Bacterial Colonization of the Skin Following Aseptic Preoperative Preparation and Impact of the Use of Plastic Adhesive Drapes

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Abstract
Surgical site contamination, for example, with coagulase-negative staphylococci, probably derives from both the patient’s own skin flora and those of the surgical team. Despite preoperative antiseptic preparation with chlorhexidine solution, complete sterilization of the skin is not possible and gradual recolonization will occur. Plastic adhesive drape is an established method used to prevent direct wound contamination from adjacent skin. In this study, the time to skin recolonization after antiseptic preparation was measured and the impact of using plastic adhesive drape on this recolonization was evaluated. Repeated bacterial sampling using three different methods over 6 hr was conducted after antiseptic preparation in 10 volunteers. Recolonization of skin was observed after 30 min with plastic drape and after 60 min without plastic drape; there were significantly more positive cultures with the plastic drape than without (31% vs. 7.5%, respectively, p < .001). Sampling with a rayon swab was the most sensitive sampling method. In conclusion, covering the skin with a plastic adhesive drape seems to hasten recolonization of the skin after antiseptic preparation. However, clinical trials to confirm this finding are warranted.

Keywords
recolonization, disinfection, plastic drape, chlorhexidine solution

Surgical site infection (SSI) is one of the most common health care-associated complications. The resulting prolonged length of stay in hospital and additional treatments lead to increased costs for the health care system, and postoperative infections may result in increased suffering and delayed recovery (Broex, van Asselt, Bruggeman, & van Tiel, 2009; de Lissovoy et al., 2009; Jenney, Harrington, Russo, & Spelman, 2001; Sparling et al., 2007; Swenne, Lindholm, Borowiec, & Carlsson, 2004; Tegnell, Aren, & Ohman, 2000; Yasunaga, Ide, Imamura, & Ohe, 2007). The epidemiology of SSI is complex due to the heterogeneous and diverse nature of these infections; indeed, SSI incidence varies widely among surgical procedures, hospitals, surgeons, and patients. In most SSIs, the causative pathogens originate from the patient’s endogenous flora (Bitkover, Marcusson, & Ransjo, 2000; Kuhme, Isaksson, & Dahlín, 2007; Mangram, Horan, Pearson, Silver, & Jarvis, 1999; Tammelin, Hambraeus, & Stahle, 2001). However, SSI pathogens may also originate from exogenous sources such as members of the surgical team (Bitkover et al., 2000; Gårdlund, 2007), the operating theater environment, and instruments and materials brought into the sterile field during the procedure (Gårdlund, 2007). Which pathogens are involved in SSIs depends on the specific surgical procedure (Mangram et al., 1999; Owens & Stoessel, 2008). However, staphylococci are the most frequently isolated microorganisms, and coagulase-negative staphylococci (CoNS) especially are commonly found following procedures involving foreign materials such as prosthetic devices and other implants. In cardiac surgery, CoNS is the most common agent involved in SSI, followed by Staphylococcus aureus (Bellchambers, Harris, Cullinan, Gaya, & Pepper, 1999; Gårdlund, Bitkover, & Vaage, 2002; Mossad, Serkey, Longworth, Cosgrove, & Gordon, 1997; Owens & Stoessel, 2008; Söderquist, 2007; Tammelin, Hambraeus, & Stahle, 2002; Tegnell et al., 2000).
Transient skin flora is easier to remove by disinfection/antiseptic procedures than resident flora, which is buried deep in hair follicles, sweat glands, and sebaceous glands (Edwards, Lipp, & Holmes, 2004; Gårdlund, 2007). Strategies to reduce the number of bacteria on the skin may include showering, using an antiseptic agent such as chlorhexidine soap the night before surgery, and cleaning the operating field with an antiseptic (e.g., with chlorhexidine solution in alcohol) immediately before surgery. As part of the preoperative procedure, the surgical field is usually draped with sterile drapes. Draping aims to prevent contamination of the wound site from the patient’s skin flora and provide a sterile work area (Edwards et al., 2004; Newsom & Rowland, 1988; Owens & Stoessel, 2008). Nonetheless, even with rigorous skin preparation, complete sterilization of the skin is not possible (Wilson, 2008). For example, in cardiac surgery, at the end of a surgical procedure, bacteria are almost always present in the wound (Kuhme et al., 2007).

Various strategies to prevent translocation of the skin flora into the wound, including the use of plastic adhesive drape, are used routinely in cardiac surgery. The idea behind the plastic adhesive drapes is to protect the wound from microorganisms that may be present on the surrounding skin during surgery, yet a recent Cochrane review indicated that the use of plastic adhesive drapes does not reduce the incidence of SSI (Webster & Alghamdi, 2007). This finding highlights the need to rigorously evaluate such strategies before considering their implementation into routine clinical practice (Casey & Elliott, 2009; Owens & Stoessel, 2008). Accordingly, in the present study, in which we simulated a cardiac surgery procedure, we measured the time to recolonization of the skin after antiseptic preparation with chlorhexidine solution in ethanol and determined differences in bacterial growth on the skin with and without the use of a plastic adhesive drape.

**Method**

**Participants**

Ten healthy volunteers (5 women and 5 men) without any association with the health care system were included in the present study. Written informed consent was obtained from all participants. The mean age of the participants was 40 (range 22–60 years). No participants had diabetes mellitus, allergy, or skin lesions, were on ongoing medication, or suffered any recent infection or other disease for 3 weeks prior to the start of the trial. All participants had a body mass index < 30 kg/m². The Central Ethic Review Board of Uppsala, Sweden (D.no. 2010/046) approved this study.

**Procedure**

The trial was performed on two occasions, with females and males separated. The day before the trial, all participants washed their whole body (including hair) with 4% chlorhexidine soap (Descutan™, Fresenius Kabi AB, Uppsala, Sweden) twice, in the morning and in the evening. Upon arrival at the hospital preoperative ward, an operating room (OR) nurse shortened chest and abdomen hair on four male participants using an electric cutter. At the preoperative ward all participants scrubbed their chests with 4% chlorhexidine soap and changed to clean patient clothes and a disposable cap. All participants (five per session) were placed on separate operating tables in a single OR with upward displacement ventilation in which the ambient temperature was set at 19 °C. The five staff members present wore special cotton scrub suits (a short-sleeved tunic shirt and a pair of trousers, both with cuffs at arms and ankles) and disposable helmets and facemasks. Two were OR nurses and wore sterile disposable surgical gowns (Thailand/Mölnlycke Health Care AB, Göteborg, Sweden) and were double gloved with indicator gloves (Malaysia/Mölnlycke Health Care AB). Both OR nurses performed the aseptic procedure, but only one OR nurse performed the skin sampling (K.F.B.). One nurse from the Department of Clinical Microbiology handled all skin samples. The two remaining staff members assisted during the study.

In the OR, nurses applied 0.5% chlorhexidine solution in 70% ethanol (Fresenius Kabi AB) for 2 min to the skin of participants’ chest then draped their chests with the Klinidrape Cardiovascular set (Mölnlycke Health Care AB). Both OR nurses performed the aseptic procedure, but only one OR nurse performed the skin sampling (K.F.B.). One nurse from the Department of Clinical Microbiology handled all skin samples. The two remaining staff members assisted during the study.

Figure 1. Staff covered the left chest area of participants with eight plastic adhesive drapes, while leaving the right chest area with bare skin only.
Health Care, Neuss, Germany), while the skin on the right chest area was not covered with plastic adhesive drapes (Figure 1).

**Skin Samples**

Bacterial samples from the skin of the chest were taken on 11 occasions: 3 days before the trial (1), the day of the trial before (2) and immediately after skin preparation with 0.5% chlorhexidine in 70% ethanol (3), and eight times (4–11) from 30 to 360 min in the OR (Figure 2). In addition, samples from the anterior nares were taken from all participants on the day of the trial. The samples were obtained from the anterior nares using routine methods, that is, rayon swabs. Samples from the skin of the chest were taken using three different methods,

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**Figure 2.** Flow chart of the procedure, including timing and type of bacteria sampling from the chest. Ro = Rodac plate; Ra = rayon swab; E = ESwab.
starting with the Rodac plate (a contact plate, imprint Trypticase Soy Agar [TSA] plates; BioMérieux, Marcy l’Etoile, France), followed by a rayon swab (COPAN Italia S.p.A., via Perotti 10, Brescia, Italy) and an ESwab (a flocked nylon fibre swab; COPAN Italia S.p.A.). Samples 1–3 were taken from the sternal area. Samples 4–11 were taken as paired samples from both the right (bare skin) and left (covered with adhesives) sides of the sternum. Each sample was taken from a separate, predefined area starting proximally. A single OR nurse performed all sampling, changing sterile gloves between participants. On the left side, the nurse removed each of the eight plastic adhesives separately immediately before taking the sample. The rayon swab and the ESwab were moistened with the transport medium and rubbed back and forth 12 times against the skin. Rodac plates were pressed against the skin for 15 s. The swabs were subcultured on blood agar medium (Columbia Blood Agar Base; Acumedia Neogen Corporation, Lansing, MI, USA) supplemented with 6% defibrinated horse blood (SVA, Uppsala, Sweden) at 36 °C aerobically, and the bacterial growth was examined after 1 day and 5 days.

Two sedimentation plates (diameter 14 cm) with TSA II 4% w/v (BBL, Sparks, MD) were placed on a table in the OR nearby the participants at the beginning of the study and remained in place for 6 hr until the last sampling was performed. The plates were then incubated at 36 °C aerobically, and the bacterial growth on the plates was examined after 1 day and 5 days.

Figure 3. Number of positive samples over time from skin with or without plastic adhesive drape using the rayon swab sampling method; 25 versus 6, respectively. p < .001.

Statistical Analysis

The bacterial cultures were categorized dichotomously as positive (growth) or negative (no growth) and were compared using the McNemar test for paired proportions. A p value less than .05, two-tailed, was considered to be statistically significant. Data were analyzed with SPSS 15.0 for Windows (SPSS, Inc., Chicago, IL). Descriptive statistics are presented as minutes, numbers, and percentages.

Results

Recolonization was detected after 30 min on the skin with plastic drape and after 60 min on the skin without plastic drape (Figure 3). All bacterial cultures were CoNS, but three samples exhibited CoNS mixed with diphteroid rods. None of the cultures showed any growth of S. aureus. Before antiseptic preparation with 0.5% chlorhexidine in 70% ethanol, all skin samples (n = 10) displayed growth of CoNS. All cultures from the anterior nares showed growth of CoNS but none of S. aureus. The sedimentation agar plates exposed to the OR environment for 6 hr contained 17 and 23 colonies of CoNS, respectively.

There was a consistent trend throughout the eight-sample time series: positive cultures derived from a significantly (p < .001) higher proportion of samples collected with the rayon swab from skin with plastic drape (31%, 25 of 80) than from skin without the drape (7.5%, 6 of 80; Figure 3).
More rayon swab samples than ESwab and Rodac samples resulted in positive bacterial cultures (Figure 4). All baseline samples taken 3 days before the trial resulted in positive cultures. While no positive cultures derived from the ESwab samples taken after chlorhexidine soap use, 7 of 10 of the rayon swab samples and 4 of 10 of the Rodac samples resulted in positive cultures. No other positive samples were identified during the trial using Rodac plates. Sampling with rayon swabs showed positive results at all time points, except at 120 min, with a higher proportion of positive results compared with ESwabs (Figure 4). Because the ESwabs were not delivered in time, data from sampling with this method at 30 and 60 min are missing.

**Discussion**

In the present study, we investigated the time to recolonization of the skin of the chest after antiseptic preparation with chlorhexidine in 70% ethanol. We attempted to simulate the preoperative procedure during cardiothoracic surgery, though we carried out no surgical incision. Furthermore, we aimed to determine whether there was any difference in bacterial growth on the skin with or without plastic adhesive drape as well as to evaluate three different sampling methods. We first detected recolonization of the skin at 30 min after antiseptic preparation (Figure 2). There was a trend toward more rapid recolonization of skin covered with plastic drape, and there was a statistically significant difference ($p < .001$) in the total number of positive-culture samples between skin with and without plastic adhesive drape: 31% versus 7.5%, respectively.

Application of a plastic drape to protect the surgical wound from direct contamination from adjacent skin is an established method in cardiothoracic surgery (Gärdlund, 2007). There is, however, no direct evidence that this strategy actually reduces the incidence of SSIs. By contrast, a Cochrane report concluded that there is some evidence that the use of adhesive plastic drape may increase infection rates (Webster & Alghamdi, 2007). To our knowledge, no prior studies, except for Johnston, Fairclough, Brown, and Morris’s study from 1987, have investigated the effect of plastic drape on recolonization of the skin or contamination of the surgical wound in humans. However, investigators did find that adhesive plastic drapes do not reduce contamination of surgical wounds in dogs (Owen, Gines, Knowles, & Holt, 2009). Theoretically, the plastic drapes could create a “greenhouse effect” that enables rapid bacterial regrowth and recolonization (Wilson, 2008). If more rapid bacterial growth is present when plastic adhesive drape is employed, the risk of bacterial contamination of the wound may increase, at least if the drape is removed before wound sealing, a scenario that is common for practical reasons. “Antimicrobial” surgical incise drapes with an iodophor-impregnated adhesive have been available for several years. However, these “antimicrobial” drapes exhibited no superior effect on the SSI rate compared to conventional incise drapes (Webster & Alghamdi, 2007).

Bacterial growth from wound samples taken at the end of cardiothoracic surgery may be explained by early recolonization of commensal skin flora already present during the operation (Kuhme et al., 2007; Tammelin et al., 2001). Even with rigorous skin preparation, complete sterilization of the skin is not possible (Wilson, 2008). To our knowledge, only one
previous study measured the time to skin recolonization after preoperative asepsis with chlorhexidine and after application of a plastic adhesive drape (Johnston et al., 1987). In our study, recolonization was detected 30 min after asepsis and increased at 180 min. However, exactly when the recolonization started was unknown. In contrast to previous reports and the current study, Johnston et al. (1987) described decreased recolonization following preoperative antiseptic preparation in combination with adhesive iodophor drapes, that is, the recolonization started after 5 min, yet there was less bacterial contamination compared to antiseptic preparation without adhesive drapes. The risk of airborne contamination of the skin must also be considered; the sedimentation agar plates used in the present study showed growth of CoNS. Yet, this observation does not explain the positive cultures that were derived from samples obtained under the plastic adhesive drape since the draping protected the skin from airborne contamination.

Investigators described the pad method to be the most sensitive method for bacterial sampling from skin (Hambraeus, Hoborn, & Whyte, 1990). However, we were unable to locate any commercially available sampling product based on this technique. Therefore, we used and evaluated three different bacterial sampling methods, including two swab methods similar to the pad method. Our findings confirmed that sampling by rayon swabs (similar to the pad method of Hambreus et al.) was more sensitive than the use of Rodac plates or ESwabs. We therefore recommend the use of rayon swabs as the preferred sampling method for future studies of skin recolonization.

Although a limitation of the present study is the small sample size, the paired experimental design reduced the influence of potential interindividual differences among subjects (Mills et al., 2009). Only healthy volunteers were included in this study, and their mean age was 40. Patients undergoing cardiovascular surgery are typically older, and it is possible that they are less observant and meticulous in their preoperative chlorhexidine showers than our healthy volunteers. In Sweden, patients usually receive only written instructions in advance regarding this preoperative shower that they will be performing at home, and poor compliance due to illness and incomprehension may influence the rate and magnitude of skin recolonization. Additionally, for practical reasons we used small plastic adhesive drapes instead of the incision film designed for surgical draping. However, the mechanism of covering the skin is identical, and there is no reason to believe that these similar plastic films would have significantly different effects on the rate of recolonization. We categorized the results of the bacterial cultures dichotomously as positive (growth) or negative (no growth), though the sample size was small.

In conclusion, the present study in healthy volunteers demonstrates that the use of plastic drapes during surgery may in fact hasten and increase recolonization of the skin following preoperative asepsis. Studies on patients undergoing cardiac surgery are warranted to verify this observation. In addition, studies on the dynamics of skin recolonization when using antimicrobial-impregnated adhesive drapes as well as assessment of correlations with wound contamination and later development of SSI are necessary. Plastic adhesive drapes are expensive so, as with any intervention, this strategy should be rigorously evaluated before implementation into routine clinical practice.

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