Chlorhexidine Cloth Overview for Surgical Infection Prevention

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ABSTRACT

Infections are one of the most devastating complications that occur after lower extremity total joint arthroplasty or any surgical procedure. As such, it has become a major priority to reduce them through various preoperative strategies. Popular prophylactic antimicrobials include alcohol-based solutions, povidone iodine, as well as combinations of chlorhexidine-based products to address an individual's microbial load on the skin. Chlorhexidine is a broad-spectrum biocide with activity against Gram-positive and Gram-negative bacteria. The use of chlorhexidine cloths may be a choice over solutions, since some studies have shown that they can reduce lower extremity infection rates by greater than two-thirds. In this report, we will describe the scientific basis for the dual application technique of these cloths, as well as our general recommendations for usage for lower extremity arthroplasties and other surgical procedures. Multiple studies have demonstrated their efficacy, with a prospective randomized study of joint arthroplasties demonstrating a 2.9% deep infection rate without their use versus a reduction to 0.4%. In conclusion, we believe that these cloths are appropriate for use in all hip and knee lower extremity arthroplasties as well as other surgical procedures.

INTRODUCTION

Periprosthetic infections are one of the most devastating complications that occur after lower extremity total joint arthroplasty.[1–3] There are some reports that describe them as being the most common reasons for readmission after these procedures and they lead to a tremendous amount of increased morbidities and costs.[4–8] These infections have even been shown to increase mortality rates, which should not be underestimated. For example, in one study, the relative survival rates of patients who had periprosthetic infections were equated to that of common cancers.[7] A total of 2,778 patients who underwent a second procedure after total joint arthroplasty were studied with the outcome of interest and incidence of mortality at approximately 30 days, 90 days, one year, two years, and five years. The relative survival rate of patients who had a periprosthetic joint infection was found to be 87% at five years. This is certainly comparable to the five-year survival rates for the top five most common cancers: 99% for prostate cancer; 91% for melanoma, 89% for breast cancer; 84% for lung and bronchial cancer, and 64% for colorectal cancer.

Nearly one million lower extremity

procedures are performed in the United States each year with an eventual lifetime infection rate of 1.5%. Therefore, cost estimates of these infections are $3.18 billion per year.[3,9–12] As such, it has become a major priority to reduce them through various preoperative, intraoperative, or postoperative strategies.[3]

Preoperative strategies used to combat the problem have included identifying comorbidities and demographic factors that are associated with increased infection rates for the purpose of mitigating them.[3] For example, we know that diabetic patients have increased infection rates. In one study of 118,645 patients, the incidence rate of any infection was found to be 70 and 45 per 1,000 person-years among diabetics and non-diabetics, respectively.[13] Patients who are obese or morbidly obese, as well as patients who have preoperative narcotic abuse, all have increased rates of infection.[14–17] D'Apuzzo et al. studied whether morbid obesity is an independent risk factor for postoperative complications in patients undergoing primary total knee arthroplasty (TKA).[16] They examined the Nationwide Inpatient Sample database and identified that 1,777,068 morbidly obese patients (BMI $\geq$ 40 kg/m^2) had a significantly higher infection risk than non-obese patients (0.24 vs. 0.17%, p=0.001). Jain et al. investigated the duration of preoperative opioid prescriptions and their relationship with the risk of postoperative adverse events after major joint arthroplasty and lumbar fusion.[18] A total of 58,082 patients were analyzed and they found that opioid use for greater than six months was associated with an increased risk of wound infection (hazard ratio=1.45, p=0.001). A list of many of the comorbidities associated with increased infection rates can be found in Table I and Appendix I.

Therefore, a way to potentially reduce periprosthetic infections would be to target modifiable comorbidities. For example, diabetic patients can undergo screening for hemoglobin A1C to identify at-risk patients so they can be more controlled before surgery. Individuals who are obese can lose weight and/or see a nutritionist. Patients can stop some of their other modifiable risk factors such as smoking and alcohol usage, as well as check for oral infections.

Table I
Common comorbidities that are associated with increased infection rates

1. Immunosuppression (i.e., DM, RA, HCV, HIV)
2. Body mass index >40 kg/m^2
3. Active smoker
4. ASA >3
5. MRSA colonization
6. Revision surgery for previous arthroplasty

Key: ASA, American Society of Anesthesiologists score; DM, diabetes mellitus; RA, rheumatoid arthritis; HCV, hepatitis C virus; HIV, human immunodeficiency virus

Table II
Some methods for operative infection prophylaxis

- Nasal swabbings
- Hair removal techniques
- Advanced skin preparations
- Skin preparations
- Operating room airflow/filtrations
- Scrubbing solutions/techniques
- Gowning techniques
- Surgical draping techniques
- Traffic patterns

Table III
Recommendations from leading health agencies

Agency	Recommendation
Centers for Disease Control[33]	◆Shower or take a bath with an antiseptic agent on at least the night before the operative day
Society for Healthcare Epidemiology of America / Infectious Diseases Society of America[39]	◆Preoperative showering with agents such as chlorhexidine (has been shown to reduce bacterial colonization of the skin)
Department of Health and Human Services[40]	◆Use appropriate antiseptic agent for skin preparation ◆Preoperative showering or bathing with agents such as chlorhexidine (has been shown to decrease bacterial colonization of the skin)

There are various other methods such as preoperative, intraoperative, and postoperative strategies that can be used to reduce the risk of infection. Present methods of infection prophylaxis include, but are not limited to, nasal swabbing, hair removal techniques, preoperative antibiotics, skin preparation, operating room (OR) ventilation, scrubbing procedures, OR attire, surgical draping technique, and controlling OR traffic patterns (Table II).[3,19–27] Nasal carriers of high numbers of *Staphylococcus aureus* have a three- to six-times higher infection risk than non-carriers or low-level carriers.[28,29] Hair removal with clippers immediately before surgery might decrease infection

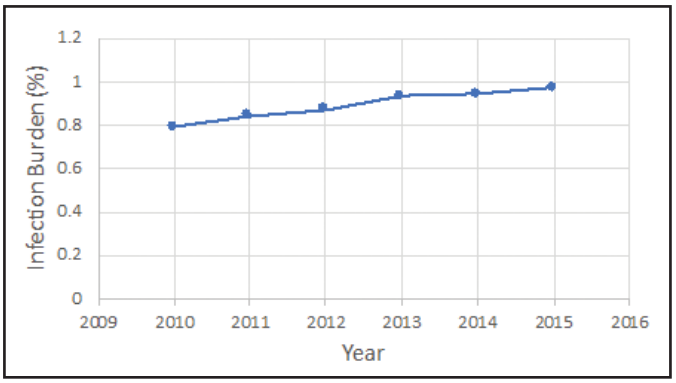

Figure 1. Mean infection burden for total hip arthroplasty across six arthroplasty registries.

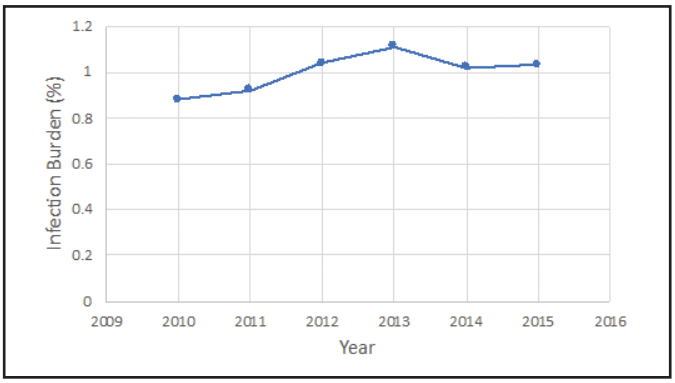

Figure 2. Mean infection burden for total knee arthroplasty across six arthroplasty registries.

risk compared with razors, because the latter causes cutaneous micro-lesions and allows endogenous flora colonization.[29–31] Intraoperative techniques include using antibiotic-impregnated irrigation solutions and reducing operative time to less than two hours.[19,20,29]

Preoperative utilization of chlorhexidine (CHG) may be one of the strategies that can further reduce infections.[3] The Association of periOperative Registered Nurses (AORN) strongly recommends that patients get some type of preoperative scrubbing, wash the night before, or on the day of surgery.[32] Other prominent agencies recommend a preoperative shower with an antiseptic agent (Table III).[33] For example, Brown et al. evaluated the efficacy of a dilute povidone-iodine lavage in preventing early deep postoperative infections after total hip and knee arthroplasty.[34] They studied and compared 1,862 consecutive cases (630 THAs and 1,232 TKAs), performed before the introduction of a protocol of dilute povidone-iodine lavage with 688 consecutive cases (274 THAs and 414 TKAs) afterward. Their outcome of interest was the occurrence of periprosthetic infections within the first 90 days postoperatively, and they found a significant reduction in infection rates with dilute povidone-iodine lavage (0.15 vs. 0.97%, p=0.04). Anis et al. evaluated the associations of operative times with prosthetic joint infections (PJIs) and surgical site infections (SSIs) in primary TKAs in 11,840 primary cases analyzed. In their multivariate analyses, the risk of PJIs and SSIs increased by 18 and 11%, respectively, for every 15-minute increase in operating time after 85 minutes.[35] Studies have demonstrated lower rates of periprosthetic joint infections for patients treated with silver-impregnated gauze dressings compared to patients receiving standard gauze dressings.[36,37] The World Health Organization recommends using negative pressure wound therapy for high-risk wounds.[38]

Despite all these efforts, there are reports that show that the risk of infection is not successfully being reduced.[9,41] A recent report by Springer et al. studied infection among hip and knee arthroplasties in six arthroplasty registries (i.e., Australian Orthopaedic Association National Joint Replacement Registry [AOANJRR], New Zealand Joint Registry, Swedish Hip Arthroplasty Register, Swedish Knee Arthroplasty Register, National Joint Registry of England, Wales, Northern Ireland, and the Isle of Man, and the American Joint Replacement Registry) between 2010 and 2015.[39] Their outcome of interest was infection burden, defined as the ratio of the total number of revisions due to infection to the total number of arthroplasties (primaries and revisions) performed in one year. They found that the incidence of periprosthetic infections over those six years was actually increasing for both hip (Fig. 1) and knee arthroplasty (Fig. 2). The THA infection burden (unweighted mean) was 0.79, 0.84, 0.87, 0.93, 0.94, and 0.97%, respectively, while it was 0.88, 0.92, 1.04, 1.11, 1.02, and 1.03%, respectively, for TKAs. Therefore, it is imperative that strategies to reduce infection continue to be advanced.

As mentioned, preoperative usage of chlorhexidine may be one of the strategies that can further reduce infection. Chlorhexidine cloths have been shown to be potentially advantageous over rinse-off solutions. Therefore, the subject of this overview is the use of chlorhexidine cloths for prophylaxis. We will describe the scientific evidence as well as our general recommendations for usage for these cloths.

COMPARISON TO OTHER ANTIMICROBIALS

Chlorhexidine is a broad-spectrum biocide with activity against Gram-positive and Gram-negative bacteria. It is bactericidal due to its salt dissociating and releasing cationic ions that bind to

Table IV
Advantages and disadvantages of common antimicrobials

Antimicrobial	Advantages	Disadvantages
Chlorhexidine Solutions	◆Broad spectrum ◆Excellent persistent and residual activity	◆Drying effect on the skin
Chlorhexidine Cloths	◆Broad spectrum ◆Excellent persistent and residual activity	◆Potential Skin Reaction
Povidone-iodine	◆Broad spectrum	◆Minimal persistent and residual activity on the skin
Alcohol	◆Broad spectrum	◆Highly flammable

Figure 3. Example of chlorhexidine-impregnated cloths.

the negatively charged bacterial cell wall to disrupt the lipid bilayer at high concentrations.[42,43] Recently, it has been used as either a solution or in the form of cloths for patients undergoing surgery. There are a number of studies that have compared chlorhexidine to other antimicrobials on the market.[44,45] They include alcohol-based solutions, povidone iodine, as well as combinations of chlorhexidine-based products (Table IV). Thus, chlorhexidine can be used alone or in combinations, but has been shown to be at least equivalent to the alcohol-based products and often superior to the other products. For example, chlorhexidine is superior to povidone-iodine on the skin with regard to duration of persistent and residual bactericidal activity (Table IV). While alcohol is slightly less irritative, chlorhexidine is not a combustion risk within the operating room. Although operating room fires are uncommon, there is a risk of fire when alcohol-based surgical prep solutions are used for skin preparation.[46,47] Batra et al. reported a case of fire while operating on a patient who had a burst fracture at the C6 vertebra and quadriplegia.[46] The cause of the fire was deemed to be due to incomplete drying of the covering drapes with an alcohol-based surgical prep solution. These authors recommended that to prevent fires, removal of the fuel (alcohol) is the most reasonable and efficacious approach. This includes shaving the skin to prevent pooling of solution in the hair. Attention must be paid to effectively drape the patient to prevent the collection of flammable vapors beneath the drapes. Furthermore, the use of alcohol-based antiseptics calls for strict adherence to the proper use of these agents, including observation of required drying time. This may take a few minutes or more (often up to a five-minute delay) until the field is completely dry. In summary, chlorhexidine without a combustion risk may be preferable to alcohol.

SPECIFIC ADVANTAGES OF CLOTH APPLICATION

There are two ways to utilize chlorhexidine for the application of prophylaxis for lower extremity hip and knee arthroplasty infections. As stated, one can simply use it as a wash the night before and then rinse it off. As with any type of disinfecting solution, another way to use it is as a cloth application. Appropriate use of this method is to apply the cloth, leave it on to dry, and not to wash it off.[48] A study done by Edmiston et al. showed that by using this application, the chlorhexidine retained its antibacterial properties for many hours.[48] They compared the activity of 2% chlorhexidine-impregnated preoperative skin preparation cloths with an application of 4% chlorhexidine solution by studying a total of 30 subjects. The microbial reduction was significantly greater for the sites treated with the cloths at approximately six hours after preparation (3.64 vs. 3.15, $p<0.01$). Therefore, it would appear from this study that chlorhexidine cloth applications would be significantly superior to using solutions in terms of reducing bacteria.

The other advantage of this approach, in addition to simply applying the chlorhexidine, is that different areas of the body can be specifically targeted with the cloths. The location of the future wound (i.e., hip or knee) can be focused to ensure consistent dosing. It has also been found that this is quite easy to use for all patients and there is a minimal amount of variation with straightforward instructions for application.[44,45] For all of these reasons, it appears that even though the solution is what was initially recommended by AORN, the cloth application may be more appropriate (Fig. 3). In fact, at the Musculoskeletal Infection Society meeting in 2013, the chlorhexidine cloth was one of the recommendations that was made as "methods of decolonization include photo-disinfection therapy, total body chlorhexidine gluconate showers and cloths preoperatively, and iodine-based solutions applied hours before surgery" and "chlorhexidine gluconate [cloths] (2%) eliminate the need to bathe just before surgery."[49] This was supported by the Johnson et al. evaluation of 2,213 total knee arthroplasty patients of which 478 used a preadmission chlorhexidine cloth protocol and 1,735 underwent standard in-hospital perioperative preparation only.[45] They found a significantly lower incidence of surgical site infections in patients who used the chlorhexidine cloth protocol versus the comparison group ($p=0.021$).

DEVELOPMENT FOR USE IN LOWER EXTREMITY SURGERIES

One of the authors (MAM) began using chlorhexidine cloth applications in 2011. At that time, the recommended usage was one application the morning of, or immediately before surgery in order for patients to be effectively prepped before they go into the operating room. Based on the aforementioned report of Edmiston et al., which showed at least six hours of persistent anti-bacterial effect after cloth application, it was postulated that usage the night before surgery might allow for an increased antibacterial effect.[48] This would theoretically further enhance anything that was done on the morning of surgery, which sometimes might not be as effective and might be rushed.

After the commencement of this dual application protocol, a prior study in the literature that further supported this technique was noted. Ryder studied whether chlorhexidine cloths had greater persistence on patient's skin compared with chlorhexidine solutions and the effect of a dual application by equally randomizing 24 subjects into two groups: usage of the applications just the morning of the test, or usage both the night before and the morning of the test.[50] The cloth subjects were found to have more residual chlorhexidine on their skin than the solution subjects and two applications of the cloths showed more residual chlorhexidine than one ($p=0.016$). Therefore, this study further supported chlorhexidine cloth usage over solutions, as well as the dual application.

Thus, the preoperative process of one surgeon (MAM) at Sinai Hospital of Baltimore was that patients were given chlorhexidine cloths to be used at home and were instructed to use them the night before and again in the morning on their own, so they would not necessarily have to rely on anything being rushed or missed when going to the hospital. They would take a leisurely shower before they went to bed, use the application, leave it on their skin, and then when they woke up in the morning, they would use another application.

Initial studies of this intervention were reported in 2013 and 2014.[44,45] For 2,213 total knee arthroplasties, the application of these cloths reduced infection rates by greater than 70%.[45] The incidence rate of surgical site infections was found to be 0.6% in patients using the chlorhexidine cloths compared to 2.2% in the patients undergoing in-hospital perioperative skin preparation only. Another study of hip arthroplasties also reduced infection rates.[44] In an investigation of total hip arthroplasty patients who used chlorhexidine-impregnated cloths (n=557) compared with patients who did not (n=1,901), a statistically significant lower incidence of infections occurred in patients who used the cloths (0.5%) when compared to patients who did not (1.7%) ($p=0.04$). Thus, this study further demonstrated the efficacy of chlorhexidine-impregnated cloths.

Once it was realized that these cloths could reduce infection rates, their use became the standard of care for all surgeons at Sinai Hospital of Baltimore and larger scale studies were performed for knee and hip arthroplasties.[51,52] Two studies of 3,717 total knee and 3,844 total hip arthroplasty patients found the preoperative use of cloths to be associated with significantly reduced relative risk of periprosthetic infection (0.03 compared with 1.9%, $p=0.002$, and 1.62 compared with 0.6%, $p=0.0226$, respectively).

ECONOMIC JUSTIFICATION FOR USING CHLORHEXIDINE CLOTHS

As noted above, periprosthetic infections can have an enormous economic impact with all hospital-acquired infections found to be a $33 billion problem nationally, per one report.[53] The chlorhexidine cloths cost about $12 per application at the time of this report, and there were some questions about providing the cloths to patients at no charge. It became apparent that this was a cost-effective policy in addition to being patient beneficial. It was noted that any one deep infection might lead to an extra incurred cost of $80,000 to $100,000. If cloths were provided to 6,000 patients and prevented just one infection, the cost-benefit ratio would still produce a savings to the facility in the cost of treatment. Unfortunately, that was not always so obvious, so there was an economic study that demonstrated this benefit.[12] Kapadia et al. evaluated the overall annual healthcare cost savings of adding a preoperative chlorhexidine cloth preparation protocol.[12] They used reports from the National Healthcare Safety Network and previously published reports to determine the rates of surgical site infections following total knee arthroplasty and the cost per revision procedure. They found that the use of chlorhexidine at the institution for total knee arthroplasty procedures produced a net savings of approximately $2.1 million per 1,000 patients. They detailed that if there was a spending of $12,000 on cloths for 1,000 patients, and this prevented one infection, there would be a saving of $80,000. In addition, more than one infection would be expected to be prevented in such a cohort by using the cloths. In extrapolating from the annual healthcare bill of $3.18 billion for PJIs, a two-thirds reduction in infections would save the country greater than $2 billion. Their results using chlorhexidine prior to undergoing total knee arthroplasty demonstrated the potential to decrease healthcare costs by decreasing the incidence of surgical site infections.

Unfortunately, even after prompting patients to use the cloths and providing the cloths at no charge, 100% patient compliance was not achieved. At best, even with directives from the surgeon and from the staff, there would be 75% compliance; with some surgeons, it was lower.[54] So, it was believed at this point, that it was appropriate to conduct prospective, randomized studies to better assess the effects of the chlorhexidine cloths. The trials were set up for a total hip, total knee, revision total hip, and revision total knee arthroplasty as four separate cohorts. After approximately 600 patients were enrolled, there were six infections noted in the non-chlorhexidine cohort and zero in the chlorhexidine cohort. The institutional review board suspended the study because it felt it was inappropriate to not use the chlorhexidine cloths.

In addition, a number of other studies in lower extremity arthroplasty have been published[55,56] describing its infection prophylaxis efficacy. Also, in a Level 1 study, Eiselt further confirmed the efficacy of the cloths.[57] Their use of a similar chlorhexidine cloth protocol as noted above, applied the evening before and the morning of surgery, demonstrated a lower incidence of infections in patients who used chlorhexidine bathing (1.59 vs. 3.19%). The beneficial effect was not found statistically in one other study (even though there was a non-statistical decrease in infections), but the surgeons only used one cloth

Table V
Studies from other surgical fields

Report	Subjects	Results
Rauk et al. 2008[65]	N/A	Resulted in no incisional SSIs associated with cesarean sections for greater than one year after implementation
Baxter et al. 2009[66]	100	Reduction in SSI rate from 3.05 to 1.04% (p=0.015)
Farber et al. 2010[67]	N/A	Showed a 57.2% relative reduction over 3 years after implementation
Hogenmiller 2011[68]	341	Found no SSIs in the 7-month time period following implementation of chlorhexidine cloth use
Lutfiyya et al. 2012[63]	625	Incidence was 21.2% before implementation of the bundle and 6.7% after. The absolute decrease of 14.5% was significant (p<0.0001)
Bell 2014[69]	N/A	Found a 90% decrease in the first 8 months post-intervention and an 80% decrease after 20 months post-intervention
Hickson et al. 2015[61]	4,942 cesarean delivery patients	Percentage of SSIs were reduced from 2.13 to 0.10% after the interventions (p<0.0001)
Bebko et al. 2015[59]	709	SSI rate in the intervention group was significantly lower (1.1%) than the control group (3.8%) (p=0.02)
Hewitt et al. 2017[60]	701	Incidence of SSIs was 13.9% prior to implementation compared to 4.7% after (p<0.01)
Schriefer et al. 2017[64]	541	SSI rate dropped from a baseline of 4% in the year the bundle was implemented (n=154) to 3.2% in the next year (n=189) and to 0% in the following year (n=198)
Worden et al. 2017[70]	N/A	Found a marked reduction in the SSI rate from 1.28 to 0.78%
Davis et al. 2018[71]	38	Chlorhexidine wipe to the wound area in preoperative holding and skin preparation with chlorhexidine in the OR were both ranked within the top 8 ICP SSI performers
Andiman et al. 2018[58]	2,099	Found 61 SSIs (4.51%) in the pre-full bundle implementation period and 14 (1.87%) in the post-full bundle implementation period (p=0.01)
Riley-McDonald 2019[72]	N/A	Found a 67% reduction in SSIs over 3 years
Loftus et al. 2020[62]	236	10 patients (7.7%) in the control group and 1 patient (0.9%) in the treatment group (CHG) developed an SSI (p=0.04)

SSIs, surgical site infections; N/A, not available; ICP, infection control practices

application on the morning of surgery study with no mention of compliance.[55] Thus, this latter study underscores the importance of utilizing the dual application methodology.

In summary, many different studies have shown and prompted the continued use of chlorhexidine to reduce the incidence of deep infections after lower extremity joint arthroplasty.

OTHER SURGICAL FIELDS

Chlorhexidine has also been used in other orthopaedic or surgical fields, such as in general surgery. Andiman et al. investigated the efficacy of a hysterectomy-specific surgical site infection prevention bundle, which included chlorhexidine-impregnated preoperative cloths, on SSI rates.[58] A total of 2,099 hysterectomies were analyzed from a single-institution and they found 61 SSIs (4.51%) in the pre-full bundle implementation period and 14 (1.87%) in the post-full bundle implementation period (p=0.01). Bebko et al. studied the effect of a decontamination protocol, which included chlorhexidine-impregnated cloths, on SSIs in patients undergoing elective orthopaedic surgery with hardware implantation.[59] A total of 709 patients (365 intervention and 344 controls) from a single-institution database were analyzed and the 30-day SSI rate in the intervention group was significantly lower (1.1%) than the control group (3.8%) (p=0.02). Hewitt et al. studied the effect of implementation of a care bundle, with chlorhexidine cloths used the night before and the morning of surgery, on SSIs.[60] A total of 701 colorectal surgery cases performed at a single institution were analyzed and the incidence of SSIs was 13.9% prior to implementation compared with 4.7% after (p<0.01).

Other studies have found decreased SSIs in patients treated with CHG cloths compared to control groups (Table V).[61–64]

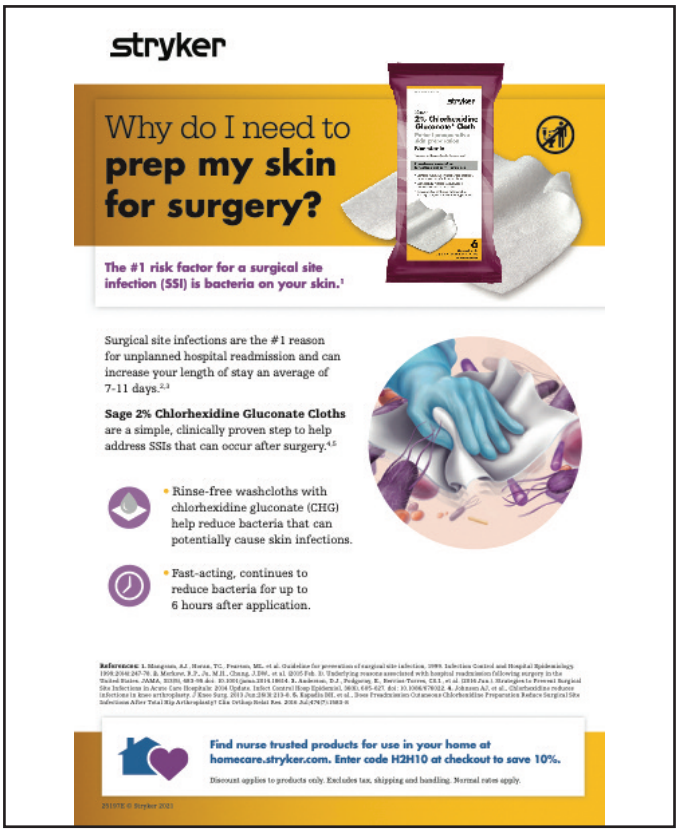

Figure 4. Example of a patient education card.

Figure 5. Picture demonstrating proper application of chlorhexidine cloth.

Appendix I
Modifiable and non-modifiable host factors that contribute to an increased risk of surgical site infections (SSI)/periprosthetic joint infections (PJI)

Modifiable host risk factors for PJI/SSI in total joint arthroplasty (TJA)

- Active infection
- Alcoholism
- Cardiovascular disease
  1. Congestive heart failure
  2. Cardiac arrhythmia
- Chronic kidney disease
- Chronic obstructive pulmonary disease
- Clotting disorders
- Depression
- Diabetes mellitus
  1. Hemoglobin A1c
  2. Serum glucose
- Drug abuse
- End-stage renal disease
- Frailty
- Human immunodeficiency virus/acquired immunodeficiency syndrome
- Immunosuppression
- Intra-articular steroid/viscosupplement injection
- Kidney disease
- Malnutrition
- Methicillin-resistant Staphylococcus aureus (MRSA) colonization
- Obesity
- Peripheral vascular disease
- Psychosis
- Renal Disease
- Rheumatoid arthritis
- Skin colonization
  1. MRSA/Methicillin-sensitive Staphylococcus aureus
- Smoking
- Untreated hepatitis C virus

Non-modifiable host risk factors for PJI/SSI in TJA

- Age
- American Society of Anesthesiologist Classification > 2
- Bariatric surgery
- Chronic anticoagulation
- Sex
- Hemiplegia/Paraplegia
- Hepatitis B virus
- Osteonecrosis
- Previous joint surgery
- Previous joint infection
- Previous infection
- Transplant

AUTHORS' PREFERRED TREATMENT

The authors want to emphasize again that their recommendation is for patients to use chlorhexidine-impregnated cloths instead of a chlorhexidine solution. Patients should apply the cloth the night before and the morning of surgery. If they have not done this the night before surgery, the nurses in the preoperative holding area should make sure that this is done. We suggest that surgeons also try to encourage patients to comply with the application practice (Figs. 4 and 5).

Certainly, these products can be used with other agents, such as other skin preparation agents, including those with povidone-iodine. Aside from a chlorhexidine allergy, which is much less common than an iodine allergy, there is no reason for patients not to use chlorhexidine.[73] In addition, chlorhexidine does not interfere with anything that the surgeons are doing in the operating room.

FUTURE WORK

As stated, an important issue with the use of chlorhexidine is low patient compliance.[54] Certainly, the surgical team could make sure that patients are compliant by screening them with a hand-held ultraviolet light to confirm that chlorhexidine was applied as instructed. Further work in other medical specialties would also be appropriate and is needed.

CONCLUSION

In summary, we have described chlorhexidine and why it is advantageous over other agents. We have shown why it is preferable to use a cloth application over a bathing solution and we have described the dual application use (i.e., night before and morning of surgery) (Table VI). A description of the gamut of studies for lower extremity joint arthroplasty and other surgical specialties showing positive results on infection is provided. We believe that these cloths are beneficial for use in all hip and knee lower extremity applications, as well as in other surgical specialties. STI

AUTHORS' DISCLOSURES

Dr. Mont is a board or committee member for The Knee Society and The Hip Society, receives research support from National Institutes of Health, and is on the editorial board for the Journal of Arthroplasty, Journal of Knee Surgery, Surgical Technology International, and Orthopaedics. Dr. Mont also receives company support from 3M, Centrexion, Ceras Health, Flexion Therapeutics, Johnson & Johnson, Kolon TissueGene, NXSCI, Pacira Pharmaceuticals, Pfizer-Lily, Skye Biologics, SOLVD Health, Smith & Nephew, Stryker, CERAS Health, MirrorAR, Peerwell, US Medical Innovations, Johnson & Johnson, RegenLab, Stryker, TissueGene, Medicus Works LLC, Up-to-Date, Wolters Kluwer Health, Lippincott Williams & Wilkins, Journal of Arthroplasty, Journal of Knee Surgery, Orthopedics, Surgical Technologies International, AAHKS, Knee Society, and Hip Society.

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