences between genders regarding bacterial growth existed at all four time points but not within genders, analysed with chi-square test.

The most commonly identified pathogens after skin disinfection both on the skin and in the wound (ordered by frequency) were *P. acnes* and CoNS (Table 5).
Table 5. Species of microorganism identified, before and after skin disinfection with chlorhexidine 5 mg/ml in 70% ethanol, at the four time points: (1) on the skin before skin disinfection, (2) on the skin after skin disinfection, (3) in the wound after incision, and (4) in the wound before skin closure. Number of patients with growth of bacteria.

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Culture 1</th>
<th></th>
<th>Culture 2</th>
<th></th>
<th>Culture 3</th>
<th></th>
<th>Culture 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36°C</td>
<td>20°C</td>
<td>36°C</td>
<td>20°C</td>
<td>36°C</td>
<td>20°C</td>
<td>36°C</td>
<td>20°C</td>
</tr>
<tr>
<td></td>
<td>n=106</td>
<td>n=112</td>
<td>n=106</td>
<td>n=112</td>
<td>n=106</td>
<td>n=112</td>
<td>n=106</td>
<td>n=112</td>
</tr>
<tr>
<td><em>P. acnes</em></td>
<td>83</td>
<td>86</td>
<td>25</td>
<td>25</td>
<td>22</td>
<td>29</td>
<td>47</td>
<td>52</td>
</tr>
<tr>
<td>CoNS</td>
<td>83</td>
<td>90</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>23</td>
<td>29</td>
</tr>
<tr>
<td><em>S. aureus</em></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alpha-haemolytic</td>
<td>9</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Anaerobic diphtheroid</td>
<td>rods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bacillus sp.</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Micrococi</td>
<td>4</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anaerobic Gram-positive</td>
<td>cocci</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Proteus sp.</td>
<td>2</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>R. mucilaginosa</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

No significant differences between study groups were found for any microorganism at any time point. Chi-square test was used as statistical method.

**Surgical site infections**

In study I, there were no significant differences regarding SSIs three months postoperatively between patients who received preheated compared to room-temperature skin disinfectant. In the preheated group 0.9% (1/108, female) was diagnosed with a SSI, while 1.8% (2/112, one female and one male) in the room-temperature group were diagnosed. Cultures taken for diagnostics showed no growth for the women, but the men showed growth of *S. aureus*, CoNS, *P. acnes*, and beta haemolytic streptococci group G.
**Skin temperature**

In study II, patients who received preheated skin disinfection had a higher mean skin temperature than the room-temperature group by 0.74°C ($p = 0.001$, 95% CI, -1.2 to -0.3), 27.25°C versus 26.51°C. There were no significant differences in skin temperature between men and women.

**Experience**

According to study II, using the NRS, patients experienced preheated skin disinfectant as more pleasant than room-temperature skin disinfectant, median score for NRS was 2 in the preheated group, whereas median NRS score for room-temperature solution was 5, $p \leq 0.001$ (Table 6).


<table>
<thead>
<tr>
<th>Skin disinfection</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheated, 36°C, %</td>
<td>29.2</td>
<td>15.1</td>
<td>16.0</td>
<td>13.2</td>
<td>7.5</td>
<td>15.1</td>
<td>2.8</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Room-temperature, 20°C, %</td>
<td>9.1</td>
<td>2.7</td>
<td>4.5</td>
<td>11.8</td>
<td>7.3</td>
<td>27.3</td>
<td>6.4</td>
<td>10.0</td>
<td>16.4</td>
<td>1.8</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Zero represent a pleasant experience regarding the temperature of the skin disinfection solution while 10 represents an unpleasant temperature.

Patients who received preheated skin disinfection solution felt less cold during the skin disinfection procedure. Fewer patients’ desired warmer solution when the solution was preheated, and more patients were satisfied with the temperature of the solution they received compared to the room-temperature group (Table 7). None desired cooler skin disinfectant. There were no significant differences between genders in either disinfectant group.
Table 7. Experienced differences between receiving preheated versus room-temperature skin disinfectant solution

<table>
<thead>
<tr>
<th>Chlorhexidine 5 mg/ml in 70% ethanol</th>
<th>Preheated 36°C</th>
<th>Room-temperature 20°C</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients n = 99</td>
<td></td>
<td>Patients n = 100</td>
<td></td>
</tr>
<tr>
<td>Felt cold during, n</td>
<td>10</td>
<td>25</td>
<td>0.006</td>
</tr>
<tr>
<td>Desired warmer, n</td>
<td>28</td>
<td>55</td>
<td>0.001</td>
</tr>
<tr>
<td>Satisfied with temperature, n</td>
<td>71</td>
<td>45</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Statistical methods used were chi-square test or Fisher’s exact test, as appropriate. A p-value of <0.05, two tailed, was considered statistically significant.

Bacterial growth and recolonization on the hands

There were differences between the groups in study III regarding the time the participants wore the gloves after the preoperative hand disinfection (Table 8).

Table 8. Comparison of baseline participant characteristics between operating room (OR) nurses and non-health care workers (HCWs)

<table>
<thead>
<tr>
<th></th>
<th>OR nurses n = 12</th>
<th>Non-HCWs n = 13</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD</td>
<td>46 ± 8</td>
<td>39 ± 13</td>
<td>0.094</td>
</tr>
<tr>
<td>Men/women</td>
<td>1/11</td>
<td>1/12</td>
<td>1.0</td>
</tr>
<tr>
<td>Minutes wearing gloves, mean ±</td>
<td>223 ± 34</td>
<td>192 ± 16</td>
<td>0.007*</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Student’s t-test and Fisher’s exact test were used as statistical method.

*Statistically significant difference.

According to study III, there were differences in bacterial growth and recolonization between the groups at four of the six culture sites, regarding the CFU/mL. After surgical hand disinfection the OR nurses had higher bacterial growth at the palm and finger sites compared to the non-HCWs, P < 0.044 and P < 0.019, but no difference regarding the nail sites, P = 0.434. After wearing surgical gloves, no difference were found
regarding the palm site between the groups, $P = 0.893$. OR nurses had higher values regarding recolonization at the finger, $P < 0.039$, but less recolonization at the nail site, $P < 0.016$ compared to non-HCWs (Table 9).

Table 9. Bacterial growth and recolonization at three culture sites on the hands of operating room nurses and non-health care workers after surgical hand disinfection, and then again after wearing surgical gloves

<table>
<thead>
<tr>
<th>Culture site</th>
<th>Operating room nurses $n = 12$</th>
<th>Non-health care workers $n = 13$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%) growth</td>
<td>CFU/mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>After hand disinfection, first time point for cultures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm</td>
<td>5 (41.7)</td>
<td>13</td>
</tr>
<tr>
<td>Finger</td>
<td>6 (50)</td>
<td>14</td>
</tr>
<tr>
<td>Nail</td>
<td>8 (66.7)</td>
<td>28</td>
</tr>
<tr>
<td>After wearing gloves, second time point for cultures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm</td>
<td>4 (33.3)</td>
<td>18</td>
</tr>
<tr>
<td>Finger</td>
<td>4 (33.3)</td>
<td>98</td>
</tr>
<tr>
<td>Nail</td>
<td>10 (83.3)</td>
<td>244</td>
</tr>
</tbody>
</table>

Mann-Whitney U test was used to calculate the numbers of bacterial differences at the different culture sites in CFU/mL between the groups. IQR, Interquartile range. *Statistically significantly more bacterial growth.

In study III, 14 different bacterial species were found. The most common species obtained from the OR nurses hands were (ordered by frequency) *Staphylococcus warneri* followed by *P. acnes*, and in the non-HCWs group *S. warneri* followed by *S. epidermidis* together with *Staphylococcus pasteuri* (Table 10).
Table 10. Bacterial species isolated from the hands of operating room (OR) nurses and non-health care workers (HCWs). Numbers of persons with specific bacteria after preoperative hand disinfection and after wearing sterile gloves.

<table>
<thead>
<tr>
<th>Bacterial species</th>
<th>Bacterial growth after preoperative hand disinfection</th>
<th>Bacterial recolonization after wearing sterile gloves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR nurses $n = 12$</td>
<td>Non-HCWs $n = 13$</td>
</tr>
<tr>
<td>S. warneri</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>P. acnes</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Bacillus sp.</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>S. epidermidis</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>S. capitis</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>S. pasteuri</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Micrococcus sp.</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>S. haemolyticus</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Alpha-haemolytic streptococci</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Brevibacteriaceae</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>S. lugdunensis</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Gemella haemolysans</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gram-positive cocci, non-typeable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

*Significant difference between groups regarding minutes, $P = 0.007$; statistical method used was Student’s $t$-test.

In study III, 9 out of 12 (75%) of the OR nurses had a visible dark area around the glove cuff and gown interface, indicating fluid (Figure 10), and five (42%) had bacterial growth found at the end of the inner glove. Four of five cultures from the OR nurses had the same bacteria at the glove cuff and gown interface as found in the cultures from the hands. Bacteria isolated from the cultures were *P. acnes*, *S. warneri*, *S. epidermidis*, and *Micrococcus* species. The CFU/mL ranged from 10 to 40 at the interface of the surgical glove cuff and gown.
Preventing interventions to reduce surgical site infections

In total 967 of 2264 OR nurses answered the questionnaire (response rate 43%). Of the 967 OR nurses who responded, 77 were excluded due to having other work positions such as chief of staff. The majority of the OR nurses were women, with a mean age of 47 years and work experience of about 16 years. Educational levels range from licensed OR nurse up to PhD (Doctor of Philosophy) graduate, working at university hospitals, county hospitals, or private hospitals, as described in Table 11. The interventions are structured and presented using the Swedish national guidelines.
**Table 11. Characteristics of operating room (OR) nurses ($n = 890$) in study IV**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>47 (9.8)</td>
</tr>
<tr>
<td>Years of experience, mean (SD)</td>
<td>16 (12.0)</td>
</tr>
<tr>
<td>OR nurses, male, $n$ (%)</td>
<td>57 (6.4)</td>
</tr>
<tr>
<td>OR nurses, female, $n$ (%)</td>
<td>833 (93.6)</td>
</tr>
</tbody>
</table>

**Level of education**

<table>
<thead>
<tr>
<th>Education</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensed OR nurse, $n$ (%)</td>
<td>455 (51.0)</td>
</tr>
<tr>
<td>Licensed OR nurse BSc, $n$ (%)</td>
<td>196 (22.0)</td>
</tr>
<tr>
<td>Licensed OR nurse MSc or higher, $n$ (%)</td>
<td>239 (27.0)</td>
</tr>
</tbody>
</table>

**Type of hospital**

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>University hospital, $n$ (%)</td>
<td>332 (37.2)</td>
</tr>
<tr>
<td>County hospital, $n$ (%)</td>
<td>475 (53.4)</td>
</tr>
<tr>
<td>Private hospital, $n$ (%)</td>
<td>22 (2.5)</td>
</tr>
<tr>
<td>Other, $n$ (%)</td>
<td>61 (6.9)</td>
</tr>
</tbody>
</table>

**Surgical specialty**

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthopedic surgery, $n$ (%)</td>
<td>285 (32.0)</td>
</tr>
<tr>
<td>General surgery, $n$ (%)</td>
<td>283 (31.8)</td>
</tr>
<tr>
<td>Thoracic surgery, $n$ (%)</td>
<td>70 (7.9)</td>
</tr>
<tr>
<td>Gynecological surgery, $n$ (%)</td>
<td>61 (6.9)</td>
</tr>
<tr>
<td>Ear, nose, and throat surgery, $n$ (%)</td>
<td>50 (5.6)</td>
</tr>
<tr>
<td>Urologic surgery, $n$ (%)</td>
<td>31 (3.5)</td>
</tr>
<tr>
<td>Neurologic surgery, $n$ (%)</td>
<td>30 (3.4)</td>
</tr>
<tr>
<td>Hand surgery, $n$ (%)</td>
<td>23 (2.6)</td>
</tr>
<tr>
<td>Vascular surgery, $n$ (%)</td>
<td>16 (1.8)</td>
</tr>
<tr>
<td>Plastic surgery, $n$ (%)</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Eye surgery, $n$ (%)</td>
<td>14 (1.5)</td>
</tr>
<tr>
<td>Other, $n$ (%)</td>
<td>12 (1.3)</td>
</tr>
</tbody>
</table>

SD, standard deviation.

**Recommended skin disinfection solution, chlorhexidine 5 mg/ml in 70% ethanol or similar, with prolonged effect**

Chlorhexidine 5 mg/ml in 70% ethanol was the most commonly used solution for skin disinfection and was used by 93.3% (806/862) of the OR nurses. This was followed by ChloraPrep®, a combination of...
chlorhexidine 20 mg/ml in 70% isopropanol used by 2.3% (20/862) of the OR nurses. Finally, 70% ethanol and Sterillium®, containing 75% isopropanol, was used, respectively, by 2.1% (18/862) of the OR nurses. Precleansing of the patient skin at the OR with a 4% chlorhexidine-containing wipe/sponge, Descutan®, of the patient skin was always performed by 29.7% (264/890) of the OR nurses prior to the preoperative skin disinfection (Table 12).

**Duration of the skin disinfection process to be two minutes, and then the site allowed to dry**

The majority of the OR nurses assessed that they performed the preoperative skin disinfection of patient skin for two to five minutes (Figure 11).

![Figure 11. Operating room nurses’ (n = 877) assessment of time spent on skin disinfection of a patient’s abdomen.](image)

The majority, 41.1% (366/890), of the OR nurses often let the skin dry before draping, but they often, 34.0% (303/890), wiped the skin dry
where the drapes were to adhere to enhance adherence of the drapes to the patient skin (Table 12).

**Sterile draping material for single use, which should stay adherent throughout the surgical procedure**

Single-use sterile draping was used by 97.4% (867/890) of the OR nurses, and they assessed the draping material to often stay adherent to the patient skin during surgery, 75.8% (675/890). Plastic adhesive drapes were used sometimes by 54.5% (485/890), and iodine-impregnated plastic adhesive drapes were used always by 33.7% (300/890) or never by 37.8% (336/890). A microbial sealant, such as Integuseal®, was never used by 89.4% (796/890) of the OR nurses (Table 12).

Table 12. Operating room nurses’ (n = 890) scaled responses regarding preparation of patients’ skin

<table>
<thead>
<tr>
<th>Preparation of patient skin</th>
<th>Always (n(%))</th>
<th>Often (n(%))</th>
<th>Sometimes (n(%))</th>
<th>Seldom (n(%))</th>
<th>Never (n(%))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorhexidine soap 4% wipes are used prior to skin disinfection, Descutan®</td>
<td>264 (29.7)</td>
<td>156 (17.5)</td>
<td>329 (37.0)</td>
<td>76 (8.5)</td>
<td>65 (7.3)</td>
</tr>
<tr>
<td>Skin is allowed to dry after skin disinfection</td>
<td>331 (37.2)</td>
<td>366 (41.1)</td>
<td>123 (13.8)</td>
<td>63 (7.1)</td>
<td>7 (0.8)</td>
</tr>
<tr>
<td>Skin is wiped with sterile paper towel for drape adherence</td>
<td>133 (14.9)</td>
<td>303 (34.0)</td>
<td>215 (24.2)</td>
<td>133 (14.9)</td>
<td>106 (11.9)</td>
</tr>
<tr>
<td>Drapes for single use</td>
<td>867 (97.4)</td>
<td>18 (2.0)</td>
<td>2 (0.2)</td>
<td>1 (0.1)</td>
<td>2 (0.2)</td>
</tr>
<tr>
<td>Drapes are adherent to patient skin during surgery</td>
<td>194 (21.8)</td>
<td>675 (75.8)</td>
<td>17 (1.9)</td>
<td>4 (0.4)</td>
<td>-</td>
</tr>
<tr>
<td>Plastic adhesive drapes are used</td>
<td>18 (2.0)</td>
<td>122 (13.7)</td>
<td>485 (54.5)</td>
<td>98 (11.0)</td>
<td>167 (18.8)</td>
</tr>
<tr>
<td>Iodine-impregnated plastic adhesive drapes are used</td>
<td>300 (33.7)</td>
<td>105 (11.8)</td>
<td>99 (11.1)</td>
<td>50 (5.6)</td>
<td>336 (37.8)</td>
</tr>
<tr>
<td>Microbial skin sealant is used</td>
<td>8 (0.9)</td>
<td>4 (0.4)</td>
<td>40 (4.6)</td>
<td>42 (4.7)</td>
<td>796 (89.4)</td>
</tr>
</tbody>
</table>
Almost half of the OR nurses, 48.9% (435/890) responded that they had learned to perform patient skin disinfection from their supervisor and OR nurse at the clinical practice during education, and 41.7% (371/890) from the educator at the university. The remaining 9.4% stated that they had learned it from colleagues and/or the Handbook for Healthcare or did not remember where they had learned it. The assessment of the skin disinfection efficiency by OR nurses regarding the proportion of patients that became free from bacteria after the skin disinfection ranged from 0 to 99%, and the distribution was fragmented. The majority of the OR nurses, 31.7% (187/890), assessed that none of the patients became completely free from bacterial growth after skin disinfection, while 5.6% (33/890) of the OR nurses believed that 99% of the patients became free from bacteria at the skin disinfection area.

Two methods for preoperative hand disinfection
Almost all OR nurses, 96.3% (857/890), stated that they had guidelines at their OR department for how to perform a preoperative hand disinfection. The mostly used preoperative hand disinfectant was an alcohol-based disinfectant solution, 89.6% (763/852), followed by chlorhexidine-based soap, 8.2% (70/852). Some of the OR nurses used both alcohol-based disinfectant solutions and chlorhexidine-based soap, 1.3% (11/852), and only a minority used plain soap, 0.9% (8/852). Many of the OR nurses, 47.2% (420/890), expected a small bacterial recolonization on their hands after the use of sterile surgical gloves while 38.4% (342/890) expected a moderate recolonization. Two per cent (18/890) expected a large recolonization, and the remaining OR nurses, 12.4%, answered that they expected no bacterial recolonization on their hands after the use of surgical gloves. OR nurses assessed the sterile outer glove to always reach over the inner glove, 83.3% (741/890), and 41.0% (365/890) of the OR nurses never noticed an indication of moisture themselves at the glove cuff end (Table 13).
Table 13. OR nurses’ (n = 890) scaled responses regarding surgical gowns and gloves

<table>
<thead>
<tr>
<th>Statement</th>
<th>Always n (%)</th>
<th>Often n (%)</th>
<th>Sometimes n (%)</th>
<th>Seldom n (%)</th>
<th>Never n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile gowns for single use</td>
<td>746 (83.8)</td>
<td>62 (7.0)</td>
<td>47 (5.3)</td>
<td>27 (3.0)</td>
<td>8 (0.9)</td>
</tr>
<tr>
<td>Staff clothing for single use at the OR department (non-sterile)</td>
<td>85 (9.6)</td>
<td>67 (7.5)</td>
<td>180 (20.2)</td>
<td>168 (18.9)</td>
<td>390 (43.8)</td>
</tr>
<tr>
<td>Double sterile surgical gloves are used</td>
<td>650 (73.0)</td>
<td>157 (17.7)</td>
<td>43 (4.8)</td>
<td>23 (2.6)</td>
<td>17 (1.9)</td>
</tr>
<tr>
<td>All sterile staff use double gloves</td>
<td>176 (19.8)</td>
<td>521 (58.5)</td>
<td>141 (15.8)</td>
<td>32 (3.6)</td>
<td>20 (2.2)</td>
</tr>
<tr>
<td>A dark area indicating moisture has been noted at the glove cuff end</td>
<td>24 (2.7)</td>
<td>67 (7.5)</td>
<td>231 (26.0)</td>
<td>203 (22.8)</td>
<td>365 (41.0)</td>
</tr>
<tr>
<td>The outer glove reaches over the inner glove</td>
<td>741 (83.3)</td>
<td>100 (11.2)</td>
<td>22 (2.5)</td>
<td>10 (1.1)</td>
<td>17 (1.9)</td>
</tr>
</tbody>
</table>

**Sterile gowns and gloves to be worn by all within the sterile area of surgery, and double gloves recommended**

Single-use sterile gowns were used by 83.8% (746/890) of the OR nurses. Of the OR nurses, 40.4% (360/890) did not know whether they had any guidelines regarding double gloves, and 37.1% (330/890) stated that they did not have any. Double gloves were used by 73% (650/890) of the OR nurses (Table 13). Reasons for changing the outer gloves varied, but the most dominant reasons were indication of puncture holes in the outer glove or the use of gloves for a long time (Table 14).
Table 14. Reasons to change the outer gloves, operating room (OR) nurses 
\((n = 890)\) total response rate, 1569

<table>
<thead>
<tr>
<th>Reasons for the change of outer glove</th>
<th>OR nurses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of responses (%)</td>
</tr>
<tr>
<td>Gloves indicated holes</td>
<td>862 (96.9)</td>
</tr>
<tr>
<td>Gloves worn for a long time</td>
<td>264 (29.7)</td>
</tr>
<tr>
<td>Contamination of outer glove</td>
<td>117 (13.1)</td>
</tr>
<tr>
<td>Before contact with implants</td>
<td>105 (11.9)</td>
</tr>
<tr>
<td>After contact with skin disinfectant or cement</td>
<td>83 (9.3)</td>
</tr>
<tr>
<td>From unclean to clean moments</td>
<td>42 (4.9)</td>
</tr>
<tr>
<td>Contact with tumors</td>
<td>20 (2.2)</td>
</tr>
<tr>
<td>Use of single gloves</td>
<td>19 (2.1)</td>
</tr>
<tr>
<td>After patient skin disinfection and draping</td>
<td>17 (1.9)</td>
</tr>
<tr>
<td>Gloves sticky with blood</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Tape or glue on the gloves</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Before applying the patient dressing</td>
<td>6 (0.7)</td>
</tr>
<tr>
<td>Change of operation field within the patient</td>
<td>4 (0.4)</td>
</tr>
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</table>

Multiple answers were possible for each OR nurse.

Staff clothing for single use at the OR departments was never used by 43.8% (390/890) of the OR nurses, but single-use sterile gowns were always used by 83.8% (746/890) (Table 13).

**Maintenance of patient body temperature perioperatively by the use of warm blankets and fluids**

The controlled OR temperature ranged between 18° and 24°C, and the three most common temperatures were 20°C (30.1%), 21°C (28.6%), and 22°C (20.8%). Blankets or mattresses with warm air were used often, 51.9% (462/890), but the incision site was not locally preheated, 82.0% (730/890). Fluids for use in the wound were sometimes preheated by 57.1% (508/890). The skin disinfection solution was always stored at room temperature, 95.5% (850/890), and the majority of the OR nurses did not preheat the skin disinfection solution before skin disinfection, 86.7% (772/890) (Table 15).
Table 15. OR nurses’ (n = 890) scaled responses regarding patient temperature preservation

| Maintenance of patient body temperature perioperative by the use of warm fluids and blankets |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Statement | Always n (%) | Often n (%) | Sometimes n (%) | Seldom n (%) | Never n (%) |
| The skin disinfection solution is stored at room temperature | 850 (95.5) | 37 (4.2) | 1 (0.1) | - | 2 (0.2) |
| The skin disinfection solution is preheated | 1 (0.1) | 1 (0.1) | 56 (6.3) | 60 (6.8) | 772 (86.7) |
| Blankets or mattresses with warm air are used | 286 (32.1) | 462 (52.0) | 106 (11.9) | 16 (1.8) | 20 (2.2) |
| Incision area is locally preheated | 16 (1.8) | 25 (2.8) | 37 (4.2) | 82 (9.2) | 730 (82.0) |
| Warm fluids are used in the wound | 31 (3.5) | 96 (10.8) | 508 (57.1) | 116 (13.0) | 139 (15.6) |

The OR nurses who used preheated skin disinfection solution had different ways of preheating it: warming cupboard, 89.1% (98/110), microwave oven, 4.5% (5/110), hot water, 3.6% (4/110), or a mix of all methods, 2.8% (3/110). The temperature of the preheated skin disinfection solution varied from 25°C to 42°C, with a mean temperature of 37°C. Those OR nurses who used preheated skin disinfection solution stated as reasons that the patient was awake, was small (children/infants), or had large areas of skin to disinfect.

**Special clothing designed to prevent spread of bacteria from staff to the surrounding air, that is, clean air suit**

Staff clothing (OR working clothing for all staff present at the OR department) for single use at the OR department was never used by 43.8% (390/890) and always used by 9.6% (85/890) (Table 13).
Discussion

Bacterial growth on patients’ skin and in the wound

It was clear that the skin disinfection did not eradicate all bacterial growth on the skin surface as wanted (study I), and that the bacteria remaining on the skin may be the cause of SSIs, together with possible exogenous bacterial air transmission from the persons within the OR. The proportions of patients with bacterial growth in the wound at wound closure were, respectively, 53.8% (36°C) and 62.5% (20°C) (study I). The amount (CFU/mL) of bacteria had tripled compared to the cultures taken after the skin disinfection (study I). Pacemaker surgery is considered to be clean surgery, but it is clear that the wounds are contaminated by bacteria consisting of *P. acnes* and CoNS (study I). Both these types of bacteria cause SSIs. To reduce SSIs, the key focus should be on improving the skin disinfection process to even further reduce the presence of bacteria, as the presence of bacteria is great both on the skin and in the wound of the surgical patients during surgery (study I). The large amount of bacteria present in the wound during cardiac device implantation in study I indicate that the contemporary skin disinfection process performed might have been insufficient. Together with the knowledge surrounding the formation of biofilm and future antibiotic resistance, it is crucial to find new interventions to enhance the skin disinfection process. Moreover, the bacteria dominating in the wound consisted mainly of CoNS and *P. acnes*, which are highly associated with SSIs involving biofilm. Preventing the skin bacteria from reaching the foreign implanted material may be the best way of preventing possible biofilm-forming SSIs.

Considering that preheated skin disinfection may have less time to affect the bacteria on the patients’ skin because of the faster vaporization, results showed that preheated skin disinfection seemed to generate somewhat less (CFU/mL) bacterial growth in the wound compared to room-temperature skin disinfection, although this was only a trend, and no statistically significant difference was shown (study I). Even though this was a non-inferiority design, analysis for differences was performed, and the statistical non-significance could be due to a type II error. In the future, it would be interesting to have a larger sample size to test whether preheated chlorhexidine leads to significantly less growth of bacteria in the wound and therefore to fewer SSIs. Melling and colleagues have reported that systemic warming of the patient reduced SSIs, and warming
locally even more so. To elaborate, warming the skin locally, together with preheated skin disinfection, could be beneficial in making the skin disinfectant solution penetrate further down into the deeper layer of the skin.

**Skin temperature**

The mean skin temperature was 32°C in both groups before the skin disinfection, which decreased the mean skin temperature in the preheated and room-temperature groups by 4.75°C and 5.49°C, respectively. The skin disinfection process alone had a large impact on the patients’ skin temperature, but preheated skin disinfection solution reduced the skin heat loss significantly. Although, core and skin temperature are different, the skin is involved in core body temperature regulation. Therefore, it is also important to use all interventions possible, including preheated skin disinfection, to prevent body heat loss and thereby to prevent hypothermia in patients, which increases the risk not only for SSIs but also for other complications such as blood loss and cardiac events.

**Experience**

The importance of the patients’ thermal comfort during hospital stay has been showed in numerous studies. The pacemaker patients were awake during the preparation and the surgical procedure (studies I and II). In clinical praxis patients often comment on the uncomfortable cold feeling they experience when the OR nurse performs the skin disinfection. Sessler and colleagues reported that little effect was achieved by preheating alcohol-based skin disinfection solutions and that interventions to reduce heat loss had to be found elsewhere. In 1977, a comment was published that described how awake patients experienced skin disinfection as cold. The comment stated that the response to preheated skin disinfection was overwhelmingly favourable, which is in concordance with a pilot study and study II. Moreover, the publication from 1977 shows that HCWs have for a long time considered room-temperature skin disinfection to be a problem with respect to patient comfort. The patients (28%) that received preheated skin disinfection in study II still desired a warmer solution. The preheated skin disinfection solution was measured to be 36°C directly taken from the warming cupboard, which gives the option to preheat up to 40°C, according to the manufacturer. To increase the temperature of the skin disinfection
solution up to 40°C may have more positive impact both on reducing bacterial growth and on patient comfort, but this has to be further investigated.

**Bacterial growth and recolonization the hands**

Study III originated from observations in clinical praxis, noticing a dark indication for moisture and fluid at the glove cuff end among the surgical team members. However, if the outer glove does not reach over the inner glove or if single gloves are used, this indication will not be visible. The indication of moisture was confirmed visually when the glove cuff ends were turned inside out (Figure 12).

![Figure 12. Moisture at the glove cuff end. Photo by Stefan B. Larsson©](image)

The interface of the gown and glove is considered a weak link, as fluids can move from the inside to the outside and vice versa.\(^{123, 124}\) The intention of the preoperative hand disinfection is to eradicate transient flora and to
reduce resident flora of the hands with a prolonged effect.\textsuperscript{125} The prolonged effect is to minimize cross-infection from the surgical team members to patients, for example, in case of punctures in the gloves.

It have been reported that recolonization occurs inside the gloves and that the bacterial counts on the hands increase with time.\textsuperscript{86, 93} Study III showed a possible trend that OR nurses had a more difficult task eradicating the bacterial growth on their hands when performing the preoperative hand disinfection. The trend (non-significant) was the opposite after wearing the sterile gloves. The non-HCWs showed higher bacterial recolonization, even though the non-HCWs wore the gloves for a significant shorter period of time.

The amount of bacterial growth found at the glove cuff end was not very high compared with the amount of bacterial growth sometimes found on the hands after wearing gloves, but this shows that the glove cuff end is a danger zone which can transfer bacterial growth, possibly from the hands; the glove cuff may also be contaminated by the hands when donning the glove.\textsuperscript{126, 127} It would be interesting to invent and test a new kind of one-piece surgical gown with the gloves attached to the sleeves. Gown size could follow the surgical glove size.

Skin flora of patients may change when they are admitted to hospitals.\textsuperscript{128} This raises the question of whether this applies to health care workers too. The surrounding environment is the same, but not the health issues. There may also be differences in bacterial growth and recolonization on the hands of OR nurses compared to those of non-HCWs due to their frequently performed preoperative hand disinfection and possible resulting skin damage.\textsuperscript{129-134}

\textbf{Preventive interventions to reduce surgical site infections}

The national guidelines, in the Handbook for Healthcare, recommend warm fluids to reduce heat loss at the OR departments. Many OR departments in Sweden have warming cupboards where personnel preheat the fluids used for intravenous or intracavity administration. The result in study IV indicated that 57\% of the OR nurses sometimes used warm fluids in the cavity. This may seem like a low proportion. However, the reason for not using warm fluids in the cavity was not investigated. The majority of the OR nurses (86.7\%) did not preheat the skin disinfection solutions, possibly because of the somewhat contradictory information regarding this possibility. The national guidelines in the Handbook for Healthcare recommend warm fluids but do not specify which fluids or
how to preheat them, nor do they specify how to administer these warm fluids.⁶ According to the Swedish environmental classification of pharmaceuticals, the skin disinfectant chlorhexidine 5 mg/ml in 70% ethanol should be stored at room temperature, no higher than 25°C.¹³⁵ The manufacturer of chlorhexidine 5 mg/ml in 70% ethanol states that this solution should be stored at room temperature but can be preheated up to 40°C for one week without any negative effects on the product.¹³⁶ To increase the use of preheated skin disinfection solution it seem like the OR nurses need support from the national guidelines, which could clearly state the possibility of preheating the skin disinfection solution. The OR nurses who preheated the skin disinfection solution stated their reasons for doing so as the patient being small or being awake during the skin disinfection process, or having large body areas to be disinfected. These reasons may originate from the idea that preheated skin disinfection solution should reduce heat loss and promote patient comfort.

The intervention regarding the prewash with chlorhexidine soap calls for it to be performed on the whole of the body including the hair, twice before surgery, normally preoperatively at the ward.⁶ Study IV showed that the majority of the OR nurses used a 4% chlorhexidine soap-containing sponge at the OR before the skin disinfection procedure started. This intervention to reduce bacterial growth is not mentioned by the national guidelines or supported by recent studies.¹³⁷, ¹³⁸ The disinfection solution manufacturer and the national guidelines emphasize the importance of the correct duration by which the skin disinfectant should affect the skin surface.⁶, ¹³⁵, ¹³⁶ Different body parts have different amounts of bacterial growth and different types of bacteria depending on the location and amount of moisture present, such as in the axillae, and therefore the time spent on skin disinfection depends on the location on the body.³⁵ In study IV the majority of the OR nurses assessed the time spent performing skin disinfection of the abdomen to be from two to five minutes. The patients’ skin should dry before being draped not only for the solution to affect the skin and for the drapes to adhere properly to the skin but also for patient safety, considering that ethanol is flammable.⁶, ⁷³ In study IV the result showed that 34% of the OR nurses did not let the skin dry completely before draping the patient, which the research team interpreted to mean when sterile wipes were used to wipe the skin dry prior to draping. The OR nurses did dry only the area that the drapes were to adhere to and not the incision site. Using sterile paper to dry the skin may increase the risk of undetected bacterial contamination.
from the surrounding area into the surgical area, but this has no evidence and needs to be investigated further. The underlying reason for not letting the skin dry was not investigated. Did the OR nurses feel pressed for time and therefore dry the skin, or was the wiping something they had learned from clinical practice? Study IV showed that the skin disinfection process was mostly learned from the supervisor (OR nurse) at the clinical practice or the instructor at the university. This requires up-to-date supervisors and instructors to provide the OR nursing students with evidence-based clinical interventions to prevent wrong and old-fashioned behaviours.

Consensus regarding plastic adhesive drapes is lacking, but the current evidence seem to go against the use of plastic adhesive drapes, with possibly more contamination in the surgical wound occurring with them. The use of plastic adhesive drapes seems to vary internationally, as it did in study IV. The fragmented use of plastic adhesive drapes in Sweden can perhaps be explained by the absence of guidelines in the Handbook for Healthcare. The national guidelines state clearly that the gowns, gloves, and patient drapes should be for single use only, with which OR nurses had high compliance (IV). The OR nurses also assessed the draping material to be highly adherent to patients’ skin during the surgical procedure (IV). This result, however, did not differentiate between the type of draping material, with or without plastic tape.

There is a lack of national guidelines for when surgical gloves should be changed or more specific guidelines to prevent individual interpretations. Studies have shown that puncture holes often occur unnoticed, and that the rate increases with time worn. Study IV showed that double gloves were always used by 73.0% of the OR nurses as recommended by the guidelines. Internationally, the trend is to support the surgical team with guidelines to change the single or outer gloves after 90 minutes of use, if no other reason exists to change them earlier; this strengthens patient safety and reduces individual interpretations, which are not always evidence based. Studies have addressed the glove cuff and gown interface as a possible route for bacterial transmission, and study III showed bacterial growth at the glove cuff end. Furthermore, the manufacturer mentions the moisture at the sleeve being unsterile. OR nurses seldom noticed visible moist at the glove cuff end (IV), which seems to reflect a rather low awareness of this risk for potential bacterial contamination. It is of importance that the outer glove reaches over the inner glove, and according to study IV, 83.3% of the OR nurses always had the outer glove reaching over the inner glove. Study IV showed that
OR nurses assessed a small or moderate bacterial recolonization under the sterile glove. Interestingly, 12.4% thought no bacterial recolonization occurred. However, it is not easy to find out the normality of the bacterial growth on the hands before or after preoperative hand disinfection and after wearing gloves, even after extensive review. The problem is complex because the methods used to discover bacterial growth are different in different studies, and the variation in bacterial growth is large from one individual to another. A conclusion drawn from studies I and III together with numerous other studies is that the skin of humans is never made totally free of bacterial growth, not with the state of contemporary knowledge.27, 37, 38, 89, 90, 113, 146-149

Methodological considerations
The strength of studies I and II was the design, a randomized controlled trial (RCT) with stratification. RCTs provide a strong internal validity because of the randomization and control of bias,150 although every study design has its weaknesses. Some weaknesses in the RCT studies were that different OR nurses performed the skin disinfection, culture swabs, and temperature measurements, which may have led to differences related to these outcomes. Men and women have significantly different amounts of bacterial growth on the skin, and this should be considered when analysing data based on bacterial counts.35 By the use of a randomized block design, the intention was to separate gender so that the groups did not become biased by the differences in skin flora. Analysis was performed between both groups, but also performed with men and women separately to investigate potential different outcomes due to gender (study I). There were significant differences between gender regarding bacterial growth at all four sampling time points, which strengthens the importance of having an equally large sample size of men and women in both groups. However, the effect of the intervention was no different for either gender (study I).

The absolute difference between the groups was zero based on bacterial growth, 28.6%, with a CI that was just outside the preset limit of 10%. Strict statistical non-inferiority has not been proven, but the merged results from study I and the statement from the manufacturer136 suggest that non-inferiority has been reached clinically and that preheated skin disinfection is not less effective than the standard room-temperature skin disinfection (study I). The follow-up regarding SSIs supports the finding that preheated skin disinfection solution was not less effective than the
room-temperature solution, in that the preheated group had one SSI versus two in the room-temperature group.

Study I had a power problem and would have needed a few more participants to reach the preset limit of 10%. The power calculation was based on a lower proportion of positive cultures, which made the sample size lack power. Another weakness of the study design was that the outcome bacterial growth was a surrogate measure for SSI. The reason for using bacterial growth instead of SSIs was to limit the sample size. A further weakness regarding the sampling technique was that the swab was moistened with saline for samples obtained from the skin; however, this was not the case for the samples taken in the wound. This may have affected the amount of CFU/mL, as the fluid in the eSwab tube may have become diluted. However, every sample became equally diluted in both groups. Future research is needed to strengthen these results with larger sample size, including other surgical specialties, and outcomes such as SSIs, with cultures as a complement. Cultures are needed to investigate and explore the understanding of SSIs so that results can confirm or refute current knowledge regarding bacterial growth and SSIs.

The choice of outcome and method for measuring temperature in study II was based on several aspects. Sampling core temperature was not suitable when patients were awake, with the discomfort associated with that kind of measurement. In a previous pilot study, skin temperature was measured using a probe that required contact with the skin and measured continuously. This was found to be time-consuming and not reliable due to the continuous measurements, which never gave a fixed temperature. The required contact of the probe with the skin would also pose a contamination risk for the patients prepared for the surgery. The probe would need to be covered with sterile plastic, which could introduce bias for reliable measurement of the skin temperature. The choice was made to measure skin temperature rather than core temperature because the skin temperature would change while performing the skin disinfection process, but the core body temperature probably would not. Considering the hygienic demands at the OR, an IR thermometer was chosen that had not been tested before in similar settings. To enhance the reliability, a specific distance of approximately 10 cm was set from the patient skin to avoid possible bias. Testing the thermometer unscientifically, repeated measurements yielded very similar temperatures. The procedure and routines for pacemaker surgery are very standardized and performed in an effective way to allow as many pacemaker surgeries as possible to be
performed in the same OR in one day. The average number of pacemaker surgery patients was five to six patients in the same OR. This standardized way of working reduces possible bias, and every patient was treated with the same routine by experienced OR staff.

The knowledge sought was whether the larger number of pacemaker patients preferred preheated skin disinfection solution compared with the standard room-temperature disinfectant. A quantitative outcome was regarded to generate a more universal result, rather than the deeper knowledge of understanding the individual experience. With that intent, the questionnaire for measuring the experience was created as a modified NRS with additional questions. A strength of the use of the NRS was that patients selected a number from zero to ten. No material rulers were used because patients’ arms were strictly by their sides to prevent bacterial contamination of the surgical area. Many patients recognize this way of measuring from pain evaluation. The questions were asked while the patients were having their skin disinfected, which reduced memory bias. A weakness of using the modified NRS was that the scale had not been validated or tested for reliability for measuring the thermal experience in these settings. In clinical practice, scales such as visual analogue scales, numerical rating scales, and verbal rating scales are frequently used and have been shown to be valid and reliable regarding pain measurement. The Cold Discomfort Scale (CDS), which is a subjective judgment scale for the assessment of patient thermal state in a cold environment, has been shown to be valid and reliable by Lundgren et al., but this study had not been published prior to the data collection. The NRS with modifications is similar in many ways to the CDS, which can strengthen, but not confirm, the modified NRS in study II. A criticism could also be that some believe that subjective experiences must be measured using qualitative methods. The choice was to operationalize subjective opinions and label them numerically, and create an instrument with certain kinds of preset definitions that the patients had to relate to in giving their answers.

The outcome in study III was bacterial growth, which was measured by the use of cultures sampled from the hands and sleeves. There were many methods to consider when deciding which sampling method to use. Different kind of swabs and methods are used in different studies. Some use agar plates to press fingers on, some use different kind of swabs that are pressed or rubbed, and some use the glove juice technique. The glove juice technique was recommended in a review by the Cochrane Collaboration. The glove juice technique was not applicable to study III.
due to the sampling at the glove cuff and gown interface. The choice was to use a swab that allowed the bacterial growth to be quantifiable. Three sites on the hand were selected for culturing that were considered more difficult to disinfect, such as the palm, between the fingers, and at the nails. To increase the reliability and minimize bias regarding the sampling technique, one person performed all the samplings in study III, according to a preset protocol. A weakness in the design was the lack of baseline regarding bacterial growth. However, the hands were thought to be heavily contaminated with a vast number of different microorganisms, both resident and transient. Damaged skin is likely to have larger amounts of bacteria compared to healthy skin.\(^{129}\) The OR nurses in study III probably had more damaged skin than the non-HCWs due to the extensive hand washing regime that OR nurses performed every day at work. Therefore, it is possible that the OR nurses had higher counts of bacteria at the start of the preoperative hand disinfection procedure, and this may have affected the result. Study III had few statistically significant differences between the groups, probably because of a power problem. The study was planned as a pilot study with few participants, to explore and test our hypothesis. The strength of only using OR nurses was that their glove sleeves did not have contact with the patients as the surgeons’ did. This strengthens the likelihood that the bacteria found under the glove sleeves originated from the OR nurses’ hands and not from the patients’ bodies.

Study IV consisted of a questionnaire constructed by the research group, which was not a validated questionnaire. The choice was made to construct the questionnaire because no suitable validated questionnaire was found that answered the aim. Face validity was reached, which means that the questionnaire seemed to measure what was intended, when tested in 10 OR nurses. In study IV, the use of a web-based questionnaire was considered both a strength and a limitation. The strength was that it was environmentally friendly and inexpensive, and the participants were at work when they answered it, which made it possible for them to control answers. The limitation was the difficulties in obtaining the email addresses. However, the survey had respondents from all 21 counties and regions in Sweden. Two regions, one in the south and the other in the middle of Sweden, had the largest response rates, with 178 and 155, respectively. The other counties and regions were fairly evenly distributed, apart from one region which generated only five respondents. The 890 OR nurses worked at 64 different hospitals from the north to the south of
Sweden. Some of the non-responses to the survey could be explained by the possibility of ‘saving’ the questionnaire while answering it. It seems it was possible to mistake this for ‘sending’. Apart from saving the answers, the respondents had to press a send button when finished. This mistake became apparent when the questionnaire reminders were sent out and respondents notified us by email that they had already answered the questionnaire. Some respondents also replied that they had been told not to open web links of unknown origin.

**Clinical implications and future studies**

This thesis has mainly focused on interventions performed by OR nurses that reduce bacterial growth on the skin in the surgical patient, with the underlying assumption that reduced bacterial growth on the skin prevent SSIs. The present study showed high compliance with national guidelines, and the implications should be to develop more evidence-based guidelines to maintain good care and enhance patient safety. This thesis has also highlighted patient satisfaction with the intervention of preheating the skin disinfection solution. The implication drawn from these results, and implemented in our OR department, should be the use of preheated chlorhexidine 5 mg/ml in 70% ethanol for patients who are awake during the skin disinfection process; this reduces heat loss and promotes a more pleasant patient experience. Moreover, the potential risk of cross-contamination via the glove cuff and gown interface needs more attention and a future solution.

Future studies should aim to test preheated chlorhexidine 5 mg/ml in 70% ethanol in a larger sample size including several surgical specialties, preferably with the outcome SSIs, but also include samples to assess the bacterial growth.

It would be interesting to enhance and try to develop a new kind of surgical gown with the sterile gloves attached to the sleeves of the gown and to clinically test the functionality of this type of gown.
Conclusions

- Preheated chlorhexidine 5 mg/ml in 70% ethanol is not less effective for skin disinfection regarding bacterial reduction compared with room-temperature disinfectant.

- Males had significantly more bacteria on the skin and in the wound than females, irrespective of the temperature of the skin disinfectant.

- A preheated skin disinfection solution reduces skin heat loss compared with a room-temperature solution.

- A preheated skin disinfection solution contributes to a more pleasant experience for the patients that are awake during the skin disinfection procedure compared to room-temperature solution.

- There were differences in bacterial growth and recolonization between the groups of OR nurses and non-HCWs, but this was inconclusive.

- Bacterial growth exists at the glove cuff and gown interface and may pose a risk for bacterial cross-contamination between patients and surgical team.

- OR nurses have high compliance with national guidelines regarding interventions to prevent SSIs, and implementing guidelines seem to be a key priority for standardizing the preventive interventions performed to reduce bacterial growth.
Svensk sammanfattning (Swedish summary)

Vid en operation finns det alltid risk för olika komplikationer där den tredje vanligaste komplikationen är postoperativ sårinfektion. Postoperativa sårinfektioner orsakas av olika bakterier som kan kontaminera såret under och efter operationen där de vanligaste bakterierna som orsakar postoperativa sårinfektioner är *Staphylococcus aureus* och koagulasnegativa stafylokokker. För att förhindra att bakterier kontaminerar såret hos patienten under operation utförs ett flertal olika åtgärder. Kontaminering och mängd av bakterier kan reduceras genom åtgärder som antibiotikaprofylax men även genom att bevara patientens kroppstemperatur, huddesinificera patientens hud, drapera patienten med steril material, aseptiskt handhavande, handdesinfektion, steril material och att använda dubbla sterilång handskar osv. Syftet med denna avhandling var att testa och beskriva olika åtgärder som svenska operationssjuksköterskor utför för att minska bakterieförekomsten och därmed förebygga postoperativa sårinfektioner hos patienter som genomgår operation samt förbättra patientupplevelsen.

Studie I och II var en randomiserad kontrollerad studie som utgår från samma patienturval, 220 pacemakerpatienter. I studie I jämfördes effekterna av uppvärmd (36°C) och rumstempererad (20°C) huddesinfectionsmedel gällande dess bakteriedödande effekt. Fyra odlingar/patient genomfördes. Odlingarna skedde på det planerat operationssnittet före huddesinfectionsmedlet och efter huddesinfectionsmedlet när huden torkat samt en odling i såret vid operationsstart och en odling i såret vid operationens slut. Postoperativa sårinfektioner följes upp efter tre månader. I studie II testades det huruvida värmd huddesinfection kylde huden mindre varvid hudtemperaturen mättes före huddesinfectionsmedlet och efter då huden torkat. Upplevelsen av huddesinfectionsmedlet gällande dess temperatur mättes med en numerisk skattnings skala som sträckte sig från 0 till 10 (0 = behagligt, 10 = obehagligt). Frågor ställdes också gällande om patienten frös och om han/hon önskade varmare, kallare eller om varmen på huddesinfectionsmedlet var bra som den var. Resultatet visade att uppvärmd huddesinfection var likvärdig gällande reducering av bakterieväxten jämfört med rumstempererad. Därutöver var värmeöptometristerna mindre i huden hos patienterna som blev desinicerade med uppvärmd huddesinfectionslösning samt att patienterna upplevde att uppvärmd huddesinfectionslösning kändes mer behagligt jämfört med den rumstempererade.

Studie IV var en enkätstudie som syftade till att beskriva vilka preventiva åtgärder svenska operationssjuksköterskor utförde dagligen i sitt kliniska arbete för att minska mängden bakterier hos patienterna som genomgår en operation. Enkätfrågorna riktade sig mot hudförberedelser, värmebevarande åtgärder och olika material som användes. Enkätan skickades ut till ca 2 200 av ca 4 000 operationssjuksköterskor i Sverige. Resultatet baserades på svaren från 890 operationssjuksköterskor. Resultatet visade stor följsamhet till de preventiva åtgärder där nationella riktlinjerna fanns framtagna men att när det saknades riktlinjer så varierade resultaten.
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Örebro University, som tillhandahållit både finansiering och arbetsplats att arbeta på.

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References


The effect of preheated versus room-temperature skin disinfection on bacterial colonization during pacemaker device implantation: a randomized controlled non-inferiority trial

Camilla Wistrand 1,4*, Bo Söderquist 2, Anders Magnusson 3 and Ulrica Nilsson 1

Abstract

Background: In clinical practice, patients who are awake often comment that cold surgical skin disinfectant is unpleasant. This is not only a problem of patients’ experience; heat loss during the disinfection process is a problem that can result in hypothermia. Evidence for the efficacy of preheated disinfection is scarce. We tested whether preheated skin disinfectant was non-inferior to room-temperature skin disinfectant on reducing bacterial colonization during pacemaker implantation.

Methods: This randomized, controlled, non-inferiority trial included 220 patients allocated to skin disinfection with preheated (36 °C) or room-temperature (20 °C) chlorhexidine solution in 70 % ethanol. Cultures were obtained by swabbing at 4 time-points; 1) before skin disinfection (skin surface), 2) after skin disinfection (skin surface), 3) after the incision (subcutaneously in the wound), and 4) before suturing (subcutaneously in the wound).

Results: The absolute difference in growth between patients treated with preheated versus room-temperature skin disinfectant was zero (90 % CI −0.101 to 0.101; preheated: 30 of 105 [28.6 %] vs. room-temperature: 32 of 112 [28.6 %]). The pre-specified margin for statistical non-inferiority in the protocol was set at 10 % for the preheated disinfectant. There were no significant differences between groups regarding SSIs three month postoperatively, which occurred in 0.9 % (1 of 108) treated with preheated and 1.8 % (2 of 112) treated with room-temperature skin disinfectant.

Conclusion: Preheated skin disinfection is non-inferior to room-temperature disinfection in bacterial reduction. We therefore suggest that preheated skin disinfection become routine in clean surgery.

Trial registration: The study is registered at ClinicalTrials.gov (NCT02260479).

Keywords: Perioperative, Skin disinfection, Bacterial growth, Non-inferiority

Background

Health-care-associated infections are a global concern for patient safety [1, 2]. With emerging antibiotic resistance, it is important to find safe preventive measures [3–5]. During clean surgery, such as pacemaker implantation, surgical site infections (SSIs) are a rare (1–1.25 %) but serious complication [6–8]. Pathogens isolated from SSIs are mainly staphylococci, both Staphylococcus aureus and coagulase-negative staphylococci, and streptococci [1, 4, 9]. Studies have shown that reducing the number of contaminating bacteria can prevent SSIs [10, 11]. Bacteria causing SSIs originate from the patient or the surgical team [12, 13]. Skin disinfection reduces the number of bacteria, thereby reducing SSIs [1]. According to the Cochrane Collaboration, there is insufficient research regarding the effects of skin disinfection [14]. In clinical practice, patients comment on the chill they experience during skin disinfection.

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skin disinfection prior to surgery. This is not only a problem of patients’ comfort; heat loss during the disinfection procedure can cause hypothermia [15]. Hypothermia causes complications including myocardial events, SSIs, coagulopathy, and prolonged hospitalization [16, 17]. A pilot study showed that preheated disinfectant seemed to be comparable to room-temperature disinfectant in reducing bacterial growth [18]. To our knowledge there are no other studies reported that have examined the effectiveness of preheated skin disinfectant on bacterial colonization or SSIs.

The primary aim of this study was to test if preheated (36 °C) skin disinfectant is non-inferior to room-temperature (20 °C) skin disinfectant regarding skin colonization. The secondary aim was to investigate whether gender had an impact on differences in bacterial colonization in the surgical wound or SSIs among patients undergoing surgery.

Methods

Study design and participants

This study was a randomized, controlled, non-inferiority trial that included 220 patients undergoing pacemaker, implantable cardioverter-defibrillator, or cardiac resynchronization therapy under local anesthesia. The study was performed at a cardiothoracic and vascular surgery department in Sweden. Inclusion criteria were age 18 years or older and ability to read and understand Swedish. Exclusion criteria were infection in an existing implanted device. The Regional Ethical Review Board of Uppsala approved the study (reference number 2012/255). Written informed consent was obtained.

Intervention and randomization

Patients were included consecutively after arriving in the operating room (OR). Enrolment to the operation was done by an external controller who had no knowledge of the present study. Patients were randomly allocated to skin disinfectant solution (chlorhexidine 5 mg/mL in 70 % ethanol, Fresenius Kabi AS, Halden, Norway) that was preheated or at room temperature. Allocation took place directly after patients provided informed consent. Patients were stratified by gender and randomly allocated based on a computer-generated randomization list made by an independent statistician. The patient and the laboratory technician that performed the analysis were blinded to the allocation.

Data collection

Patients showered twice with Descutan®, a 4 % chlorhexidine soap (Fresenius Kabi AB, Uppsala, Sweden), prior to surgery. Most patients received elective surgery and arrived at the hospital on the morning of surgery. Following standard procedures, intravenously administered antibiotic prophylaxis (cloxacillin 2 g) was given in the ward 15–30 min prior to surgery. The operating room had an average temperature of 19 °C with upward displacement ventilation. Sterile disposable surgical gowns and indicator gloves were worn by the OR team. Participants underwent skin disinfection during 2 min. The skin disinfectant was stored at room-temperature and kept at 20 °C, while the preheated skin disinfectant was stored in a warming cupboard and kept at 36 °C. The manufacturer provided a written statement that the bottles could be stored in a warming cupboard at temperatures up to 40 °C for 7 days without changing the compound.

The participants were disinfected from the cheek down and over the sternum according to routine procedures. Sterile draping was for single use only. Cultures were obtained at four time-points using a nylon-flocked swab (ESwab, COPAN Italia S.p.A., via Perotti 10, Brescia, Italy); 1) before skin disinfection on the skin surface, 2) after skin disinfection on the skin surface, 3) directly after the incision (subcutaneously in the wound), and 4) before closing with sutures (subcutaneously in the wound). Swabs for cultures were moistened with saline then rubbed for 15 s on the skin surface (incision site, approximately 10 mm × 50 mm). Swabs taken in the wounds were rubbed along the inside of the incision and along the edges for 15 s with a dry swab. Surgery was performed by a cardiologist. Cultures were kept cold until their arrival at the laboratory then analysed according to a specific study protocol.

The swabs were vortexed for a few seconds and 50 µl aliquots of the liquor transportation media was subcultured in hematin agar medium 4.3 % (w/v) (Columbia Blood Agar Base, Acumedia Neogen Corporation, Lansing, MI, USA) supplemented with 6 % (v/v) chloro-latized defibrinated horse blood and incubated at 36 °C under aerobic conditions. Samples were also subcultured on FAA plates (LAB 90 Fastidious Anaerobe Agar 4.6 % (w/v); LAB M Ltd., Lancashire, UK) supplemented with 5 % (v/v) defibrinated horse blood and incubated under anaerobic conditions (10 % H2, 10 % CO2, 80 % N2) at 37 °C for 5 days. After 24 and 48 h of incubation under aerobic conditions or 5 days under anaerobic conditions, bacterial growth was determined quantitatively (colony forming units [cfu]/mL). Culture diagnostics and species verification were performed based on characteristic colony morphology, and using routine diagnostic procedures.

Patient follow-up

After surgery, all patients were followed-up for three months to detect SSIs, which were defined according
to the United States Centers for Disease Control and Prevention (CDC) criteria for SSI [1].

Statistical analyses
Analyses were performed using SPSS, version 22. The primary outcome was based on a non-inferiority hypothesis, and the sample size was guided by an earlier study [18]. A sample size of 102 participants per group provided 80 % power at a one-sided significance level of 5 % with an expected proportion of bacterial growth of 0.09 and the maximal allowable difference of 0.10 non-inferiority limit, which means that a proportional difference of no more than 0.10 in favour of the pre-heated disinfectant was accepted as non-inferiority. To cover potential missing data, the sample size was increased by 16 participants for a total of 220 participants divided into two groups. Due to a non-inferiority hypothesis, the absolute difference of the primary outcome was supplemented with a two-sided 90 % confidence interval (CI); otherwise, a regular two-sided 95 % significance level of 5 % was used.

Bacterial counts and other non-normally distributed variables were analysed with the Mann–Whitney U test and normally distributed variables with an unpaired t-test. Categorical variables were evaluated with $\chi^2$ -test or Fisher’s exact test as appropriate.

Results
Recruitment
Between January 2013 and November 2014, 220 patients receiving pacemakers were enrolled and randomly allocated to receive skin disinfectant that was preheated ($n = 108$) or at room-temperature ($n = 112$). Patients were followed for three months after surgery (Fig. 1). Characteristics that are known risk factors affecting SSI are; diabetes, eczema, age and others (Table 1).

Bacterial growth
One hundred and one of 106 (95.3 %) skin cultures taken before receipt of preheated skin disinfectant showed growth compared with 108 of 112 (96.4 %) taken before receipt of room-temperature disinfectant. Thirty of 105 (28.6 %) skin cultures after receipt of preheated skin disinfectant showed growth compared with 32 of 112 (28.6 %) receiving room-temperature skin

![Flow chart](image-url)
disinfectant. The absolute difference in growth was zero (90 % CI –10.1 to 10.1) (Table 2). Microorganisms identified before skin disinfection included *Propionibacterium acnes*, coagulase-negative staphylococci (CoNS), alpha-haemolytic streptococci, anaerobic diphtheriod rods, *Bacillus* species, *Micrococcus* species, *Staphylococcus aureus*, anaerobic gram-positive cocci, *Proteus* species, and *Rothia mucilaginosa*. At subsequent time points, the amount of different bacteria and the number of bacteria changed (Fig. 2). The most frequently identified pathogen after skin disinfection both on the skin and in the wound was *P. acnes* followed by CoNS (Table 3). No significant differences were observed in any of the cultures at the 4 time-points regarding growth or median or mean cfu/mL between the groups (Table 4).

### Gender

Cultures showed that males had significantly more bacteria at the four time-points than females irrespectively of the temperature of the skin disinfectant. Gender differences at the first time-point appeared in both the preheated (*p* = 0.011) and room-temperature disinfectant groups (*p* = 0.037). A gender difference was also seen during the second, third, and fourth time-point (*p* ≤ 0.001). Analyses performed on the overall group or with males and females separately showed no significant differences regarding disinfection with preheated or room-temperature disinfectant (Table 4).

### Surgical site infections

There were no significant differences in SSIs three months postoperatively between patients who received preheated versus room temperature skin disinfectant; 1 (female) of 108 (0.9 %) vs 2 (1 male and 1 female) of 112 (1.8 %), respectively. At the time of surgery, samples from females showed growth only before skin disinfection, whereas the male displayed growth of *P. acnes* at all four time-points and CoNS at the first and last time points. Cultures taken postoperatively, when patients were diagnosed for SSI, were negative for both female patients, whereas the cultures from the male patient were positive for *S. aureus*, CoNS, *P. acnes*, and beta-haemolytic streptococci group G.

### Discussion

#### Bacterial growth

In this study, no significant differences were found related to the presence of bacteria, confirming that preheated and room-temperature skin disinfectant have similar bactericidal effects, as shown in our previous pilot study [18]. The results clearly show that preheated

### Table 1 Patients baseline characteristics and surgical factors

<table>
<thead>
<tr>
<th>Skin disinfection (chlorhexidine 5 mg/mL in 70 % ethanol)</th>
<th>36 °C</th>
<th>20 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics</strong></td>
<td><strong>36 °C</strong></td>
<td><strong>20 °C</strong></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>72 (11.9)</td>
<td>74 (12.5)</td>
</tr>
<tr>
<td>Body mass index (BMI), mean (SD)</td>
<td>27 (4.5)</td>
<td>27 (5.4)</td>
</tr>
<tr>
<td>Length of surgery, minutes, median (IQR)</td>
<td>33 (30)</td>
<td>34 (32)</td>
</tr>
<tr>
<td>Colony forming units, median (IQR)</td>
<td>1180 (4690)</td>
<td>2080 (4770)</td>
</tr>
<tr>
<td>Male, %</td>
<td>55</td>
<td>57</td>
</tr>
<tr>
<td>Eczema, %</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Incision site hair shorten, %</td>
<td>31</td>
<td>26</td>
</tr>
<tr>
<td>Diabetes, %</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Bacterial skin growth, %</td>
<td>95</td>
<td>96</td>
</tr>
</tbody>
</table>

#### Table 2 Bacterial growth at the four time points

<table>
<thead>
<tr>
<th>Skin disinfection (chlorhexidine 5 mg/mL in 70 % ethanol)</th>
<th>All</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 °C</td>
<td>20 °C</td>
<td>Absolute difference</td>
<td>36 °C</td>
</tr>
<tr>
<td>n = 106</td>
<td>n = 112</td>
<td>(90 % CI)</td>
<td>n = 62</td>
</tr>
<tr>
<td>Before skin disinfection</td>
<td>95.3</td>
<td>96.4</td>
<td>100</td>
</tr>
<tr>
<td>After skin disinfectiona</td>
<td>28.6</td>
<td>28.6</td>
<td>0 (–0.101 to 0.101)</td>
</tr>
<tr>
<td>After incision (wound)</td>
<td>24.5</td>
<td>30.4</td>
<td>–0.059 (–0.158 to 0.040)</td>
</tr>
<tr>
<td>Before wound closure (wound)</td>
<td>53.8</td>
<td>62.5</td>
<td>–0.087 (–0.197 to 0.023)</td>
</tr>
</tbody>
</table>

Proportion of swabs from patients that showed any bacterial growth at the various time points. Data are shown as percentages and absolute difference with confidence intervals (CI)
aPrimary outcome
Fig. 2 Bacterial growth before and after skin disinfectant. Bacterial growth before and after treatment with skin disinfectant (chlorhexidine 5 mg/mL in 70 % ethanol) at the four time points. The median is identified by a line inside the box. The length of the box is the interquartile range (IQR), and whiskers are min and max if no outliers are present. Outliers of more than 1.5 IQR’s are labeled as (o) and outliers of more than three IQR are labelled as (*)

Table 3 Species of bacteria identified

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Culture 1</th>
<th>Culture 2</th>
<th>Culture 3</th>
<th>Culture 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36 °C</td>
<td>20 °C</td>
<td>36 °C</td>
<td>36 °C</td>
</tr>
<tr>
<td></td>
<td>n = 106</td>
<td>n = 112</td>
<td>n = 105</td>
<td>n = 112</td>
</tr>
<tr>
<td>P. acnes</td>
<td>83</td>
<td>86</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>CoNS</td>
<td>83</td>
<td>90</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>S. aureus</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Alpha-haemolytic</td>
<td>9</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anaerobic diphtheroid rods</td>
<td>5</td>
<td>3</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Bacillus species</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Micrococi</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anaerobic gram-positive cocci</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Proteus sp.</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R. mucilaginosa</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

No significant differences between study groups for any microorganism at any time point. Chi-2 test were used as statistical method. Bacterial species identified from swabs taken from patients who received preheated and room-temperature skin disinfectant (chlorhexidine 5 mg/mL in 70 % ethanol) with growth in cultures taken perioperatively; 1) before skin disinfection, 2) after skin disinfection, 3) after incision (wound), and 4) before skin closure (wound).
Skin disinfection (Chlorhexine 5 mg/mL in 70% ethanol) was applied to all men and women at the same time-points than females irrespectively of temperature. Mann Whitney U test used as statistical method. Cultures showed that male had significantly more bacteria at all four time-points than females irrespectively of temperature. Mann Whitney U test used as statistical method.

Supports that finding [12, 24]. The effectiveness of preheated or room temperature skin disinfectant was shown in earlier studies [23]. The most frequently identified bacteria in the wound after disinfection was *P. acnes*, which also inhabits deeper layers of the skin [19, 20]. A possible explanation is that when the incision is made, deeper layers of the skin are exposed and *P. acnes* relocate into the wound [20]. *P. acnes* can be a causative factor of SSIs [20–23].

### Gender

Earlier studies have shown that the amount of bacteria differs between males and females and this study supports that finding [12, 24]. The effectiveness of preheated or room temperature skin disinfectant was equivalent.

### Surgical site infections

The male patient who experienced SSI showed growth in cultures taken at all four time-points. Two other species of bacteria, *S. aureus* and beta-haemolytic streptococci group G, were also found when the SSI was diagnosed. These species were not present at the time of surgery. Cultures taken postoperatively to determine the causative pathogens were negative in the female patients with SSIs. According to the criteria, SSI could be diagnosed as purulent drainage, fever, tenderness, and usually a positive culture or diagnosed as SSI by the attending physician [1]. The reason these cultures did not show any growth could possibly be due to an ability of the bacteria to protect themselves with biofilm [19], but also because *P. acnes* has a slow-growing nature [23].

### Limitations

There are limitations to this study. First, this study had a power problem related to the population size because the power calculation was made based on 10% growth, whereas in the present study the patients showed 28.6% bacterial growth after skin disinfection. Secondly, this study was designed as a non-inferiority trial to detect differences in bacterial contamination, not to detect differences in SSIs.

In conclusion, recommendations aimed at preventing SSIs should be evidence based [25]. The assumption that preheated skin disinfection is non-inferior to room-temperature disinfectant in bacterial reduction appears to be correct. We therefore suggest that preheated skin disinfection can be used routinely prior to clean surgery. Additional studies involving other types of surgery, including those affecting other body sites and levels of complexity and length, are warranted.

### Competing interests

B. Söderquist has been a consultant for Pfizer and Janssen-Cilag. Otherwise, the authors have no financial, personal, or other relationship that could be viewed as presenting a potential conflict of interests.

### Authors’ contributions

All named authors have seen and agreed to the submitted version of the manuscript. BS was responsible for the protocol and the main author. BS and UN supervised the writing and was also involved in the planing of the manuscript. Authors

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Skin disinfection (Chlorhexine 5 mg/mL in 70% ethanol) All Men Women

positive culture or diagnosed as SSI by the attending

Cultures taken postoperatively to determine the causative

These species were not present at the time of surgery.

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Limitations

Surgical site infections

bacteria differs between males and females and this study

Earlier studies have shown that the amount of bac-

...ber of bacteria on the skin and prevent SSIs equally well.

disinfectant at the four perioperative time-points. Data were combined for the overall group and for males and females separately

U

No statistically significant differences between preheated and room-temperature skin disinfectant within study groups at any time point evaluated for all patients

Wistrand

23.


Positive impact on heat loss and patient experience of preheated skin disinfection: a randomised controlled trial

Camilla Wistrand, Bo Soderquist and Ulrica Nilsson

Aims and objectives. The aim of this study was to compare the effect of preheated (36°C) and room-temperature (20°C) skin disinfectant solution on skin temperature and patients' experience of the skin disinfection process.

Background. To prevent surgical site infections, it is important to disinfect skin prior to invasive surgery. In clinical practice, conscious patients often comment on the coldness of the preoperative skin disinfection solution. Evidence is lacking, as to whether preheated skin disinfectant has any positive effects during preoperative skin disinfection.

Design. Randomised controlled trial.

Methods. A total of 220 patients undergoing pacemaker, implantable cardioverter-defibrillator, or cardiac resynchronisation therapy under local anaesthesia were included and randomly allocated to preheated or room-temperature skin disinfection. Skin temperature was assessed before and after skin disinfection at the planned incision site; in addition, three study-specific questions were used to assess how patients experienced the temperature.

Results. Patients experienced the skin disinfection process with preheated disinfectant as significantly more pleasant. They felt less cold and reported increased satisfaction with the temperature of the solution compared to patients who were disinfected with room-temperature solution. Skin disinfection with preheated solution also yielded a significantly higher mean skin temperature compared to room-temperature solution.

Conclusions. Preoperative skin disinfection with preheated disinfectant may prevent heat loss and contribute to a more pleasant experience for patients.

Relevance to clinical practice. Skin disinfection with preheated skin disinfectant is an easy and inexpensive nursing intervention that has a positive impact on heat loss and on patients' experience of the disinfection process.

Key words: experience, intraoperative, perioperative, randomised controlled trial, skin disinfection, temperature

What does this paper contribute to the wider global clinical community?

• The use of preheated skin disinfectant may reduce heat loss during preoperative skin disinfection.

• Patients experience preheated skin disinfectant during the disinfection process as more pleasant; it makes them feel less cold and increases satisfaction with the temperature of the disinfection solution compared to disinfection with room-temperature solution.

• Skin disinfection with preheated disinfectant is an easy and inexpensive nursing intervention that can influence patients' safety and well-being.
Positive impact on heat loss and patient experience of preheated skin disinfection: a randomised controlled trial

Camilla Wistrand, Bo Söderquist and Ulrica Nilsson

Aims and objectives. The aim of this study was to compare the effect of preheated (36 °C) and room-temperature (20 °C) skin disinfectant solution on skin temperature and patients’ experience of the skin disinfection process.

Background. To prevent surgical site infections, it is important to disinfect skin prior to invasive surgery. In clinical practice, conscious patients often comment on the coldness of the preoperative skin disinfection solution. Evidence is lacking, as to whether preheated skin disinfectant has any positive effects during preoperative skin disinfection.

Design. Randomised controlled trial.

Methods. A total of 220 patients undergoing pacemaker, implantable cardioverter-defibrillator, or cardiac resynchronisation therapy under local anaesthesia were included and randomly allocated to preheated or room-temperature skin disinfection. Skin temperature was assessed before and after skin disinfection at the planned incision site; in addition, three study-specific questions were used to assess how patients experienced the temperature.

Results. Patients experienced the skin disinfection process with preheated disinfectant as significantly more pleasant. They felt less cold and reported increased satisfaction with the temperature of the solution compared to patients who were disinfected with room-temperature solution. Skin disinfection with preheated solution also yielded a significantly higher mean skin temperature compared to room-temperature solution.

Conclusions. Preoperative skin disinfection with preheated disinfectant may prevent heat loss and contributes to a more pleasant experience for patients.

Relevance to clinical practice. Skin disinfection with preheated skin disinfectant is an easy and inexpensive nursing intervention that can influence patients’ safety and well-being.

Key words: experience, intraoperative, perioperative, randomised controlled trial, skin disinfection, temperature

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• The use of preheated skin disinfectant may reduce heat loss during preoperative skin disinfection.
• Patients experience preheated skin disinfectant during the disinfection process as more pleasant; it makes them feel less cold and increases satisfaction with the temperature of the disinfection solution compared to disinfection with room-temperature solution.
• Skin disinfection with preheated disinfectant is an easy and inexpensive nursing intervention that can influence patients’ safety and well-being.
Introduction

Patient safety- and health care-associated infections are of international concern (Mangram et al. 1999, World Health Organization 2011). There are different strategies to reduce surgical site infections (SSIs), such as the use of basic hygiene procedures, controlled operating room ventilation, sterile material, surgical techniques, antibiotics, nor-mothermia and surgical skin disinfection (Mangram et al. 1999).

However, there is no consensus regarding which type of skin disinfection is the most effective. Irrespective of which disinfection solution is used, it should prevent or at least reduce SSIs. The most widely used disinfection solutions are iodine/iodophors (aqueous or alcoholic) and alcohol and chlorhexidine gluconate (aqueous or alcoholic) (Dumville et al. 2013).

Some invasive procedures, such as pacemaker device implantation, are generally performed under local anaesthesia, meaning that the patient is awake during skin disinfection. In clinical practice, conscious patients often comment that room-temperature skin disinfectant in the operating room feels cold. This is not only a problem with respect to the patients’ comfort; heat loss during disinfection can result in hypothermia. For conscious patients, it may be preferable to use preheated skin disinfectant to increase their comfort (Kurz et al. 1996, Wistrand & Nilsson 2011). Even mild hypothermia can cause complications such as SSIs (Kurz et al. 1996), and actively keeping patients warm may reduce the likelihood of SSIs (Melling et al. 2001).

Background

To prevent SSIs, it is important to disinfect skin prior to invasive surgery or other procedures that comprise perforation of the skin, such as central vein catheterisation, epidural catheter anaesthesia or placing drain tubes (Dumville et al. 2013). Depending on clinic routines, different skin disinfection solutions are used. Solutions can have a cooling effect on the skin, and heat is drawn from the skin as it dries. If the skin disinfectant used contains alcohol, the effect is even more enhanced, since alcohol evaporates more readily than water, resulting in a potentially greater heat loss (Sessler et al. 1993). The impact of thermal sensation is different on different parts of the body; the back and chest seem to be most sensitive to changes in temperature (Zhang et al. 2004). Most patients are satisfied with the care they receive in the operating room (Leinonen et al. 2001, 2003, Bäckström et al. 2006, Tinnfält & Nilsson 2011); however, some patients experience the sensation of being cold, especially when undergoing surgery with local anaesthesia (Leinonen et al. 1996, 2001, Tinnfält & Nilsson 2011). Guidelines regarding perioperative skin disinfection directly before surgery are important for the prevention of SSIs (Mangram et al. 1999). According to FASS (Swedish Medicines Compendium for healthcare professionals), chlorhexidine 5 mg/ml in ethanol should be applied to the incision site for two minutes and then the skin should be allowed to dry (FASS 2015).

Reports of patients’ experience of skin disinfection are lacking, as well as reports on the effects of increasing the temperature of disinfectant solutions. In a pilot study by Wistrand and Nilsson (2011), preheated and room-temperature skin disinfection was performed on 10 healthy volunteers. The study showed that preheated skin disinfectant was experienced as more pleasant and less cold compared to room-temperature disinfectant. Furthermore, there was a significant difference in skin temperature before and after disinfection when using a room-temperature solution, whereas there was no significant difference in skin temperature before and after disinfection with preheated skin disinfectant (Wistrand & Nilsson 2011). This is an important finding, since even mild perioperative hypothermia can cause a number of complications, such as morbidity myocardial events, surgical wound infections, coagulopathy and prolonged hospitalisation (Kurz et al. 1996, Flores-Maldonado et al. 2001, Moslemi-Kebria et al. 2012). A possible means by which hypothermia could cause SSIs is by impairing the phagocytic capacity of neutrophils and their oxidative killing (Wenisch et al. 1996, Fairchild et al. 2000, Qadan et al. 2009). Hypothermia causes peripheral vasoconstriction which can cause tissue hypoxia (Hopf et al. 1997) and thereby reduce phagocytic killing (Qadan et al. 2009).

The aim of this study was to compare preheated (36 °C) with room-temperature (20 °C) skin disinfectant solution. We focused on changes in skin temperature before and after skin disinfection and on patients’ experience with skin disinfection.

Methods

Study design and participants

This study was the second part of a randomised controlled trial that included 220 patients undergoing implantation with pacemaker, implantable cardioverter-defibrillator or cardiac resynchronisation therapy devices under local anaesthesia. The aim of the first part of the study was to
evaluate bacterial growth (Wistrand et al. 2015). The study was performed at the Department of Cardiothoracic and Vascular Surgery at the University Hospital in Örebro, Sweden, between January 2013 and November 2014. Inclusion criteria were age 18 years or older and the ability to read and understand Swedish. Exclusion criteria included infection in an existing implanted device. The study was registered at FoU Sweden (110071) and Clinicaltrials.gov (NCT02260479).

**Intervention and randomisation**

Patients were randomly allocated to preheated (36 °C) skin disinfection (chlorhexidine 5 mg/ml in 70% ethanol; Fresenius Kabi AS, Halden, Norway) or room-temperature (20 °C) skin disinfection (chlorhexidine 5 mg/ml in 70% ethanol; Fresenius Kabi AS). The temperature of the unheated skin disinfection solution was 20 °C, which was the actual temperature of the solution when stored in the operating room (OR). After being stored in a warming cupboard, the preheated solution had a controlled temperature of 36 °C. Patients were included consecutively when they arrived at the OR. Patient enrolment for surgery was made by an external controller who did not have close knowledge of this study. All patients were asked to participate in the sequence in which they arrived at the OR department if the research assistant nurse was present. Allocation took place directly after patients gave their informed consent. Patients were stratified by gender and thereafter randomly allocated to the intervention or control group based on a computer-generated randomisation list made by an independent statistician. Patients were not informed as to whether they received preheated skin disinfection or not.

**Procedure**

Patients were undergoing elective surgery and arrived at the hospital on the morning of the surgery. Patients waited in at the ward and were brought to the OR immediately before the procedure. Data collection was performed in the OR, with a temperature of 19 °C with upward displacement ventilation. The patients were placed upon an operating table under a blanket, and they wore a gown backward so that their chest could be easily exposed. Before skin disinfection, the blanket and gown were folded down until the chest was bare from below the head to just below the sternum. The participants’ skin was disinfected from the cheek downward over the sternum and toward the left shoulder.

The procedure was in accordance with the clinic’s routine, which is to disinfect the planned incision site area with a cotton swab saturated with chlorhexidine 5 mg/ml in ethanol held with a forceps, beginning in the middle and continuing outward, changing cotton swabs when returning to the middle. Both groups underwent skin disinfection for two minutes with the same amount of solution on 10 cotton swabs. The room-temperature skin disinfection solution was stored at room temperature, and kept at 20 °C, while the preheated disinfection solution was stored in a warming cupboard and kept at 36 °C. The manufacturer provided a written statement that the bottles could be stored in a warming cupboard at up to 40 °C for seven days without changing the compound.

**Outcome measures**

Skin temperature was measured at two time-points, before and after skin disinfection, at the planned incision site on the left side below the clavicle, with an infrared (IR) thermometer (CIR8819; Injektor, Stockholm, Sweden) held approximately 10 cm from the skin. The IR thermometer had two IR dots that indicated where on the skin the temperature was being measured. Patients’ experience of the disinfection process was measured by means of a numeric rating scale (NRS) with anchor words from positive to negative (0, pleasant to 10, unpleasant). A similar scale [a visual analogue scale (VAS) composed of rulers with a slider indicator] had been used in a previous pilot study by Wistrand and Nilsson (2011) but was changed in the present study to an NRS because patients had difficulty indicating where to place the VAS slider since they were unable to use their arms once skin disinfection had been performed. The following questions were asked in accordance with a written protocol at the start of the skin disinfection procedure.

- ‘On a scale of 0 to 10, where 0 is pleasant and 10 is unpleasant, how are you experiencing the temperature of the skin disinfectant?’
- ‘Are you cold now?’ (answered by YES or NO)
- ‘If you could choose, would you like the skin disinfection solution to be; warmer, colder or as it is?’

None of the patients received any sedative drugs before answering the questions. When the questions had been answered and the skin was completely dry, skin temperature was measured again in the same manner as above with the IR thermometer. All measurements were performed by or with the help of the research assistant nurse.
Ethics

The trial was performed in accordance with the ethical principles of the Declaration of Helsinki 1996 (World Medical Association 2013). Participants were given written and verbal information about the voluntary nature of participation and the right to withdraw at any time, with no need to explain. Informed consent was obtained from all participants before the start of the study, and confidentiality was assured. Approval for this study was received from the Regional Ethical Review Board of Uppsala (reference number 2012/255).

Statistical analysis

Analysis was performed with SPSS, version 22 (New York, NY, USA). A sample size of 220 participants was chosen in the first part of this randomised controlled study and was based on the expected proportion of bacterial growth (Wistrand et al. 2015) and (ClinicalTrials.gov, NCT02260479) following a power analysis and on experience gleaned from a previous pilot study (Wistrand & Nilsson 2011). The pilot study detected significant differences in both patients’ experiences and skin temperature; thus, we decided that 220 participants were sufficient to investigate patients’ experiences and skin temperature in the present study.

Student’s t-test was used for analysis of skin temperature, and the NRS was analysed with the Mann–Whitney U test. Categorical variables were evaluated with chi-square test or Fisher’s exact test when appropriate. Descriptive statistics are presented as mean, median, number, percentage, confidence interval and standard deviation. A p-value of <0.05, two tailed, was considered statistically significant.

Results

Recruitment

Skin temperature was obtained from 220 patients, with data missing for two patients. Two hundred and sixteen patients answered the NRS, and 199 patients answered the closed-ended questions. Missing data could be explained by difficulties in hearing and understanding questions, often due to being nervous or tense, with a many disrupting elements in the environment (Fig. 1). There were no differences between the groups in terms of age, or gender (Table 1).

Temperature

All patients received preoperative skin disinfection directly before surgery. Patients who received preheated skin disinfection had a higher mean skin temperature than the room-temperature group, 27.25 °C vs. 26.51 °C. The difference in skin temperature between the groups was 0.74 °C (p = 0.001, 95% confidence interval (CI), −1.2 to −0.3). There were no significant differences in skin temperature between men and women.

Experience

According to the NRS results, patients experienced preheated skin disinfectants as more pleasant than room-temperature skin disinfectant (Table 2). The median NRS value was two compared to five in the room-temperature group (p ≤ 0.001) (Fig. 2).

Ten of 99 (10%) patients felt cold during disinfection with preheated skin disinfectant vs. 25 out of 101 (25%) in the room-temperature skin disinfectant group (p = 0.006). Twenty-eight of 99 (28%) patients in the preheated disinfectant group expressed a desire for warmer skin disinfectant solution compared to 55 of 100 (55%) in the room-temperature disinfectant group (p ≤ 0.001). Furthermore, a significantly higher number of patients in the preheated compared to room-temperature group were satisfied with the temperature of the skin disinfection solution: 71 of 99 (72%) vs. 45 of 100 (45%) (p ≤ 0.001). None of the 220 patients indicated a preference for cooler skin disinfectant when asked (Fig. 3).

Gender did not seem to play a role in how patients experienced the temperature of the skin disinfectant. There were no significant differences between genders in either disinfectant group.

Discussion

Experienced temperature

In 1977, a comment was published that described how conscious patients experience room-temperature skin disinfectant as cold: it stated that the response to preheated skin disinfectant was overwhelmingly favourable. This publication provided no scientific evidence, but it shows that care givers have for a long time considered room-temperature skin disinfectant to be a problem with respect to patient satisfaction (Restall & Schmidt 1977). In the present study, patients preferred preheated skin disinfection solution to
room-temperature skin disinfection solution. This finding is in concordance with the results of a previous pilot study (Wistrand & Nilsson 2011). It is possible that preheating skin disinfectant to a temperature of ≥36 °C would have been experienced as even more satisfactory, since 28% of the patients wanted a warmer solution when they were undergoing skin disinfection with the preheated 36 °C solution. Fresenius Kabi AS, the manufacturer of chlorhexidine 5 mg/ml in 70% ethanol, has stated that it is stable and that the compound will not change when heated up to 40 °C. This affords us the option of preheating the solution to an even higher temperature if desired. Alcohol has a cooling effect when it is drying (Sessler et al. 1993), but when skin disinfectant with alcohol is preheated, the sudden feeling of coldness can be prevented. Patients’ subjective experience regarding the temperature in the present study is supported by the temperature measured on the skin after the disinfection procedure, which showed significantly higher temperatures after disinfection with preheated disinfectant.
Table 1 Comparison of baseline patient characteristics between preheated and room-temperature skin disinfectant groups (disinfectant at 36 and 20 °C respectively)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Preheated</th>
<th>Room-tempered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean ± SD</td>
<td>72 ± 11.9</td>
<td>74 ± 12.5</td>
</tr>
<tr>
<td>Skin temperature (°C), mean ± SD</td>
<td>32 ± 1.2</td>
<td>32 ± 1.1</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>57 (62)</td>
<td>55 (62)</td>
</tr>
<tr>
<td>Women</td>
<td>43 (46)</td>
<td>45 (50)</td>
</tr>
<tr>
<td>Type of surgery, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device change</td>
<td>45.4 (49)</td>
<td>46.4 (52)</td>
</tr>
<tr>
<td>DDD</td>
<td>35.2 (38)</td>
<td>36.6 (41)</td>
</tr>
<tr>
<td>VVI</td>
<td>6.5 (7)</td>
<td>6.3 (6)</td>
</tr>
<tr>
<td>ICD</td>
<td>1.9 (2)</td>
<td>3.6 (4)</td>
</tr>
<tr>
<td>CRT</td>
<td>1.9 (2)</td>
<td>1.8 (2)</td>
</tr>
<tr>
<td>Other</td>
<td>9.2 (10)</td>
<td>5.4 (7)</td>
</tr>
</tbody>
</table>

DDD, dual chamber rate adaptive pacemaker; VVI, single ventricular rate adaptive pacemaker; ICD, implantable cardioverter-defibrillator; CRT, cardiac resynchronisation therapy; SD, Standard deviation. Continuous and dichotomous variables were analysed using t-test and Mann-Whitney U test; no significant differences between groups.

**Outcome measurements**

**Skin temperature**

To our knowledge, no other studies have investigated patients’ experience of skin disinfection with preheated solution, with the exception of our previous pilot study. For this reason, it was difficult to determine which standardised thermometers to use, since no IR thermometers had been used and validated previously in this setting. Only a few thermometers were considered to be suitable for data collection at the time of the study. The intention was to measure skin temperature and not core temperature, because the core temperature is not likely to change during local anaesthesia. The thermometer had to be easy to clean, and it could not be in contact with the skin when measuring temperature, since the skin was disinfectant prior to surgery. Digital thermometers that had to be in contact with the skin were rejected because of the risk of contaminating the incision site before surgery. Because the patients were awake, thermometers used in the nasopharynx would not have been appropriate, because of the discomfort associated with having a tube in the nose. The decision to use an IR thermometer was also based on our experience in a previous pilot study (Wistrand & Nilsson 2011), in which a digital thermometer was used. Using this thermometer was time consuming, and we were concerned that it might not be entirely sterile. An IR thermometer was therefore judged to be the best choice, as it is easy to use and measures skin temperature quickly and, in our experience, reliably.

**Experience**

The NRS has been validated for the measurement of pain (Price et al. 1983, 1994). However, in the present study,
Gender, Type of surgery, Age (years), mean

Skin temperature

Table 1

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>Skin disinfection (chlorhexidine 5 mg/ml in 70% ethanol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDD</td>
<td>Room-tempered 20°C, Preheated 36°C, Other 9°C</td>
</tr>
<tr>
<td>VVI</td>
<td>Room-tempered 20°C, Preheated 36°C, Other 9°C</td>
</tr>
<tr>
<td>CRT</td>
<td>Room-tempered 20°C, Preheated 36°C, Other 9°C</td>
</tr>
<tr>
<td>Other</td>
<td>Room-tempered 20°C, Preheated 36°C, Other 9°C</td>
</tr>
</tbody>
</table>

-_preheated (n = 99) or room-temperature (n = 100) skin disinfectant, patients were asked, ‘If you could choose, would you like the skin disinfection solution to be warmer, colder, or as it is?’ Bars show the number of patient responses regarding the temperature of the skin disinfectant with three choices. Variables were analysed using chi-square test, and there was a significant difference between the groups (p ≤ 0.001).

this scale was modified to measure thermal sensation. The intent was to measure patients’ experience of the temperature of the disinfection solution in the same manner as in the pilot study (Wistrand & Nilsson 2011). Patients did not seem to have any difficulty understanding how to use the scale, and many of them recognised it from clinical use in pain evaluation. In a recent study by Lundgren et al. (2014), the cold discomfort scale (CDS) was tested for psychometric properties and was found to be reliable and valid. The CDS is based on the NRS and was modified to assess the thermal state of patients in cold environments. The CDS is very similar to the modified NRS used in the present study (Lundgren et al. 2014).

Future research

Conscious patients may benefit from preheated skin disinfectant, because warming the incision site may reduce SSIs (Melling et al. 2001). Therefore, reducing local heat loss should be beneficial for patient safety. Whether the difference in skin temperature after preheated vs. room-temperature skin disinfection leads to reduced numbers of SSIs remains to be tested. Hypothetically, if preheated skin disinfection solution maintains open pores in the skin, disinfectant could penetrate deeper, thereby reaching a deeper layer of the skin and killing resident bacteria further down.

It would also be interesting to determine if preheated skin disinfectant reduces the vasoconstriction that may occur locally when the skin is prepared and whether this might lead to better oxidative saturation in the tissue.

Conclusion

Preheated skin disinfection (36 °C) with a solution of chlorhexidine 5 mg/ml in 70% ethanol prevented heat loss to a greater extent and contributed to a more pleasant experience for patients with respect to the disinfection process compared to skin disinfection with room-temperature (20 °C) chlorhexidine.

Relevance to clinical practice

The safety and well-being of patients during surgical interventions are primary concerns for OR nurses. Preheated skin disinfection is an easy and inexpensive nursing intervention that can influence safety and well-being by its positive impacts on heat loss and on patients’ experience of the disinfection process. Preheated skin disinfection can be used to improved patients’ experience in many different clinical settings, such as emergency rooms, intensive care units and wards, when patients are conscious and there is a need for skin disinfection.

Acknowledgements

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Disclosure

The authors have confirmed that all authors meet the ICMJE criteria for authorship credit (www.icmje.org/ethical_author.html), as follows: (1) substantial contributions to conception and design of the study or acquisition, analysis, and interpretation of data; (2) drafting the article or revising it critically for important intellectual content and (3) final approval of the version to be published.

Conflict of interest

B. Söderquist has been a consultant for Pfizer and Janssen-Cilag. Besides that, the authors have no financial, personal or other relationship that could be viewed as presenting a potential conflict of interest.

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References


TITLE

BACTERIAL GROWTH AND RECOLONIZATION AFTER PREOPERATIVE HAND DISINFECTION AND SURGERY: A PILOT STUDY.

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TITLE

BACTERIAL GROWTH AND RECOLONIZATION AFTER PREOPERATIVE HAND DISINFECTION AND SURGERY: A PILOT STUDY.

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Abstract

Background. To prevent cross infection the surgical team perform preoperative hand disinfection before dressed in surgical gowns and gloves. Preoperative hand disinfection does not make hands sterile and the surgical glove cuff end has been regarded as a weak link, since it is not a liquid-proof interface. The aims were to investigate if there were differences in bacterial growth and recolonization of hands between operating room nurses and non-health care workers as well as to investigate if bacterial growth existed at the surgical glove cuff end during surgery.

Methods. This pilot project was conducted as an exploratory comparative clinical trial. Bacterial cultures were taken from the glove and gown interface and at three sites of the hands of 12 operating room nurses and 13 non-health care workers controls directly after preoperative hand disinfection and again after wearing surgical gloves and gowns. Colony forming units were analysed with Mann-Whitney U test and Wilcoxon Sign Ranks test comparing repeated measurements. Categorical variables were evaluated with chi-square test or Fisher's exact test.

Results. Operating room nurses compared to non-health care workers had significant higher bacterial growth at two of three culture sites after surgical hand disinfection. Both groups had higher recolonization at one of the three culture sites after wearing surgical gloves. There were no differences between the groups in total colony forming units, that is, all sampling sites. Five out of 12 of the operating room nurses had bacterial growth at the glove cuff end and of those, four had the same bacteria at the glove cuff end as found in the cultures from the hands. Bacteria isolated from the glove cuff were P. acnes, S. warneri, S. epidermidis and Micrococcus species, the CFU/mL ranged from 10 to 40.

Conclusions. There were differences in bacterial growth and recolonization between the groups but this was inconclusive. However, bacterial growth exists at the glove cuff and gown.
interface, further investigation in larger study is needed, to build on these promising, but preliminary, findings.

**Trial registration.** Trial registration was performed prospectively at Research web (FOU in Sweden, 117971) 14/01/2013, and retrospectively at ClinicalTrials.gov (NCT02359708) 01/27/2015.

**Keywords** Bacterial growth, hand disinfection, preoperative, cross infection, bacterial recolonization, surgical gloves, intraoperative, surgery, surgical site infections.
BACKGROUND

Prevention of surgical site infections (SSIs) is important to avoid patient suffering and death and to lower the cost of health care providers [1]. There are different strategies to reduce SSIs in an operating room (OR), such as the use of basic hygiene procedures, controlled OR ventilation, normothermia, surgical techniques, sterile materials, prophylactic antibiotics, and preoperative skin disinfection [2]. A preventive method is to perform preoperative hand disinfection prior to wearing surgical gloves and to double glove for easy detection of puncture in the outer glove [3]. With the use of indicator gloves, the puncture site becomes a dark spot, and outer gloves can be changed. In an attempt to reduce transmission of bacteria from the hands into the wound of the patient, surgical team members perform preoperative hand disinfection and then put on sterile surgical gowns and double sterile surgical gloves. It is important to reduce the sum of bacteria on the hands of the surgical team. Therefore, it is of interest to find out whether or not surgical team members have altered bacterial growth and recolonization i.e. that differs from that of non-hospital care workers (non-HCWs).

In an intraoperative environment causative bacteria for SSI often originate either from the patient’s skin or from the surgical team [4, 5]. Transient bacteria have been found to be transmitted from the surgeon, the assistant and the OR nurses into the wound, as have resident bacteria from the patient’s own skin [4]. It is of great importance to reduce the amount of both transient and resident bacteria on the patient skin before surgery [6, 7]. Depending on where the SSI is located, an SSI can be devastating for the patient, as well as costly for society. For example, a severe SSI might be one that occurs after open heart surgery, where a deep sternal infection can double or even triple the usual cost of treatment [8-10]. The most common bacteria causing sternal infections are coagulase negative staphylococci, Staphylococcus aureus, and gram-negative bacteria [5, 8, 11-13].
Strategies have been recommended to reduce the incidence of SSIs, and great attention has been focused on the liquid-proof barrier of the surgical gown and gloves [3]. Double gloving has become routine in many departments because of its effect of reducing the risk of transmitting bacteria through puncture of the gloves [3, 14]. Less focus has been centred on the largest hole in the glove, the glove cuff, the place at which the hand enter the glove. There are few studies that address this issue but these studies are not performed recently. However, the issue is nevertheless current because the problem still exists. If, while wearing a liquid-proof surgical gown and surgical gloves, the hands and arms were set under a water tap, the arms would get wet [15, 16]. The surgical glove cuff and gown interface has previously been regarded as a weak link in the barrier through which fluid may be transmitted, since there is not a liquid-proof interface between the surgical glove and gown [15, 16]. It has been noted in clinical practice that during surgical procedures, the gloves will become moist at the end of the surgical glove cuff. Often the gloves will turn dark, indicating that fluid is present (Figure 1), a process that can only be detected by using double gloves with an indicator system by which a darker colour appears. A question to be raised is if the fluid originates from the skin of the hand and if it may contain bacteria.

Figure 1. Photo illustrating a dark visible indication of fluid at the glove cuff end.
Another important strategy to reduce the incidence of SSIs is the preoperative hand disinfection in order to reduce the amount of bacterial growth on the hands of the surgical team. There may be differences in bacterial growth and recolonization on the hands of OR nurses compared to those of non-HCWs, due to their frequently performed preoperative hand disinfection and frequent exposure to virulent bacteria [17-21]. A need existed to investigate whether OR nurses had different amounts or type of bacteria present on their hands after preoperative hand disinfection and wearing surgical gloves compared to a control of non-HCWs. Skin damage on the hands caused by frequent disinfection has been shown to change the bacterial growth and add to the sum of microorganisms [22]. Although, OR nurses and HCWs in general need to continue disinfecting their hands to prevent cross-infections.

No previous study was found that has investigated whether repetitive preoperative hand disinfection affects the results regarding bacterial growth and recolonization on the hands, both directly after the preoperative hand disinfection process and then after wearing surgical gloves. It has also been reported that recolonization of bacteria inside the gloves does occur and that bacterial counts on hands increase with the length of surgery [23, 24]. It is of importance to know whether repetitive preoperative hand disinfection affects the bacterial growth and recolonization among HCWs. This can be investigated by comparing HCWs with persons who do not repetitively perform preoperative hand disinfection, using the same hand disinfection methods and disinfection solution before taking cultures.

The aim was to investigate if there were differences in bacterial growth and recolonization of hands between OR nurses and non-HCWs as well as to investigate if bacterial leakage existed at the surgical glove cuff and gown interface during surgery.
METHODS

Study design and participants
This pilot project was designed as an exploratory comparative clinical trial with two groups for comparison. All OR nurses (n=14) employed at one cardiothoracic surgery department in Sweden and non-HCWs (n=14) without any recent contact with medical care were invited to participate. The non-HCWs were adjusted to match the OR nurses regarding gender. For both groups, exclusion criteria were artificial nails, hand eczema, jewellery or other preoperative hand disinfectant solution than protocol stated. The study has been performed in accordance with Declaration of Helsinki [25] and the Regional Ethical Review Board of Uppsala approved the study (reference number 2013/283). The study participants received oral and written information about the study, and written informed consent was obtained before data collection. The trial was registered at Researchweb (FOU in Sweden, 117971) ClinicalTrials.gov (NCT02359708). The data collection for the OR nurses was performed between March 2014 and June 2014 at an OR department in Sweden, and between December 2014 and April 2015 for the healthy participants.

Procedure for OR nurses

OR nurses, employees at the same OR department, were informed orally of the study and asked to participate in the study at a workplace meeting. Preoperatively, they performed preoperative hand disinfection accordingly to clinic routine by washing their hands under running water with soap and cleaning their nails if necessary for one minute, and then drying their hands and forearms properly with paper and rubbing hands and forearms with a fluid alcohol (Dax preop 80, CCS Healthcare AB, Sweden). During surgery the OR nurses wore caps, masks, nonwoven surgical gowns (BARRIER, Mölnlycke Heath Care, Gothenburg, Sweden), and double gloves (Biogel PI indicator system, Mölnlycke Health Care, Gothenburg, Sweden). Intraoperative, the OR nurses prepared and assisted at a clean surgery procedure until they were either relieved or the surgery was completed.
Procedure for non-HCWs

The non-HCWs were recruited from the first author’s circle of friends. The group consisted of office workers and students, all healthy individuals. The trial was performed at three occasions, with a maximum of five persons at a time, and took place at the same OR department as the nurses’ trial. All non-HCWs performed the preoperative hand disinfection with instructions and the assistance of an OR nurse, who also helped them with donning the nonwoven surgical gowns and double gloves (BARRIER® and Biogel PI system®, Mölnlycke Health Care, Gothenburg, Sweden). The gloves used did not contain any bactericidal agency and the size of the gowns and gloves were set by an experienced OR nurse. The non-HCWs performed the preoperative hand disinfection in the same manner as the OR nurses. To simulate nearly the same workload as preparing and assisting a patient for surgery, they performed a heart and lung resuscitation (HLR) course while dressed in gowns, caps, and gloves.

Data collection procedure

Skin cultures were taken at two time points, directly after the preoperative hand disinfection when the hands were dry, and again after wearing sterile surgical gloves and gowns. The OR nurses were sampled in total at seven sites, and the non-HCWs at six sites. The non-HCWs had six cultures taken because these participants’ gloves and gowns were not kept sterile during the HLR course; the culture from the glove cuff and gown interface was excluded. Sampling was performed by one of the researchers (CW). At the first time point cultures were obtained at three sites on the right hand: (1) in the palm, (2) between the index finger and middle finger, and (3) at the nail/cuticle of the index finger.

Cultures obtained at the second time point, at the end of surgery and the HLR course, respectively, after taking the gloves off, were obtained from (1) the hand palm, (2) between the index finger and the middle finger, and (3) at the nail/cuticle of the index finger (Figure 8).
1) The OR nurses had an additional culture taken at the glove cuff and gown interface, which was obtained before taking the gloves off.

All cultures were taken using a nylon-flocked swab (ESwab, Copan Italia S.p.A., Brescia, Italy). The swabs were moisturized with two drops of saline and rubbed for 15 seconds at the skin culture sites. The culture area was approximately 5 mm × 15 mm. At the nail site the area was smaller. The choice of culture swab was chosen for its ability to answer the research question and was based from a study testing its sensibility [26]. Cultures were kept cold until arrival at the Department of Laboratory Medicine, Clinical Microbiology, and analysed according to a specific study protocol. The laboratory technician that performed the analysis was blinded regarding group allocation.

**Culture analysis**

The swabs were vortexed, and 50 µL of the media was subcultured on hematin agar medium 4.3% (w/v) (Columbia Blood Agar Base, Acumedia Neogen Corporation, Lansing, MI, USA) supplemented with 6% (v/v) chocolatized defibrinated horse blood and incubated at 36°C aerobically. Samples were also subcultured on FAA plates (LAB 90 Fastidious Anaerobe Agar 4.6% (w/v); LAB M Ltd., Lancashire, UK), supplemented with 5% (v/v) defibrinated horse blood and incubated under anaerobic conditions (10% H2, 10% CO2, 80% N2) at 37°C. After 24 and 48 hours of aerobic incubation and 5 days of anaerobic incubation, bacterial growth was determined quantitatively (CFU/mL, colony-forming units per mL). Culture diagnostics and species verification were performed based on characteristic colony morphology and using routine diagnostic procedures, including MALDI-TOF mass spectrometry (MicroflexLT and Biotyper 3.1, Bruker Daltonics, Bremen, Germany).

**Statistical analysis**
**Statistical analysis**

No previous study has been performed on this specific topic so sample size calculation was not possible. This study will enable us to perform a power calculation for future research. Analysis was performed using SPSS version 22 (SPSS Statistics; IBM, Armonk, NY, USA). The bacterial counts and other non-normal distributed variables were analysed with Mann-Whitney U test and Wilcoxon Sign Ranks test comparing repeated measurements. Categorical variables were evaluated with chi-square test or Fisher’s exact test, as appropriate. Descriptive statistics are presented as means, median, numbers, percentage, confidence interval, standard deviation, and interquartile range (IQR). A p-value <0.05, two tailed, was considered statistically significant.

**RESULTS**

Two of the 14 OR nurses were excluded due to use of another preoperative hand disinfection method, that is, chlorhexidine containing soap, resulting in a total of 12 OR nurses. One of the 14 non-HCWs was excluded because of nail extensions (Figure 2), resulting in a total of 13 non-HCW. There were no significant differences between the groups except for the length of time wearing the surgical gloves (Table 1).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OR nurses n = 12</th>
<th>Non-HCWs n = 13</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>46 (8)</td>
<td>39 (13)</td>
<td>0.094</td>
</tr>
<tr>
<td>Men/women, numbers</td>
<td>1/11</td>
<td>1/12</td>
<td>1.0</td>
</tr>
<tr>
<td>Minutes wearing gloves, mean (SD)</td>
<td>223 (34)</td>
<td>192 (16)</td>
<td>0.007*</td>
</tr>
</tbody>
</table>

Student’s t-test and Fisher’s exact test were used as statistical method. *Statistically significant difference.

**Bacterial growth and recolonization at the different culture sites**

There were differences in bacterial growth and recolonization between the groups at four of six culture sites, regarding the CFU/mL. After preoperative hand disinfection the OR nurses
had higher bacterial growth at the palm and the finger sites compared to the non-HCWs, \( p = 0.044 \) and \( p = 0.019 \), but no difference regarding the nail sites \( p = 0.434 \). After wearing surgical gloves no difference were found regarding the palm site between the groups, \( p = 0.893 \). OR nurses had higher values regarding recolonization at the finger, \( p = 0.039 \) but less recolonization at the nail site, \( p = 0.016 \) compared to non-HCWs (Table 2).

### Table 2. Bacterial growth and recolonization at three culture sites on the hands of operating room nurses and non-health care workers after preoperative hand disinfection and after wearing surgical gloves

<table>
<thead>
<tr>
<th>Culture</th>
<th>Operating room nurses, ( n = 12 )</th>
<th>Non-health care workers, ( n = 13 )</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CFU/mL growth</td>
<td>CFU/mL median</td>
<td>CFU/mL IQR</td>
</tr>
<tr>
<td>Palm</td>
<td>5 (41.7)</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Finger</td>
<td>6 (50.0)</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Nail</td>
<td>8 (66.7)</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>Palm</td>
<td>4 (33.3)</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Finger</td>
<td>4 (33.3)</td>
<td>98</td>
<td>0</td>
</tr>
<tr>
<td>Nail</td>
<td>10 (83.3)</td>
<td>244</td>
<td>55</td>
</tr>
</tbody>
</table>

Mann-Whitney U Test was used to calculate the numbers of bacterial differences at the different culture sites in CFU/mL between the groups. IQR = interquartile range. *Statistically significant difference.

**Total CFU/mL after preoperative hand disinfection and after wearing surgical gloves**

There were no differences between the groups in total CFU/mL, that is, all sampling sites. After preoperative hand disinfection the OR nurses had a median bacterial growth of 35 (IQR 88) versus non-HCWs, who had 0 (IQR 40), \( p = 0.186 \). The difference in CFU/mL between the OR nurses and the non-HCWs after wearing surgical gloves was 105 (IQR 453) vs. 790 (IQR 2970), \( p = 0.06 \).

**Differences within the groups**

The median of CFU/mL, that is, the three sites all together, on the hands within the OR nurses after preoperative hand disinfection showed a median of 35 compared to 105 CFU/mL after
wearing gloves, \( p = 0.031 \). Within the non-HCWs the median of CFU/mL was 0 vs. 790 CFU/mL, \( p = 0.002 \).

**Number of persons with growth and recolonization**

The number of OR nurses who had growth at any sampling site after preoperative hand disinfection, before donning gloves, was 10 out of 12 (83%), compared to 6 out of 13 (46%) for the non-HCWs, \( p = 0.053 \). The number of OR nurses who had bacterial growth after wearing gloves was 11 out of 12, while all of the non-HCWs had growth in one or more of the three culture sites.

**Isolated bacteria**

Fourteen different bacterial species were found. The most frequent species obtained from the OR nurses were *Staphylococcus warneri* followed by *Propionibacterium acnes* and in the non-HCWs group *S. warneri* followed by *Staphylococcus epidermidis* together with *Staphylococcus pasteuri* (Table 3).

<table>
<thead>
<tr>
<th>Bacterial species isolated from hands</th>
<th>OR nurses ( n = 12 )</th>
<th>Non-HCWs ( n = 13 )</th>
<th>OR nurses ( n = 12 )</th>
<th>Non-HCWs ( n = 13 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial growth after preoperative hand disinfection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. warneri</em></td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td><em>P. acnes</em></td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><em>Bacillus sp.</em></td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><em>S. epidermidis</em></td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><em>S. capitis</em></td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td><em>S. pasteuri</em></td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>Micrococcus sp.</em></td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td><em>S. haemolyticus</em></td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Alpha-haemolytic streptococci</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><em>Brevibacteriaceae</em></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td><em>S. lugdunensis</em></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td><em>Gemella haemolysans</em></td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Gram-positive cocci, non-typeable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td><em>Enterobacteriaceae</em></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 3. Bacterial species isolated from the hands of operating room (OR) nurses and non-health care workers (HCWs). Numbers of persons with specific bacteria after preoperative hand disinfection and after wearing sterile gloves**

\*Significant difference between groups regarding minutes, \( p = 0.007 \); statistical method used was student’s t-test.
Bacteria present during surgery

Nine out of 12 (75%) of the OR nurses had a visible dark area around the glove cuff and gown interface, indicating fluid, and in five of them (42%) there was bacterial growth. Four of five cultures from the OR nurses’ had the same bacteria at the glove cuff and gown interface as found in the cultures from the hands. Bacteria isolated from the cultures were *P. acnes*, *S. warneri*, *S. epidermidis* and *Micrococcus* species. The CFU/mL ranged from 10 to 40 at the interface of the surgical glove cuff and gown.

**DISCUSSION**

The aim of preoperative hand disinfection is to eradicate transient flora and reduce resident flora of the hands and promote a prolonged effect [27]. The preoperative hand disinfection solution used in this study was approved according to EN Standard EN12791. Bacteria have not shown resistance towards alcohol, but studies have reported signs of decreased susceptibility to chlorhexidine [28, 29]. In the present study the amount of bacteria was greater in OR nurses than in non-HCWs at the beginning of wearing gloves, whereas the opposite occurred after wearing surgical gloves. It seems as the recolonization rate was higher in the group consisting of non-HCWs. The duration of wearing gloves may have an impact on the recolonization rate [23]. Considering that the OR nurses wore the surgical gloves for a significantly longer period of time and had a greater amount of bacteria on their hands at the start, they still had a lower bacterial recolonization compared to the non-HCWs. This may suggest that repeatedly performing hand disinfection inhibits the bacterial recolonization rate of the hands, but this has to be further investigated.

This pilot study was performed to investigate whether bacterial growth from the surgical glove cuff and gown interface could be found, since bacterial growth was suspected, and no previous study had addressed this issue. The bacteria present at the surgical glove cuff and
gown interface were the types that could cause SSIs [5]. It is speculated that bacteria might migrate from the skin of the hands to the surgical glove cuff and further on to the sleeve of the sterile surgical gown. It is unlikely that bacteria will pass through the material of the gown when the gown used is liquid proof. It is also noted in clinical practice that the sleeves of the surgical gloves roll down and turn inside out. In some OR departments’ staff routinely seal the inner gloves with sterile sticky tape to prevent the insides of the gloves being exposed. Our study has indicated that bacterial leakage seems to exist between the surgical glove cuff and gown interface. In an attempt to enhance the barrier, some clinicians put on the inner glove before the gown. When the sterile gown is on, they use sterile scissors to make a small hole in the gown cuff so that the thumb can pass through. When this is done the outer glove can be donned. This technique can be seen in a technical note by Fernandez and colleagues; note, however, that they use this technique for another reason and use only single gloves [30]. Sealing the inner glove and changing the order of gloves and gowns might prevent bacterial leakage; this has still to be investigated.

There is a need to develop surgical gloves with a secure interface between gloves and gowns. A suggestion is to develop a one-piece gown with sealed inner gloves attached directly to the gown. Gown size could follow the glove size. The limitation of a one-piece garment incorporating gown and gloves would be the capability of changing only outer gloves. Yet, a change of inner gloves is seldom needed [31].

**Limitations**

A limitation of this pilot study to consider is that it was conducted at only one specific OR department. The glove juice technique recommended in a Cochrane review was not applicable for this specific sample site [24]. The technique used in our present study was chosen to investigate if bacterial growth existed at the surgical glove cuff and gown interface. This
means that the culture had to be sampled at the glove cuff and gown interface. A weakness in the design was the lack of bacterial baseline for the two groups. It is possible that the groups had significantly different amount of bacteria at the start of the preoperative hand disinfection procedure and this may have affected the results. Damaged skin is more likely to have a higher amount of bacteria compared to healthy skin [22]. The risk that more of the OR nurses had damaged skin than the non-HCWs are probable higher due to the extensive hand wash regime OR nurses perform every day at work. The origin of the fluid is most likely to be sweat or evaporations from the user’s hands, but this was not tested in present study. Furthermore, the differences in performed activities between the two groups during data collection i.e. surgery versus HLR, may have influenced the results. As well as the lack of experience in the non-HCWs group how to perform the preoperative hand disinfection and donning gowns and gloves, even though they were assisted by an OR nurse.

The reliability of taking cultures can be questioned and no method is yet perfect. One person performed all the skin samples according to a pre-set way which minimize bias regarding possible differences in sampling technique. At the department of clinical microbiology a study specific protocol was prepared for the sample analysis to strengthen the method.

Conclusions

Although the outcome data should be treated with caution, the pilot study demonstrated that bacterial growth existed on the hands and at the glove cuff and gown interface that indicates the need for a more secure surgical glove and gown interface to avoid transmitting bacteria during surgery. A larger study is needed to build on these promising, but preliminary, findings.
DECLARATIONS

**Ethics approval and consent to participate**
The study has been performed in accordance with Declaration of Helsinki and the study is registered prospectively at Researchweb (FOU in Sweden, 117971) and registered retrospectively at ClinicalTrials.gov (NCT02359708). The study was approved by the Regional Ethical Review Board of Uppsala (reference number 2013/283), by the chairman Erik Lempert. The study was voluntary, oral and written informed consent was obtained from all participants before data collection.

**Consent for publication**
Not applicable.

**Availability of data and material**
The datasets generated and/or analysed during the current study are not publicly available due to ethical considerations of the participant integrity. Bacterial growth can be seen as sensitive data. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**
The authors declare that they have no competing interests.

**Funding**
This study was supported by grants from the Research Committee of Örebro County Council and Örebro University, Sweden.

**Authors’ contributions**
All authors have been involved in the design and the writing of the manuscript. CW has performed the statistical analysis. All named authors have seen and agreed to the submitted version of the paper as well as those included in the acknowledgements section.

**Acknowledgements**
We wish to express our gratitude to Bengt Hellmark for excellent technical assistance and to Pia Essinger for the art of heart and lung resuscitation.
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The authors declare that they have no competing interests Competing interests

Authors' contributions

All authors have been involved in the design and the writing of the manuscript. CW has performed the statistical analysis. All named authors have seen and agreed to the submitted version of the paper as well as those included in the acknowledgements section.

Data availability

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Funding

No funding sources were required for this study.

Competing interests

No competing interests exist.

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STUDY III


REFERENCES
NATIONAL SURVEY OF OPERATING ROOM NURSES
ASEPTIC TECHNIQUES AND INTERVENTIONS TO REDUCE SURGICAL SITE INFECTIONS
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School of Health Sciences, Faculty of Medicine and Health, Örebro University, SE 701 82, Sweden
Keywords: Survey, perioperative, guidelines, patient preparation, surgical site infection
NATIONAL SURVEY OF OPERATING ROOM NURSES’ ASEPTIC TECHNIQUES AND INTERVENTIONS TO REDUCE SURGICAL SITE INFECTIONS

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Keywords Survey, perioperative, guidelines, patient preparation, surgical site infection
ABSTRACT

The aim was to describe the daily clinical preventing interventions guided by national guidelines that Swedish operating room nurses performed to reduce surgical site infections. This descriptive cross-sectional study used an online questionnaire with a response rate of 890 operating room nurses. The study-specific questionnaire included 32 questions addressing aspects of the interventions performed to prevent bacterial growth, such as preparation of the patient skin (n = 12), patient temperature (n = 10) and choice of materials used (n = 10). The proportion of the operating room nurses who complied with the national guidelines preventing interventions were high: skin disinfection solution (93.5%), drapes (97.4%), and sterile gowns (83.8%), and double gloves (73%). However, when guidelines were lacking, the interventions that operating room nurses performed lost conformity. To standardize operating room nurses’ preventive interventions, implementing guidelines seems to be the key priority.

INTRODUCTION

Patient safety, including prevention of healthcare-associated infections, is of international concern (Mangram, Horan, Pearson, Silver, & Jarvis, 1999; World Health Organization, 2011). Surgical site infection (SSI) is a patient injury that should be actively prevented. A report by the Swedish Association of Local Authorities and Regions showed that among nosocomial infections, the third most common type was SSIs (Swedish Association of Local Authorities and Regions, 2013). Swedish law regarding patient safety (2010:659) states that the caregivers shall lead and control the activity in such a way that good care is sustained and also provide needed interventions to prevent patient injury (Socialdepartementet, 2010). Therefore, this study describes the preventing interventions that operating room (OR) nurses perform daily to prevent SSIs regarding preparation of patients skin, maintenance of patient temperature, and material used.

BACKGROUND

Evidence-based guidelines for the prevention of surgical site infections (SSIs) can be found in many countries, such as those of the National Institute for Clinical Excellence (NICE) in the United Kingdom (National Institute for Health and Care Excellence, 2008) and the Centers for Disease Control (CDC) in the United States (Mangram et al., 1999). Internationally the prevention of SSIs is implementing evidence-based care bundles, identified as, for example, correct antibiotic prophylaxis, hair removal, perioperative skin disinfection and preservation of normothermia (National Institute for Health and Care Excellence, 2008). A care bundle consists of a set of interventions which together aim to improve the outcome for the surgical patient (McCarron, 2011). Results from care bundle interventions have been contradictory, showing in some cases positive impact and in others no impact regarding SSIs (Ghuman et al., 2015; Hill, Holubar, Garfield Legare, Luurtsema, & Barth, 2015; Stulberg et al., 2010).
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There are more strategies to prevent SSIs at the operating departments than the care bundles suggest, such as the use of basic hygiene procedures, controlled OR ventilation, sterile material, surgical techniques and preoperative hand disinfection and adherence to guidelines (Mangram et al., 1999). Sustaining good care for the surgical patient includes preparing the skin, maintaining normal body temperature, maintaining an aseptic environment and so forth (Kelvered, Ohlen, & Gustafsson, 2012). Guidelines exist, but we have not found any studies describing the practical work and whether on national level the work performed conforms to the guidelines and provides equally good care for the surgical patients.

Internationally, differences exist as to which profession is responsible for preparing the patient regarding hygienic procedures such as skin disinfection and draping the patient for surgery at the OR; this work may be performed by nurses with different educational levels or by the surgeon. In Sweden it is the OR nurse that prepares the patient for the surgical procedure at the OR department. However, preparing the patient anaesthesia is responsibility of the team of anaesthesiologists and nurse anaesthetists (Nilsson & Jaensson, 2016). In Sweden the OR nurse must have a minimum of four years of education: three years to achieve a bachelor’s degree in nursing, followed by one year of postgraduate education at an advanced level in OR nursing care. OR nurses’ duties encompass providing a secure environment for the patient regarding a hygienic, aseptic environment; preparing the patient’s skin; draping the patient; and maintaining the patient’s body temperature. Other duties include instrument care and circulating roles, that is, as a non-sterile person assisting the sterile surgical team (Kelvered et al., 2012).

National guidelines and regulations regarding patient care in Sweden can be found in the Handbook for Healthcare Workers, which resembles the international guidelines by NICE (National Institute for Health and Care Excellence, 2008) and the CDC (Mangram et al., 1999). The Handbook for Healthcare Workers is based on the Swedish Health and Medical
Service Act and Social Services Act. Guidelines regarding OR departments consist of several different preventive interventions, both for patients and for staff (Swedish Association of Local Authorities and Regions).

Compliance with these guidelines for intervention to prevent bacterial growth and SSIs in clinical practice is hard to find. The aim was therefore to describe the daily clinical interventions guided by national guidelines that Swedish OR nurses performed to prevent bacterial growth.

MATERIAL AND METHODS

Study design and participants

This was a descriptive cross-sectional study. A web-based questionnaire survey was carried out in a population of Swedish OR nurses from December 2015 to the end of January 2016.

Questionnaire

The study-specific questionnaire was developed based on an extensive review; on evidence from earlier research produced by the research group regarding skin disinfection effects, both of patient skin (Falk-Brynhildsen, Soderquist, Friberg, & Nilsson, 2013; Wistrand & Nilsson, 2011; Wistrand, Soderquist, Magnusson, & Nilsson, 2015) and of the hands of the staff; and on existing guidelines in Sweden (Swedish Association of Local Authorities and Regions). The following guidelines were selected for the study-specific questionnaire:

- Recommended skin disinfection solution, chlorhexidine 5mg/ml in 70% ethanol or similar, with a prolonged effect;
- Duration of the skin disinfection process to be two minutes, and then the site allowed to dry;
- Sterile draping material for single use, which should stay adherent throughout the surgical procedure;
- Two methods for preoperative surgical hand disinfection: method 1, rub—the use of plain soap and water and thereafter rubbing of the hands and forearms fluidly with alcohol; and method 2, scrub—the use of soap, containing 4% chlorhexidine or similar solution, and water;
- Sterile gowns and gloves to be worn by all within the sterile area of surgery, and double gloves recommended;
- Special work suit designed to prevent spread of bacteria from staff to the surrounding air, that is, a clean-air suit;
- Maintenance of patient body temperature perioperatively by the use of warm fluids and blankets; and
- Preoperative shower with a chlorhexidine containing soap at least twice before surgery, the cleansing to begin the day before surgery at home and be completed the morning of the surgery at the ward or at home.

Study-specific questions were also based on the research group members’ own clinical experience of working in an OR setting as OR nurses and nurse anaesthetist. The questionnaire addressed the daily activities an OR nurse performs to prevent bacterial growth and SSI, such as preparation of the patient skin (n = 12), maintenance of the patient’s temperature (n = 10) and use of OR materials (n = 10), in which the responses were registered on a 5-point scale with the range of answers always, often, sometimes, seldom or never (n = 19). Other questions comprised a 4-point scale regarding recolonization and changes of gloves: large, moderate, small or none; and puncture of glove: long duration, use single gloves or open-ended (n = 2); a fixed set of three choices with an open-ended alternative regarding guidelines: yes, no, unsure or open-ended (n = 2); a 5-point scale regarding education with
respect to patient skin disinfection to be answered with educator (university), supervisor (OR
nurse), handbook for healthcare workers, colleagues, unsure or open ended (n = 1); and
finally, eight open-ended questions, such as Which preoperative hand disinfection solution do
you use? and At what controlled temperature is the OR mostly maintained? The questionnaire
also included six socio-demographic variables: age, type of hospital, work experience,
educational level, surgical specialty and region of Sweden in which they worked. Three
questions were excluded from the present results and will be presented elsewhere. These
questions describe the information given by the OR nurse to the patient prior to skin
disinfection, the patient’s response when receiving skin disinfection, and finally, the OR
nurse’s assessment of the most important interventions to prevent SSIs.

The questionnaire’s appropriateness was evaluated by 10 OR nurses in order to improve the
clarity of the questions before the questionnaire was sent out. Corrections were not needed
after feedback from the 10 OR nurses. The questions were formatted as a web-based
questionnaire by a professional web survey company, which also handled the data collection
and compiled the data.

All Swedish county councils were asked to participate. The IT department of the participating
hospitals or regions delivered the lists of OR nurses’ email addresses to the first author. The
web-based questionnaire was distributed by email together with information about the study
to 2264 of a total of 4000 OR nurses in Sweden. The remaining OR nurses’ email addresses
were not available. Information regarding the study was also published in the Swedish journal
for OR nurses as well as in a closed face book group for OR nurses. Inclusion criteria were; a
specialist degree as an OR nurse. Exclusion criteria were OR nurses that no longer worked
actively as an OR nurse.
Ethical considerations

The study was performed in accordance with the Helsinki Declaration (World Medical Association, 2013). Ethical approval was not required according to Swedish law concerning ethical review of research involving humans, since the study did not involve patients, and no sensitive data were obtained (Sweden The Ministry of Education and Cultural Affairs, 2003). By sensitive data, we mean that no information was retrieved regarding political opinions, ethnicity, religion, union membership, philosophy, health or sexual preferences. Written information was given regarding the study, and participation was voluntary. The data were stored depersonalized on data files on the hospital’s servers, well protected with firewalls and private codes. No key codes existed to connect the answers with any individuals, and the results were presented at group level with no possibility of identification.

Statistical analysis

Data were entered and analysed using descriptive statistics computed in SPSS version 22.0 (SPSS Statistics; IBM, Armonk, NY, USA). Descriptive statistics were computed for all variables and were described using mean, median, number, percentage and standard deviation.

RESULTS

Participants

In total 967 of 2264 OR nurses answered the questionnaire (response rate 43%). Of these 967 OR nurses, 77 were excluded due to not working as OR nurses, but rather, for example, as a chief of staff, given a total of 890 respondents. The OR nurses represent more than 11 different surgical specialities such as orthopaedics, thoracic, vascular and general surgery (Table 1). The results of the OR nurses’ preventive interventions are presented according to guidelines.
**Recommended skin disinfection solution, chlorhexidine 5mg/ml in 70% ethanol or similar, with a prolonged effect**

Chlorhexidine 5mg/ml in 70% ethanol was the most commonly used solution for skin disinfection and was used by 93.5% (806/862) of the OR nurses. The use of Chloraprep®, which is a combination of chlorhexidine 20mg/ml in 70% isopropanol, was used by 2.3% (20/862). Finally, both 70% ethanol and Sterillium® containing 75% isopropanol were used by 2.1% (18/862). Pre-cleansing of the patient skin at the OR with a 4% chlorhexidine-containing wipe/sponge (Descutan®) was sometimes performed prior to the preoperative skin disinfection by 37.0% (329/890) of the OR nurses (Table 2).

**Duration of the skin disinfection process to be two minutes, and then the site allowed to dry**

The majority of the OR nurses assessed that they performed the preoperative disinfection of patient skin for two to five minutes (Figure 1). Most, 41.1% (366/890), of the OR nurses often let the skin dry before draping, and to enhance adherence of the drapes to the patient’s skin, 34% (303/890) of the OR nurses often wiped the skin dry where the drapes should adhere, using sterile paper towels (Table 2).

**Sterile draping material for single use, which should stay adherent throughout the surgical procedure**

Sterile draping for single use was used by 97.4% (867/890) of the OR nurses, and 75.8% (675/890) assessed the draping material to often stay adherent to the patient skin during surgery (Table 2). Plastic adhesive drapes were sometimes used by 54.5% (485/890) and iodine-impregnated plastic adhesive drapes were always used by 33.7% (300/890) (Table 2). A microbial sealant such as Integuseal® was never used, according to 89.4% (796/890) of the OR nurses (Table 2). Most of the OR nurses responded that they had learned to perform
patient skin disinfection from their supervisor (an OR nurse), or at the clinical practice during in-service education (48.9%, 435/890), while 41.7% (371/890) learned the technique from the educator at the university. The remaining 9.4% of the OR nurses stated that they had learned it from colleagues and/or the Handbook for Healthcare Workers, or did not remember. The assessment of the skin disinfection efficiency by OR nurses regarding the proportion of patients that became free from bacteria after the skin disinfection ranged from 0% to 99%. The distribution was fragmented. The largest number of the OR nurses assessed that none of the patients became completely free of bacterial growth after skin disinfection (31.7%, 187/589), while 5.6% (33/589) believed 99% of the patients became free of bacteria at the disinfected skin site.

Two methods for preoperative hand disinfection: method 1, rub—the use of plain soap and water and thereafter rubbing of the hands and forearms fluidly with alcohol; and method 2, scrub—the use of soap, containing 4% chlorhexidine or similar solution, and water

Almost all OR nurses, 96.3% (857/890), stated that guidelines existed at their OR department for how to perform a preoperative hand disinfection. The most used preoperative hand disinfection solutions were alcohol-based disinfection solutions, 89.6% (763/852), followed by chlorhexidine-based soap, 8.2% (70/852). Some of the OR nurses used both alcohol-based disinfection solutions and chlorhexidine-based soap, 1.3% (11/852), and only a small minority used only plain soap, 0.9% (8/852). Of the OR nurses, 47.2% (420/890) expected a small bacterial recolonization on their hands after the use of surgical gloves, and 38.4% (342/890) expected a moderate recolonization. Two per cent (18/890) expected a large recolonization, while the remaining 12.4% answered that they expected that no bacterial recolonization to occur on their hands after the use of surgical gloves. The sterile outer glove was assessed by
83.3% (741/890) of the OR nurses to always reach over the inner glove, and 41.0% (365/890) did not indicate any moisture at the glove cuff end (Table 2).

**Sterile gowns and gloves to be worn by all within the sterile area of surgery, and double gloves recommended**

Sterile gowns for single use were used by 83.8% (746/890) of the OR nurses. Of the OR nurses, 40.4% (360/890) did not know if they had any guidelines regarding the use of double gloves, and 37.1% (330/890) stated that they did not have any. Double sterile surgical gloves were used by 73.0% (650/890) by the OR nurses, and they assessed other members of the surgical team to often wear sterile double gloves (58.5%, 521/890) (Table 2). Reasons for changing the outer gloves varied, but the most dominant reasons were indication of puncture holes in the glove or the use of the outer glove for a long time (Table 3).

**Special work suit designed to prevent spread of bacteria from staff to the surrounding air, that is, clean-air suit**

Staff clothing (unsterile clothes to wear within the OR department) for single use at the OR departments was never used by 43.8% (390/890) and always used by 9.6% (85/890) (Table 2).

**Maintenance of patient body temperature perioperatively by the use of warm fluids and blankets**

The controlled OR temperature ranged between 18°C and 24°C, and the three most common temperature were 20°C (30.1%), 21°C (28.6%) and 22°C (20.8%). Blankets or mattresses with warm air were often used by 51.9% (462/890) of the OR nurses, but the incision area was not locally preheated by 82.0% (730/890) (Table 2). Fluids for use in the wound were sometimes preheated by 57.1% (508/890) of the OR nurses (Table 2).
The skin disinfection solution was always stored at room temperature by 95.5% (850/890), and the majority of the OR nurses did not preheat the skin disinfection solution before skin disinfection (86.7%, 772/890). Those that used preheated skin disinfection solution had different ways of preheating the solution: warming cupboard (89.1%), microwave oven (4.5%), hot water (3.6%) or by all different methods (2.8%). The temperature of the preheated skin disinfection solution varied from 25°C to 42°C, with a mean temperature of 37°C. The OR nurses who used preheated skin disinfection solutions stated the reasons for this as being that the patient was awake or was small (child/infant), or that the disinfection area covered a large portion of the patient’s body.

**DISCUSSION**

The main result was that the majority of the interventions recommended by the national guidelines seemed to be implemented in the daily work, and the interventions were fairly consistently performed nationally. However, when guidelines were lacking, variation of the intervention used increased.

Recent research has focused on the educational levels and workloads of nurses related to the outcome survival, for inpatients. Research by Aiken and colleagues (Aiken et al., 2014) implicates that higher education such as a bachelor’s degree reduces patient mortality, and one may correlate the high compliance to national guidelines with the high educational level of the Swedish OR nurses. Furthermore, in the light of this research it is important to maintain high educational levels to provide a high standard of care and a good outcome for the surgical patient. There is a need for more guidelines, such as to address why and when surgical gloves should be changed, and for more specific guidelines to prevent individual interpretations. There is a lack of guidelines in Sweden regarding criteria for when changes of both single gloves, and the outer of double gloves, should take place. Studies have showed that puncture
The skin disinfection solution was always stored at room temperature by 95.5% (850/890), and the majority of the OR nurses did not preheat the skin disinfection solution before skin disinfection (86.7%, 772/890). Those that used preheated skin disinfection solution had different ways of preheating the solution: warming cupboard (89.1%), microwave oven (4.5%), hot water (3.6%) or by all different methods (2.8%). The temperature of the preheated skin disinfection solution varied from 25°C to 42°C with a mean temperature of 37°C. The OR nurses who used preheated skin disinfection solutions stated the reasons for this as being that the patient was awake or was small (child/infant), or that the disinfection area covered a large portion of the patient's body.

DISCUSSION

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Consensus regarding the effectiveness of plastic adhesive drapes is lacking (Ward, Jennings, Potgieter, & Lombard, 2001; Webster & Alghamdi, 2015), but the current evidence is against their use (National Institute for Health and Care Excellence, 2008), with possibly more contamination in the surgical wound occurring with plastic adhesive drapes (Falk-Brynildsen et al., 2013). The fragmented use of plastic adhesive drapes with or without iodine shown in our study can perhaps be explained by the absence of national guidelines. However, the reason behind the use of plastic adhesive drapes was not explored. The national guidelines state clearly that the gowns, gloves and patient drapes should be for single use, with which OR nurses showed high compliance (Table 2).

Many OR departments have warming cupboards where fluids for intravenous and intracavity administration can be preheated. The result showed that the OR nurses sometimes (57.1%) used warm fluids in the wound/cavity (Table 2). The reason for not using warm fluids was not investigated, and several reasons may be considered, such as that fluids tend to cool off quickly if not used immediately, or it may be planned for the patient to be hypothermic, as in heart surgery, or it may depend on the amount of fluid used. The information regarding the possibilities to preheat the skin disinfection solution such as chlorhexidine 5mg/ml is somewhat contradictory. The chlorhexidine 5mg/ml in 70% ethanol should be stored at room temperature, no higher than 25°C, according to the Swedish Environmental Classification of Pharmaceuticals (Swedish Environmental Classification of Pharmaceutical). But according to the manufacturer, the chlorhexidine 5mg/ml in 70% ethanol can be preheated in a warming cupboard up to 40°C for one week without any negative effects on the package or the product (Fresenius Kabi, 2011). Our research group has in earlier studies addressed the positive impacts of preheated chlorhexidine 5mg/ml in 70% ethanol, which results in a more pleasant patient experience, less heat loss regarding skin temperature and equally effective skin disinfection (Wistrand & Nilsson, 2011; Wistrand et al., 2015; Wistrand, Soderquist, &
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According to this study, many OR nurses used a sponge containing chlorhexidine soap 4% to pre-wash the surgical area of the patient before the skin disinfection (Table 2). This intervention at the OR has no support in the Handbook for Healthcare Workers (Swedish Association of Local Authorities and Regions), or in recent research (Farber, Chen, Bartsch, Feigel, & Klatt, 2013; Hsieh, Cheng, Lin, Kuo, & Chen, 2014). The disinfection solution manufacturer and the national guidelines, the Handbook for Healthcare Workers, emphasize the importance of the correct duration for the skin disinfection solution to be in contact with the skin surface (Care Fusion, 2016; Fresenius Kabi, 2011). The majority of the OR nurses assessed the time it took to perform the preoperative skin disinfection as between two to five minutes, as guidelines recommend (Swedish Association of Local Authorities and Regions). The patient’s skin should dry completely before draping, with the intention being for the solution to affect the skin and for the drapes to adhere properly to the skin, but also for patient safety, considering that ethanol is flammable (Association of periOperatie Registered Nurses,
The result shows that OR nurses do not let the skin dry completely before draping the patient, extrapolated from the fact that wipes were often used by 34% of the OR nurses to wipe the skin dry prior to draping. Using sterile paper towels to wipe the skin dry may increase the risk for undetected bacterial contamination from the surrounding area into the surgical area, but this has no evidence and needs to be investigated further. However, the underlying reason for wiping was not investigated. Did the OR nurses wipe because they felt they were stressed or pressured to work fast and save time, or was the wiping of the skin something they had learned from clinical practice? The skin disinfection process was mostly learned from the supervisor (OR nurse) at the clinical practice or the instructors at the university, which requires updated supervisors and instructors to provide the OR nursing students with evidence-based clinical interventions, to prevent wrong and traditionally behaviours.

**Strengths and limitations**

Using a web-based questionnaire offered an environmentally friendly and inexpensive alternative to the conventional paper-based questionnaires. To facilitate answering and to control answers, for example, regarding which disinfection solution was used in the department, the questionnaires were sent to the OR nurses’ email addresses at work. To increase the validity of the study, specific questionnaire face validity was performed by 10 OR nurses, which supported a finding that the questions appeared to measure what they were reported to measure. No analyses of differences between educational levels or work experience regarding the answers were performed, hence education level and its content have changed over time, and it is therefore difficult to differentiate between education and working experience.
No collective database for retrieval of OR nurses’ email addresses existed, and the retrieval of email addresses depended on the ability of the different counties and regions to disclose email lists. However, the survey had respondents from all counties and regions in Sweden. One region had only five respondents, and this was due to the difficulties of getting access to the email addresses. The largest numbers of respondents were from two different regions, one in the south and the other in the middle of Sweden, with 178 and 155 respondents, respectively. Apart from these three regions the rest of the respondents were fairly evenly distributed among the counties and regions. The 890 respondents worked at 64 different hospitals from the north to the south of Sweden.

Non-response to this survey could be explained by the possibility to pause and “save” the questionnaire while answering it. In addition to saving the answers, the respondents had to press a send button. This seems to have been misunderstood, which became apparent when, in response to reminders that were sent out, respondents notified us by email that they already had answered the questionnaire. In these cases the questionnaire was most likely only saved, but never sent. Some respondents also replied that they were told not to open a web link of unknown origin. These issues may have been avoided by using a paper-based questionnaire.

CONCLUSIONS

Overall the compliance of OR nurses with the national guidelines was high. However, when guidelines were lacking, the preventive interventions that OR nurses perform lose conformity. Guidelines are lacking regarding when the outer gloves should be changed, whether plastic adhesive drapes should be used, and the possibility of preheating chlorhexidine 5mg/ml in 70% ethanol. To standardize OR nurses’ preventive interventions, implementing guidelines seems to be the key priority.
Conflict of interest
None to declare.
REFERENCES


Table 1. Respondents’ characteristics of 890 operating room nurses in Sweden

<table>
<thead>
<tr>
<th></th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years mean (SD)</strong></td>
<td>47 (9.8)</td>
</tr>
<tr>
<td><strong>Years of experience</strong></td>
<td>16 (12.0)</td>
</tr>
<tr>
<td><strong>OR nurses, male, n (%)</strong></td>
<td>57 (6.4)</td>
</tr>
<tr>
<td><strong>OR nurses, female, n (%)</strong></td>
<td>833 (93.6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Level of education</strong></th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensed OR nurse</td>
<td>455 (51.0)</td>
</tr>
<tr>
<td>Licensed OR nurse BSc</td>
<td>196 (22.0)</td>
</tr>
<tr>
<td>Licensed OR nurse MSc or higher</td>
<td>239 (27.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Type of hospital</strong></th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University hospital</td>
<td>332 (37.2)</td>
</tr>
<tr>
<td>County hospital</td>
<td>475 (53.4)</td>
</tr>
<tr>
<td>Private hospital</td>
<td>22 (2.5)</td>
</tr>
<tr>
<td>Other</td>
<td>61 (6.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Surgical Specialty</strong></th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthopaedic surgery</td>
<td>285 (32.0)</td>
</tr>
<tr>
<td>General surgery</td>
<td>283 (31.8)</td>
</tr>
<tr>
<td>Thoracic surgery</td>
<td>70 (7.9)</td>
</tr>
<tr>
<td>Gynaecological surgery</td>
<td>61 (6.9)</td>
</tr>
<tr>
<td>Ear, nose, and, throat surgery</td>
<td>50 (5.6)</td>
</tr>
<tr>
<td>Urologic surgery</td>
<td>31 (3.5)</td>
</tr>
<tr>
<td>Neurologic surgery</td>
<td>30 (3.4)</td>
</tr>
<tr>
<td>Hand surgery</td>
<td>23 (2.6)</td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>16 (1.8)</td>
</tr>
<tr>
<td>Plastic surgery</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Eye surgery</td>
<td>14 (1.5)</td>
</tr>
<tr>
<td>Other</td>
<td>12 (1.3)</td>
</tr>
</tbody>
</table>

SD, standard deviation.
Table 2. OR nurses’ (n = 890) scaled responses regarding areas such as preparation of patient skin, maintenance of patient temperature, and use of surgical gloves and gowns.

### Recommended skin disinfection solution, chlorhexidine 5mg/ml in 70% ethanol or similar, and then allowed to dry

<table>
<thead>
<tr>
<th>Statement</th>
<th>Always n (%)</th>
<th>Often n (%)</th>
<th>Sometimes n (%)</th>
<th>Seldom n (%)</th>
<th>Never n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorhexidine soap 4% wipes used prior to skin disinfection, Descutan®</td>
<td>264 (29.7)</td>
<td>156 (17.5)</td>
<td>329 (37.0)</td>
<td>76 (8.5)</td>
<td>65 (7.3)</td>
</tr>
<tr>
<td>Skin is allowed to dry after skin disinfection</td>
<td>331 (37.2)</td>
<td>366 (41.1)</td>
<td>123 (13.8)</td>
<td>63 (7.1)</td>
<td>7 (0.8)</td>
</tr>
<tr>
<td>Skin is wiped with sterile paper towel for drape adherence</td>
<td>133 (14.9)</td>
<td>303 (34.0)</td>
<td>215 (24.2)</td>
<td>133 (14.9)</td>
<td>106 (11.9)</td>
</tr>
</tbody>
</table>

### Sterile draping material for single use, which should stay adherent throughout the surgical procedure

<table>
<thead>
<tr>
<th>Statement</th>
<th>Always n (%)</th>
<th>Often n (%)</th>
<th>Sometimes n (%)</th>
<th>Seldom n (%)</th>
<th>Never n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile draping for single use is used</td>
<td>867 (97.4)</td>
<td>18 (2.0)</td>
<td>2 (0.2)</td>
<td>1 (0.1)</td>
<td>2 (0.2)</td>
</tr>
<tr>
<td>Sterile draping is adherent to patient skin during surgery</td>
<td>194 (21.8)</td>
<td>675 (75.8)</td>
<td>17 (1.9)</td>
<td>4 (0.4)</td>
<td></td>
</tr>
<tr>
<td>Plastic adhesive drapes are used</td>
<td>18 (2.0)</td>
<td>122 (13.7)</td>
<td>485 (54.5)</td>
<td>98 (11.0)</td>
<td>167 (18.8)</td>
</tr>
<tr>
<td>Iodine-impregnated plastic adhesive drapes are used</td>
<td>300 (33.7)</td>
<td>105 (11.8)</td>
<td>99 (11.1)</td>
<td>50 (5.6)</td>
<td>336 (37.8)</td>
</tr>
<tr>
<td>Microbial skin sealant is used, Integum®</td>
<td>8 (0.9)</td>
<td>4 (0.4)</td>
<td>40 (4.6)</td>
<td>42 (4.7)</td>
<td>796 (89.4)</td>
</tr>
</tbody>
</table>

### Maintenance of patient body temperature perioperative by the use of warm fluids and blankets

<table>
<thead>
<tr>
<th>Statement</th>
<th>Always n (%)</th>
<th>Often n (%)</th>
<th>Sometimes n (%)</th>
<th>Seldom n (%)</th>
<th>Never n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The skin disinfection solution is stored at room temperature</td>
<td>850 (95.5)</td>
<td>37 (4.2)</td>
<td>1 (0.1)</td>
<td></td>
<td>2 (0.2)</td>
</tr>
<tr>
<td>The skin disinfection solution is preheated</td>
<td>1 (0.1)</td>
<td>1 (0.1)</td>
<td>56 (6.3)</td>
<td>60 (6.7)</td>
<td>772 (86.7)</td>
</tr>
<tr>
<td>Blankets or mattresses with warm air are used</td>
<td>286 (32.1)</td>
<td>462 (52.0)</td>
<td>106 (11.9)</td>
<td>16 (1.8)</td>
<td>20 (2.2)</td>
</tr>
<tr>
<td>Incision area is locally preheated</td>
<td>16 (1.8)</td>
<td>25 (2.8)</td>
<td>37 (4.2)</td>
<td>82 (9.2)</td>
<td>730 (82.0)</td>
</tr>
<tr>
<td>Warm fluids are used in the wound</td>
<td>31 (3.5)</td>
<td>96 (10.8)</td>
<td>508 (57.1)</td>
<td>116 (13.0)</td>
<td>139 (15.6)</td>
</tr>
</tbody>
</table>

### Sterile gown and gloves to be worn by all within the sterile area of surgery, and double gloves recommended

<table>
<thead>
<tr>
<th>Statement</th>
<th>Always n (%)</th>
<th>Often n (%)</th>
<th>Sometimes n (%)</th>
<th>Seldom n (%)</th>
<th>Never n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile gowns for single use are used</td>
<td>746 (83.8)</td>
<td>62 (7.0)</td>
<td>47 (5.3)</td>
<td>27 (3.0)</td>
<td>8 (0.9)</td>
</tr>
<tr>
<td>Double sterile surgical gloves are used</td>
<td>650 (73.0)</td>
<td>157 (17.7)</td>
<td>43 (4.8)</td>
<td>23 (2.6)</td>
<td>17 (1.9)</td>
</tr>
<tr>
<td>All sterile staff use double gloves</td>
<td>176 (19.8)</td>
<td>521 (58.5)</td>
<td>141 (15.8)</td>
<td>32 (3.6)</td>
<td>20 (2.2)</td>
</tr>
<tr>
<td>A dark area indicating moisture has been noted at the glove cuff end</td>
<td>24 (2.7)</td>
<td>67 (7.5)</td>
<td>231 (26.0)</td>
<td>203 (22.8)</td>
<td>365 (41.0)</td>
</tr>
<tr>
<td>The outer glove reaches over the inner glove</td>
<td>741 (83.3)</td>
<td>100 (11.2)</td>
<td>22 (2.5)</td>
<td>10 (1.1)</td>
<td>17 (1.9)</td>
</tr>
<tr>
<td>Staff clothing for single use is used</td>
<td>85 (9.6)</td>
<td>67 (7.5)</td>
<td>180 (20.2)</td>
<td>168 (18.9)</td>
<td>390 (43.8)</td>
</tr>
</tbody>
</table>
Table 3. Reasons to change the outer gloves, operating room nurses (n = 890) total responses, 1569

<table>
<thead>
<tr>
<th>Reasons for the change of outer gloves</th>
<th>OR nurses Number of responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloves indicated holes</td>
<td>862 (96.9)</td>
</tr>
<tr>
<td>Gloves worn for a long time</td>
<td>264 (29.7)</td>
</tr>
<tr>
<td>Contamination of outer glove</td>
<td>117 (13.1)</td>
</tr>
<tr>
<td>Before contact with implants</td>
<td>105 (11.9)</td>
</tr>
<tr>
<td>After contact with skin disinfectant or cement</td>
<td>83 (9.3)</td>
</tr>
<tr>
<td>From unclean to clean moments</td>
<td>42 (4.7)</td>
</tr>
<tr>
<td>Contact with tumors</td>
<td>20 (2.2)</td>
</tr>
<tr>
<td>Use of single gloves</td>
<td>19 (2.1)</td>
</tr>
<tr>
<td>After patient skin disinfection and draping</td>
<td>17 (1.9)</td>
</tr>
<tr>
<td>Gloves sticky with blood</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Tape or glue on the gloves</td>
<td>15 (1.7)</td>
</tr>
<tr>
<td>Before applying the patient dressing</td>
<td>6 (0.7)</td>
</tr>
<tr>
<td>Change of operation field within the patient</td>
<td>4 (0.4)</td>
</tr>
</tbody>
</table>

Multiple answers were possible for each OR nurse.
Table 3. Reasons to change the outer gloves, operating room nurses (n = 890) total responses, 1569

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Multiple answers were possible for each OR nurse.

Figure 1. Operating room nurses’ (n = 877) assessment for duration of time spent on skin disinfection of a patient abdomen.
Publications in the series
Örebro Studies in Care Sciences*

Doktorsavhandling/Doctoral thesis with focus on Nursing.

Doktorsavhandling/Doctoral thesis with focus on Nursing.

Vetenskaplig uppsats för licentiatexamen/Academic essay.

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Doktorsavhandling/Doctoral thesis with focus on Occupational Therapy.

Vetenskaplig uppsats för licentiatexamen/Academic essay.

* Seriens namn var tidigare (nr 1–24) ”Örebro Studies in Caring Sciences”.


<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Title</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>Tollén, Anita</td>
<td>(2013): Äldre personers dagliga liv och betydelsen av dagrehabilitering.</td>
<td>Doktorsavhandling/Doctoral thesis</td>
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