Preoperative Chlorhexidine Preparation and the Incidence of Surgical Site Infections After Hip Arthroplasty

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Abstract: The purpose of this study was to evaluate effectiveness of an advance, at-home chlorhexidine-impregnated skin preparation cloth in decreasing the incidence of deep periprosthetic hip arthroplasty infections. Arthroplasty surgeons at the senior author's institution provided their patients with chlorhexidine-impregnated single-use cloths for use at home the night before and the morning of surgery. Between January 2007 and December 2009, the compliance of this practice, as well as the incidence of periprosthetic infections, was monitored for all patients who underwent hip arthroplasty. Of the 1134 patients who underwent hip arthroplasty, 157 patients completely complied with the preoperative chlorhexidine preparation protocol. There were 14 infections in the group that was not compliant (1.6% infection rate), and there were no infections in the compliant patient population. Based on the results of this study, at-home preoperative patient skin preparation appears to be a simple and cost-effective method to reduce periprosthetic hip infection rates. **Keywords:** chlorhexidine preparation, surgical site infections, hip arthroplasty, periprosthetic hip infections.

Although hip arthroplasty continues to provide excellent functional results for patients having debilitating arthritis, a major concern for patients and surgeons is the risk of infection. Infection can lead to extensive treatment and hospital stays and can be an economic burden to both the patient and the health care institution [1]. Although treatment methods have advanced in recent years, with success rates near 90% for revision total hip arthroplasty after periprosthetic infection, the optimal medical care would be infection prevention [2-4]. Over the past decades, numerous advances have been made in reducing the deep periprosthetic infection rate to nearly 1% after total hip arthroplasty. These include the use of perioperative intravenous antibiotics [5], laminar flow operating rooms [6], the effects of body exhaust suits [7,8], optimized sterile draping techniques [9-11], multiple instrument trays [1], and reductions of intraprocedure operating room traffic [12]. Studies have analyzed areas that have the potential to introduce microbes into the surgical site and changes have been made in an attempt to further decrease infection rates [9].

Recently, studies have been performed addressing the effectiveness of preoperative preparation techniques, specifically, the cumulative effect of chlorhexidine gluconate (CHG) when applied by patients twice at home before their joint arthroplasty (one application the night before and one the morning of surgery) [10]. The United States Centers for Disease Control has recommended patients shower at least the night before surgery with an antiseptic rinse [13]. However, there are problems with liquid rinses [14]. Chlorhexidine binds preferentially to the cotton in washcloths instead of the skin [15], making application of sufficient solution difficult. Subsequently, a new CHG product was developed—a ready-to-use, single-use cloth applicator for the delivery of CHG onto the patients' skin. At the senior author's institution, a protocol was developed to implement the use of this CHG preparation cloth, in the interest of assessing patient compliance, and to monitor infection outcomes after use of the

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preoperative at-home CHG preparation when used the night before and the morning of surgery.

The purpose of this study was to compare the surgical site infection rates after hip arthroplasty between a group of patients who used 2 applications of at-home preoperative chlorhexidine preparations and a group that did not undergo the preparations. The results were stratified by patient compliance (full, partial, or none), by surgeon, and by National Nosocomial Infections Surveillance System (NNIS) surgical risk classification to assess for differences.

Methods

At the senior author's institution, a prospectively collected infection-tracking database of all patients who underwent hip arthroplasties between January 1, 2007, and December 31, 2008, was reviewed. During this 2-year period, all surgeons at the institution were asked to have their patients perform an at-home skin preparation, consisting of 2 applications of CHG (once the night before and once the morning of surgery). Of the 1134 patients who underwent hip arthroplasty, 80 were excluded because of incomplete or incorrect compliance with the preparation protocol, but their results will also be described. This left 954 patients in the study. One hundred fifty-seven patients completed the at-home skin preparation, and the remaining 897 patients received only the standard, perioperative skin preparation (described below). Table 1 gives mean values for patient age, sex, body mass index, and NNIS risk classification, which incorporates the American Society of Anesthesiologists physical status classification system as described below, between the 2 groups. Approval for this study was received from the institutional review board.

All surgeons were instructed to preoperatively give patients undergoing a hip arthroplasty a packet containing detailed instructions, along with 12 cloths impregnated with 2% CHG (Sage Products, Inc, Cary, Ill). Patients were instructed to use the cloths in 2 applications: one the night before surgery and one the morning before surgery. Each application consisted of 6 cloths. One was applied to the head and trunk, one to the arms, one to each leg (2), and one to the surgical site. Although bathing was not required, if the patient wished to do so, they were asked to bathe or shower at least 2 hours before the application of the CHG on the night before surgery. After application, the patient was instructed to wait at least 1 minute before dressing and was asked to not apply any creams, lotions, or powders, as well as not to bathe after application. The same procedure was repeated in the morning before surgery. To measure compliance, patients were given a data collection sheet on which they were instructed to place adhesive stickers that were found on each individual package of chlorhexidine-impregnated cloths.

Patients were stratified into 3 categories as determined by the adhesive sticker data collection sheet: those who completed both skin preparations, those who completed one skin preparation only, and those who did not use the at-home chlorhexidine preparation and received standard perioperative skin preparation only. For this study, those who did not comply 100% with the protocol were separately stratified but did not form the basis of the primary study that comprised 2 cohorts: those who did and those who did not complete the at-home skin preparation.

All patients received the same in-hospital preparation, regardless of their compliance with the at-home preparation. Once in the operating room, and after induction of anesthesia, the surgical site was painted with a combination iodine poyacrylex/alcohol preparation (DuraPrep solution; 3M, St Paul, Minn). Following a hospital initiative, all patients received perioperative antibiotic prophylaxis within 1 hour of incision as per the American Academy of Orthopedic Surgeons recommendations for the use of antibiotic prophylaxis in primary total joint arthroplasty [16]. Immediate postoperative care and follow-up were provided according to each surgeon's standard protocol after hip arthroplasty.

Infections were categorized as either superficial or deep. Only deep infections (those that infected the deep fascial layers or the joint space itself) were considered for this study; superficial wound infections, hematomas, and incisional irritations were not considered periprosthetic infections.

Additional stratification was performed based on operating surgeon as well as patient infection risk categories. Infection risk categories were made using the NNIS surgical risk rating system. A score of 0 or 1 is assigned for each of 3 components to the NNIS classification: surgical incision time (< or >2 hours), American Society of Anesthesiologists risk category (<3 or 3+), and wound classification (clean or clean-contaminated, or contaminated and dirty). The highest score a patient can receive is a 3. Patients who receive a score of 0 are considered low risk, those who receive a score of 1 are considered moderate risk, and those who receive scores of 2 or 3 are considered high risk for surgical site infections. Table 2 summarizes this risk classification.

Table 1. Comparison of Demographic Factors of Patient Groups

	Advance-Preparation Compliant Patients	No Advance Preparation Patients	*P*
Mean age (range), y	58 (26-89)	58 (16-89)	.98
Ratio of sex (men-women)	79:80	472:425	.547
Mean body mass index (range), kg/m^2	28 (17-60)	29 (15-59)	.7362
Ratio of risk category (low-medium-high)	65:29:7	54:39:7	.035

Any surgeon that did not perform more than 20 hip arthroplasty surgeries in a year was excluded from the surgeon stratification, although their patients remained in the overall analysis. There were 4 surgeons from the senior author's practice who had their results individually analyzed. Each surgeon's cases were evaluated for compliance and noncompliance with the preoperative skin preparation protocol, and their infection outcomes were categorized.

Statistical Analysis

All data were collected using an Excel (Microsoft, Redmond, Wash) spreadsheet. A statistical analysis was conducted using a χ^2 test to provide P values and to evaluate differences between the study groups. A power analysis was also performed to determine the optimal number of patients who would be required for a prospective, randomized study to significantly demonstrate a reduction in infection rates by at least 50%.

Results

When a comparison was made between the group of patients who complied with the at-home chlorhexidine cloth preparation and those who did not, there was a notably lower incidence of infections in the group of patients who used the at-home chlorhexidine preparation. There were no surgical site infections in the 157 patients who completed the advance skin preparation. Of the 897 patients who were not compliant with the advance preoperative skin preparation, 14 had infections (1.6%; $P = .231$). Of the group of 80 partially compliant patients, there were no infections.

When stratified into NNIS surgical risk categories, there were increases in infection rates in the patients who did not comply with the advanced skin preparation. Results are summarized in Table 3. The infection rate in the noncompliant group ranged from 0.4% to 5.2%, whereas there were no infections in the patient group that complied with the at-home preparation.

The results were also stratified by surgeon, which again showed that infection rates after compliance with advance preoperative skin preparation (no infections) were lower than infection rates in patients who were not compliant (infection rates ranging from 0.2% to 4.8%) with the advance skin preparation protocol. Results are shown in Table 4.

Table 3. Incidence of Surgical Site Infection Stratified by Risk Category

		Knees		
Risk Category	Compliance	Total Joints Operated	No. of Infected Joints	Incidence (%)
Low	Noncompliant	256	4	1.6
	Compliant	52	0	0
Medium	Noncompliant	332	9	2.7
	Compliant	54	0	0
High	Noncompliant	123	9	7.3
	Compliant	30	0	0

Discussion

Although much attention and controversy continues to exit concerning on the appropriate treatment of periprosthetic infections after hip arthroplasty, greater consensus exists concerning the prevention of infections after primary arthroplasty procedures. A number of strategies have been shown to reduce contamination and/or infection rates after orthopedic procedures including the use of perioperative intravenous antibiotics, careful draping techniques and occlusive dressings, laminar air flow, body exhaust suits, and appropriate operating room management [17]. Topical CHG has been reported to be an effective long-lasting antiseptic, but at-home rinse preparations have shown inadequate delivery compared to no-rinse cloths, with less chlorhexidine remaining on the skin with liquid preparations [15]. In this study, we wanted to assess whether no-rinse chlorhexidine preparation cloths demonstrated a clinical improvement in infection rates after hip arthroplasty when applied at home the night before and morning of surgery.

There are several limitations in this study including low compliance with the advance skin preparation protocol. All of the surgeons were strongly encouraged by the hospital infectious disease control staff to

Table 2. Surgical Wound Infection Risk Categorization

	Score
Wound class	
Clean or clean-contaminated	0
Contaminated, dirty	1
American Society of Anesthesiologists score	
<3	0
3+	1
Surgical cut time (h)	
<2	0
≥2	1
Total score	0: low risk
	1: moderate risk
	2,3: high risk

Table 4. Incidence of Surgical Site Infection Stratified by Operating Surgeon

		Hips		
Surgeon	Preparation Use	Total Joints Operated	No. of Infected Joints	Incidence (%)
1	Noncompliant	71	2	2.8
	Compliant	9	0	0
2	Noncompliant	124	2	1.6
	Compliant	14	0	0
3	Noncompliant	543	1	0.2
	Compliant	101	0	0
4	Noncompliant	143	7	4.8
	Compliant	33	0	0

distribute a packet of information and chlorhexidine cloths to all patients at their final preoperative visit. However, surgeon and patient participation was not mandatory, and there was poor overall compliance. Although variability was seen in the compliance rate between surgeons, insufficient information is available from the design of the study to ascertain the reasons for these differences. It is likely that differences in surgeon buy-in, individual surgeons' surgical booking procedures and workflow, patient compliance, or a combination of all 3, contributed to these differences. In addition, although the infection rate in the noncompliant group was 1.6%, compared to no infections in the group that followed the protocol, the results were not statistically significant because a larger study would be necessary to effect this. This study was limited by the number of procedures that were performed in a 2-year period. After performing a retrospective power analysis, approximately 2400 hips would be required to detect a significant difference between the 2 patient populations. Nevertheless, the authors feel that these are important preliminary findings and that further prospective randomized studies with larger numbers of compliant patients should be conducted to further validate these findings.

Although no other studies have specifically addressed the use of advanced preparation chlorhexidine-impregnated cloths for full-body preparation and their effectiveness in reducing operative site infections, our findings confirm the results of Eiselt [10], who assessed the effectiveness of chlorhexidine-impregnated cloths when applied twice (once the night before, once the morning of surgery) to the surgical site only. In their study, Eiselt [10] found that the infection rate was cut in half (from 3.19% to 1.59%) in 727 total joint procedures involving the hip and the knee. It is notable that their study decreased the infection rate, whereas in the present study, there was a further dramatic effect suggesting an additive preventive effect with total body preparations with the chlorhexidine cloth, as opposed to cleansing only the surgical site with the chlorhexidine cloth.

Our study confirmed reports by other authors of reduced infection rates after invasive procedures when chlorhexidine was used for cleaning. Bleasdale et al [18] reported on 836 patients admitted to a single intensive care unit. Three hundred ninety-one patients were bathed daily with no-rinse chlorhexidine cloths, whereas 445 patients were bathed with soap and water only. The number of bloodstream infections was significantly lower in the chlorhexidine group, with 9 infections compared to 21 ($P = .01$). Another study of patients in an intensive care unit was performed by Climo et al [19] who showed that there were less infections in the group of 2650 patients bathed with chlorhexidine daily when compared to the group of 2670 patients cleaned with soap and water. There was a reported 32% decrease ($P = .046$) in methicillin-resistant *Staphylococcus aureus* infections and a 50% reduction ($P = .008$) in vancomycin-resistant *Enterococcus* infections.

In contrast to our results, not all studies report reduced infection rates with CHG skin preparation. Other authors have compared the effectiveness of various skin preparations in the operating room. In a study by Swenson et al [1], there was a significantly higher infection rate with chlorhexidine skin preparation (8.2%) when compared to patients who had skin preparation with either povidone-iodine scrub or iodine povacrylex paint (4.8% each; $P = .001$). Interestingly, however, a study by Edmiston et al [20] compared the application of 4% chlorhexidine scrub and 2% chlorhexidine-impregnated no-rinse cloths to the inguinal regions of healthy volunteers. Although 4% chlorhexidine skin preparation solution rapidly lost its effect on skin asepsis, when the area was cleaned with a 2% chlorhexidine-impregnated cloth, the aseptic effect was retained for a significantly longer period. This suggests that although chlorhexidine may not be superior to iodine-based scrub preparations, the no-rinse chlorhexidine-impregnated cloth appears to have longer lasting effects than the scrub and could explain why it demonstrated effectiveness in the present study.

In conclusion, the results of this study are encouraging in that use of chlorhexidine-impregnated cloths, used for preoperative preparation both the night before and the morning of surgery, appear to reduce the infection rate in patients undergoing hip arthroplasty. This may be a simple and cost-effective method of reducing surgical site infections, and although larger prospective studies are needed to fully confirm these findings, it is the recommendation of the authors that this protocol be considered as an adjunct to current infection prevention methods for hip arthroplasty patients.

References

1. Swenson BR, Hedrick TL, Metzger R, et al. Effects of preoperative skin preparation on postoperative wound infection rates: a prospective study of 3 skin preparation protocols. Infect Control Hosp Epidemiol 2009;30:964.
2. Kurtz SM, Ong KL, Lau E, et al. Prosthetic joint infection risk after TKA in the Medicare population. Clin Orthop Relat Res 2010;468:45.
3. Kurtz SM, Lau E, Schmier J, et al. Infection burden for hip and knee arthroplasty in the United States. J Arthroplasty 2008;23:984.
4. Ong KL, Kurtz SM, Lau E, et al. Prosthetic joint infection risk after total hip arthroplasty in the Medicare population. J Arthroplasty 2009;24:105.
5. Hill C, Flamant R, Mazas F, et al. Prophylactic cefazolin versus placebo in total hip replacement. Report of a multicentre double-blind randomised trial. Lancet 1981;1:795.
6. Lipsett PA. Do we really need laminar flow ventilation in the operating room to prevent surgical site infections? Ann Surg 2008;248:701.

7. Der Tavitian J, Ong SM, Taub NA, et al. Body-exhaust suit versus occlusive clothing. A randomised, prospective trial using air and wound bacterial counts. J Bone Joint Surg Br 2003;85:490.
8. Pasquarella C, Pitzurra O, Herren T, et al. Lack of influence of body exhaust gowns on aerobic bacterial surface counts in a mixed-ventilation operating theatre. A study of 62 hip arthroplasties. J Hosp Infect 2003;54:2.
9. Brown AR, Taylor GJ, Gregg PJ. Air contamination during skin preparation and draping in joint replacement surgery. J Bone Joint Surg Br 1996;78:92.
10. Eiselt D. Presurgical skin preparation with a novel 2% chlorhexidine gluconate cloth reduces rates of surgical site infection in orthopaedic surgical patients. Orthop Nurs 2009; 28:141.
11. Saltzman MD, Nuber GW, Gryzlo SM, et al. Efficacy of surgical preparation solutions in shoulder surgery. J Bone Joint Surg Am 2009;91:1949.
12. Pryor F, Messmer PR. The effect of traffic patterns in the OR on surgical site infections. AORN J 1998;68:649.
13. Mangram AJ, Horan TC, Pearson ML, et al. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Committee. Infect Control Hosp Epidemiol 1999;20:250.
14. Edmiston Jr CE, Krepel CJ, Seabrook GR, et al. Preoperative shower revisited: can high topical antiseptic levels be achieved on the skin surface before surgical admission? J Am Coll Surg 2008;207:233.
15. Ryder M. Evaluation of chlorhexidine gluconate (CHG) delivered to skin following standard pre-op prepping protocols of 4% CHG solution versus no-rinse 2% CHG cloth. Am J Infect Control 2009;35:E25.
16. American Academy of Orthopaedic Surgeons. Information Statement 1027: recommendations for the use of intravenous antibiotic prophylaxis in primary total joint arthroplasty. Rosemont (Ill): American Academy of Orthopaedic Surgeons; 2004. Accessed: February 8, 2010. http://www.aaos.org/about/papers/advistmt/1027.asp.
17. Fletcher N, Sofianos D, Berkes MB, et al. Prevention of perioperative infection. J Bone Joint Surg Am 2007;89: 1605.
18. Bleasdale SC, Trick WE, Gonzalez IM, et al. Effectiveness of chlorhexidine bathing to reduce catheter-associated bloodstream infections in medical intensive care unit patients. Arch Intern Med 2007;167:2073.
19. Climo MW, Sepkowitz KA, Zuccotti G, et al. The effect of daily bathing with chlorhexidine on the acquisition of methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and healthcare-associated bloodstream infections: results of a quasi-experimental multicenter trial. Crit Care Med 2009;37:1858.
20. Edmiston Jr CE, Seabrook GR, Johnson CP, et al. Comparative of a new and innovative 2% chlorhexidine gluconate-impregnated cloth with 4% chlorhexidine gluconate as topical antiseptic for preparation of the skin prior to surgery. Am J Infect Control 2007;35:89.