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Are preoperative chlorhexidine gluconate showers associated with a reduction in surgical site infection following craniotomy? A retrospective cohort analysis of 3126 surgical procedures

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Abstract

OBJECTIVE—Surgical site infection (SSI) is a complication linked to increased costs and length of hospital stay. Prevention of SSI is important to reduce its burden on individual patients and the healthcare system. The authors aimed to assess the efficacy of preoperative chlorhexidine gluconate (CHG) showers on SSI rates following cranial surgery.

METHODS—In November 2013, a preoperative CHG shower protocol was implemented at the authors' institution. A total of 3126 surgical procedures were analyzed, encompassing a time frame from April 2012 to April 2016. Cohorts before and after implementation of the CHG shower protocol were evaluated for differences in SSI rates.

RESULTS—The overall SSI rate was 0.6%. No significant differences ($p = 0.11$) were observed between the rate of SSI of the 892 patients in the preimplementation cohort (0.2%) and that of the 2234 patients in the postimplementation cohort (0.8%). Following multivariable analysis, implementation of preoperative CHG showers was not associated with decreased SSI (adjusted OR 2.96, 95% CI 0.67–13.1; $p = 0.15$).

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Author Contributions

Conception and design: Chan, Ammanuel, Edwards, McDermott. Acquisition of data: Chan, Ammanuel, Edwards, Kidane, Vargas, D'Souza. Analysis and interpretation of data: Chan, Ammanuel, Edwards. Drafting the article: Chan, Ammanuel, Edwards, McDermott. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chan.

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CONCLUSIONS—This is the largest study, according to sample size, to examine the association between CHG showers and SSI following craniotomy. CHG showers did not significantly alter the risk of SSI after a cranial procedure.

Keywords

surgical site infection; chlorhexidine; craniotomy; antisepsis; preoperative showers

Surgical site infection (SSI) ranks among the most common hospital-acquired infections across all surgical procedures.[1] SSIs are associated with increased morbidity and mortality, as well as increased length of stay and increased readmission and reoperation rates.[1,2] Financial costs alone have been estimated to be upwards of $10 billion annually.[2,3] As a result, lowering the number of SSIs after surgical procedures is of great importance for a variety of stakeholders in the healthcare system.

Microorganisms from native skin flora cause the majority of SSIs.[4] As such, interventions that reduce the number of microbes present on skin preoperatively may be helpful to reduce the SSI rate. One such intervention is the use of chlorhexidine gluconate (CHG) liquid soap when showering on the days prior to surgery. CHG is an antiseptic with broad-spectrum antimicrobial activity.[5] Notably, CHG has been associated with decreased SSI rates after various neurosurgical and nonneurosurgical procedures, ostensibly by reducing native skin microflora.[5–8] One study compared SSI in patients who underwent total joint replacement before and after implementation of a skin antisepsis protocol that used 2% CHG cloths and found a reduction in SSIs after CHG cloths were used.[8] Furthermore, a previous study examined the implementation of a CHG shower protocol prior to spine surgery and found a significant reduction in SSI rates.[5]

On the contrary, other evidence suggests that CHG cleansing may have limited utility in preventing SSIs. A Cochrane review of randomized controlled trials scrutinized the effect of CHG antiseptic preparation on SSI rates after surgery.[9] This review concluded that the relative risk of SSI following CHG use was comparable to placebo. Furthermore, a meta-analysis illustrated that preoperative CHG bathing did not significantly reduce the risk of SSI compared with soap, placebo, or no shower.[10] However, none of the aforementioned trials focused on cranial surgery specifically, and thus the efficacy of CHG in preventing SSI after craniotomy is unknown.

In November 2013, as part of a University of California Health system–wide quality improvement mandate aimed at reducing SSIs after surgery, our institution implemented an antiseptic protocol utilizing preoperative CHG showers. This uniform policy change permits the assessment of SSI in the preimplementation and postimplementation periods.

Methods

This study conformed to STROBE guidelines. All data were anonymized. Because this study was considered a quality improvement initiative, institutional review board approval and patient consent were not required. Data were collected from April 2012 to April 2016. A

preoperative shower protocol utilizing CHG was implemented at our institution in November 2013 as part of a quality improvement initiative.

The handout for the CHG shower protocol is shown in Fig. 1.[11,12] Patients were instructed to shower with CHG liquid soap a minimum of 3 times before surgery. For each shower, patients were instructed to wash in warm water and apply CHG to all areas of the body except for the eyes, nose, ear canals, and mouth. Patients were then asked to lather and massage their body without water before rinsing with warm water. No specific interval for a prerinse pause was provided. Patients were then instructed to dry themselves with a clean towel. Once dry, patients were asked to abstain from applying lotions and powders.

Infection Classification and Outcome Monitoring

The SSI rate and absolute number of SSIs per quarter were identified in accordance with the SSI event identification guidelines of the National Healthcare Safety Network (https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf). The National Healthcare Safety Network also provides information on the surgeons involved in each case and their level of training. Surgeon and resident involvement were logged in the electronic medical record by an in-room circulating nurse at the outset of each surgery. The Department of Hospital Epidemiology and Infection Control at our institution reviewed the records of patients who underwent cranial surgery, as identified by the ICD-9 procedure codes. All surgical procedures occurred at a single facility within our institution, and consecutive patients who fit the inclusion criteria were included. Transsphenoidal procedures were excluded due to the absence of a scalp incision. Wound revisions and incision drainage cases were also excluded. Procedures that were not classified as clean (e.g., clean-contaminated, dirty, infected) were excluded.

During the 90-day surveillance window following the procedure, we used our electronic surveillance system to identify patient records associated with any of the following: 1) positive culture result for tissue, bodily fluid, wound, or blood; 2) return to surgery for incision and debridement; or 3) ICD-9 diagnosis codes suggestive of SSI (996.6, 996.69, 998.51, and 998.58). Patient records meeting any of the abovementioned criteria were then reviewed by an infection preventionist not associated with the present study. SSIs were classified as either superficial or deep. Superficial SSIs were defined as infections that occurred within 30 days of surgery and involved only the skin and subcutaneous tissue, and deep SSIs were defined as infections that occurred within 30 days of surgery and involved deeper layers (e.g., fascial and muscle layers).

Statistical Analysis

Descriptive statistics were used to summarize group characteristics. Quarterly SSI rates and group variables were compared between the preimplementation and postimplementation periods using unpaired t-tests. Quarterly SSI rates and numbers were also stratified by craniotomy region (frontal, parietal, temporal, pterional, retrosigmoid, occipital) and analyzed separately. Means, standard errors, and percentages were reported where appropriate. A multivariable logistic regression model was fit for SSI after controlling for covariates of interest. Covariates included any baseline factor that reached $p < 0.05$ on

univariate analysis. Post hoc power analyses were conducted. Effect sizes were calculated for t-tests using Cohen's D formula, while the phi coefficient was used to calculate the effect size for chi-square tests. Statistical analyses were conducted using IBM SPSS (version 25, IBM Corp.); p values were 2-tailed, with an alpha value of 0.05 considered statistically significant.

Results

A total of 3126 cranial procedures were performed between April 2012 and April 2016. Eight hundred ninety-two (28.5%) of these procedures occurred before implementation of the CHG shower protocol, and 2234 (71.5%) procedures occurred after protocol implementation. Demographic and procedural characteristics are listed in Table 1. Comparisons were made between the 20 patients with SSI and the 3106 patients without infection. The overall mean SSI rate was 0.6%, with no significant univariate differences between the preimplementation (0.2%) and postimplementation (0.8%) groups ($p = 0.11$). A greater proportion of patients with infection had resident involvement ($p = 0.04$) and more than two surgeons ($p = 0.03$). Additionally, infection was associated with use of postoperative CSF drainage ($p < 0.001$) and CSF leak ($p = 0.001$), either as an indication for index surgery or as a postoperative complication. Infection was associated with fewer surgical drain placements ($p = 0.04$).

Table 2 compares the patient and surgical characteristics of the preimplementation cohort with those of the postimplementation cohort. Univariate analyses found significant differences ($p < 0.05$) between groups with respect to diabetes mellitus, American Society of Anesthesiologists (ASA) score, resident involvement, postoperative antibiotics, number of surgeons, surgical drains, and operative time. After adjustment for these covariates, implementation of the CHG protocol was not associated with SSI (adjusted OR 2.96, 95% CI 0.67–13.08; $p = 0.15$). The multivariable analysis results are presented in Table 3. Of note, use of surgical drains was the sole factor associated with a significant reduction in SSI (adjusted OR 0.24, 95% CI 0.07–0.84; $p = 0.03$).

Cultured Microorganisms Associated With SSI

The cultured microorganisms associated with SSIs in the preimplementation and postimplementation cohorts are shown in Table 4. There were no significant differences in the proportions of resistant microorganisms (2/2 [100.0%] SSI isolates were resistant in the preimplementation cohort vs 3/18 [16.7%] isolates in the postimplementation cohort) (Yates' $\chi^2 = 2.963$; $p = 0.09$).

Discussion

This is the largest study, in terms of sample size, to examine the association between preoperative CHG showers and SSI following craniotomy. On both univariate and multivariable analyses, implementation of the preoperative CHG showering protocol was not associated with decreased SSI following craniotomy. In predictor analyses, the only identified risk factor of SSI development following craniotomy was the absence of surgical drains.

Some discussion about preoperative factors associated with SSI development is worthwhile. Placement of surgical drains was the sole risk factor that remained significant in our multivariable analysis and was associated with significantly reduced odds of SSI. These data suggest that retained postoperative subgaleal fluid may play an important role in the development of postoperative SSI. Within cranial neurosurgery, surgical drains have not demonstrated a consistent association with SSI.[13–15] However, some studies do implicate prolonged drainage (≥ 72 hours) with increased SSI rates.[16,17] Interestingly, we did not find a significant association between SSI development and diabetes mellitus, ASA score, operative time, number of surgeons, and resident involvement following cranial surgery. Diabetes mellitus is a relatively well-known risk factor for SSI following multiple procedure types, as well as for craniotomies specifically.[18–20] Similarly, some evidence demonstrates that an ASA score > II is related to increased rates of SSI.[21–23] Other studies have demonstrated an association between increased operative time and development of SSI.[23–25] With respect to personnel within the operating room, involvement of residents does not seem to have a consistent association with SSIs, and there seems to be a dearth of data on the total number of surgeons and specifically the number of surgeons during craniotomy.[26,27] In our series, patients with more than two surgeons often underwent skull base surgery, which accounted for 3 (15%) of our SSIs. These cases were likely correlated with increased surgical times, as well as factors unique to skull base surgery such as crossing of the paranasal sinuses.

The evidence relating preoperative CHG showers to the development of postoperative SSI is inconsistent. In 1987, a randomized controlled trial found that, over a 2-year period, preoperative CHG showers significantly decreased infection following elective surgery (9.1% infection rate) compared with placebo (11.7%) or soap (12.8%).[28] In 1983, a separate crossover study involving general, gynecological, orthopedic, and urological surgery patients found that, over a 60-week period, CHG bathing (5.4% SSI rate) was not associated with a notable decrease in SSI compared with preoperative bathing with unmedicated soap (4.9%).[29] More recent evidence has continued to show inconsistent results, with studies showing both decreased[30] and even increased SSI[31] when preoperative CHG showers were used.

A limited number of studies have included CHG showers in analyses of infection specifically following cranial surgery. In an examination of the use of a standardized protocol to reduce shunt infection, the Hydrocephalus Clinical Research Network found that preoperative hair washing with CHG shampoo was significantly associated with a decreased infection rate (3.4% of 477 patients vs 7.4% of 620 patients; $p = 0.004$).[32] Furthermore, no differences in bacterial meningitis rates were observed in a retrospective examination of a staphylococcal decolonization regimen that involved a daily body bath with 4% CHG and intranasal application of 10% betadine ointment (622 elective craniotomies performed before regimen implementation vs 727 elective craniotomies performed after implementation). Interestingly, there was a significantly reduced risk of aseptic meningitis.[33]

Additional studies on the effects of CHG have been performed in the presence of screening protocols for nasal *Staphylococcus aureus*. *S. aureus* is the most common cause of SSI, with mupirocin administration to the nares and CHG to the skin being the cornerstone of

decolonization protocols.[34] A study that compared the use of a screening protocol, which administered mupirocin to 63 patients with *S. aureus* who underwent deep brain stimulation, with 119 control patients found a significant decrease in SSI in the screening group (1.6% vs 10.9%, respectively; p = 0.04).[35] A prospective, randomized controlled trial with 84 patients who underwent head and neck surgery—of which 42 patients underwent a preoperative 5-day regimen of CHG skin rinses and received intranasal mupirocin, and the other patients did not undergo a decolonization regimen—found a trend toward decreased SSI after decolonization, but significance was not reached (p = 0.079).[36] These results suggest that prophylaxis against methicillin-resistant *S. aureus* may warrant further consideration.

Although there was no significant association between SSI and preoperative CHG showers in patients who underwent craniotomy, an investigation by Chan et al. on the effect of this CHG protocol on SSI after spine surgery found a decrease in the odds of SSI.[5] This suggests differences in the utility of CHG between patients undergoing cranial and spinal procedures. Both the study by Chan et al. (investigating spine surgery) and the present study (in unadjusted analyses) revealed that an increased number of surgeons was a risk factor for SSI, but the studies did not identify any other identifiable risk factors.[5] The higher proportion of patients in our SSI cohort who underwent cranial surgery that involved more than two surgeons may reflect longer, more complex operations with skull base approaches that required assistance from otolaryngology.[37]

A study by Guzel et al. cultured skin flora samples from 100 patients before 50 cranial and 50 spinal procedures and found similar percentages of patients with coagulase-negative staphylococci and *S. aureus* before and after 3-minute cleaning with a CHG antiseptic.[38] This suggests that there should be no differences between CHG application to the scalp versus the spine; however, differences in application of CHG to the scalp may be indicated, particularly given the presence of hair. This may partially explain the lack of effect seen in the present study. Moreover, the proximity of the nares may be crucial in patients with *S. aureus*, considering that 40% of the observed SSIs involved *S. aureus* bacteria. Indeed, this notion is further supported by evidence suggesting the benefits of intranasal mupirocin in decolonization regimens for patients undergoing craniotomy.[35,36,38]

Study Limitations

This study is not without several important limitations. First, due to its retrospective nature, this study is inherently limited by the ongoing evolution of surgical practice. Over time, shaving the scalp has been eliminated, and instead clippers are used to remove hair. Subgaleal drains are increasingly used postoperatively, povidone-iodine is used to rinse tissues after the dura mater is closed,[39] and antibiotic powder (e.g., vancomycin powder) is applied to the subgaleal space prior to closure, in addition to personnel changes and procedure types that cannot be fully taken into account. On the other hand, at our institution, most patients received preoperative intravenous antibiotics, most commonly cefazolin. To ensure antibiotic administration, we incorporated perioperative antibiotic administration into the operative timeout required before each procedure's incision. Moreover, there were no other concurrent quality improvement protocols regarding cranial SSI in the study period.

Furthermore, whether this particular protocol is the most optimal with respect to CHG dose and concentration, shower frequency, and shower duration has not been fully delineated.[40] Second, this study did not compare CHG with other potential preoperative antiseptics, and thus analysis of multiple antiseptics is beyond this study's capabilities. Third, stringent criteria were used to determine each SSI (i.e., SSI definitions of the National Healthcare Safety Network), possibly leading to a lower rate of infection of 0.6% compared with reports of 1.6%–9% in the literature.[23,41,42] Our SSI rate may not account for patients whose admissions for SSI were outside the University of California, San Francisco system. Indeed, these may not have been captured by the data provided to us by the National Healthcare Safety Network. This is especially important considering the possibility of indolent infection occurring outside the 30-day postoperative period (i.e., the window used to define SSI in our series). However, we do not believe that this impacted our results to a significant extent, given that an analysis of 93,920 nonemergency craniotomies by Buchanan et al. found only an additional 682 (0.74%) readmissions for SSI within 30 to 90 days following surgery.[18] Moreover, our study did not include other infections such as meningitis that may have been affected by CHG antiseptics.

Additionally, rates of compliance with the protocol were not ascertainable; thus, compliance bias may affect our results.[43,44] Of note, when intraoperative imaging guidance was planned, several practitioners requested the placement of scalp-based fiducial markers for registration of imaging to physical space, but others did not. Imaging studies with fiducials were typically completed the evening before surgery. Patients with fiducials in place were specifically instructed not to remove the fiducials or wash their hair the night before surgery. We did not control for the placement of fiducials in this analysis. In a similar fashion, although the placement of drains was accounted for, the length of time that these drains were in place was unavailable and therefore not adjusted for in our analysis. Typically, however, drains are removed on postoperative day 1 at our institution. Importantly, in other unpublished analyses of our surgical drain protocol, we have not found a correlation between length of drain placement and development of SSI.

This study had relatively low power (45%) to detect differences between patients with and those without infection based solely on preoperative CHG showering. The effect size between patients with and those without infection was also small (0.07). Yet, based on a similar paper by Abode-Iyamah et al. that assessed the use of vancomycin powder,[19] the effect size can be expected to be small in the context of low SSI rates. To reach 80% statistical power with our current effect size, the overall patient cohort would need to more than double, to a total of 7895 patients.

Conclusions

This is the largest study to examine the association between preoperative CHG showering and SSI following craniotomy. CHG showering was not associated with decreased SSI following cranial surgery, even after we adjusted for potential confounding variables. In multivariable-adjusted analyses, use of surgical drains was the sole factor associated with reduced SSI. Further prospective studies are needed to better define any potential impact CHG showering may or may not have on SSI rates following cranial surgery.

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ABBREVIATIONS

ASA	American Society of Anesthesiologists
CHG	chlorhexidine gluconate
SSI	surgical site infection

References

1. Ban KA, Minei JP, Laronga C, et al. American College of Surgeons and Surgical Infection Society: surgical site infection guidelines, 2016 update. J Am Coll Surg. 2017; 224(1): 59–74. [PubMed: 27915053]
2. Anderson DJ, Podgorny K, Berríos-Torres SI, et al. Infection control & hospital epidemiology strategies to prevent surgical site infections in acute care hospitals: 2014 update strategies to prevent surgical site infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol Infect. 2014; 3535(356): 605–627.
3. Urban JA. Cost analysis of surgical site infections. Surg Infect (Larchmt). 2006; 7(suppl 1): S19–S22. [PubMed: 16834543]
4. Napolitano LM. Decolonization of the skin of the patient and surgeon. Surg Infect (Larchmt). 2006; 7(Suppl 3): s-3–s-15. [PubMed: 16895500]
5. Chan AK, Ammanuel SG, Chan AY, et al. Chlorhexidine showers are associated with a reduction in surgical site infection following spine surgery: an analysis of 4266 consecutive surgeries. Neurosurgery. 2019; 85(6): 817–826. [PubMed: 30590721]
6. Zywiel MG, Daley JA, Delanois RE, et al. Advance preoperative chlorhexidine reduces the incidence of surgical site infections in knee arthroplasty. Int Orthop. 2011; 35(7): 1001–1006. [PubMed: 20563806]
7. Edmiston CE Jr, Okoli O, Graham MB, et al. Evidence for using chlorhexidine gluconate preoperative cleansing to reduce the risk of surgical site infection. AORN J. 2010; 92(5): 509–518. [PubMed: 21040815]
8. 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(3): 141–145. [PubMed: 19494763]
9. Webster J, Osborne S. Preoperative bathing or showering with skin antiseptics to prevent surgical site infection. Cochrane Database Syst Rev. 2015; 2015(2): CD004985. [PubMed: 25927093]
10. Chlebicki MP, Safdar N, O'Horo JC, Maki DG. Preoperative chlorhexidine shower or bath for prevention of surgical site infection: a meta-analysis. Am J Infect Control. 2013; 41(2): 167–173. [PubMed: 22722008]

11. Marmor R, El-Kareh R, Abeles S, et al. Home CHG bathing component of perioperative SSI prevention bundle independently decreases infection risk. Presented at: American College of Surgeons 2017 Annual Clinical Congress; October 2017; San Diego, CA.
12. Marmor R, El-Kareh R, Abeles S, et al. Increased OR traffic is not associated with increased SSIs. Presented at: 2017 American College of Surgeons Quality and Safety Conference; July 2017; New York, NY.
13. Hamou HA, Kotliar K, Tan SK, et al. Surgical nuances and placement of subgaleal drains for supratentorial procedures-a prospective analysis of efficacy and outcome in 150 craniotomies. Acta Neurochir (Wien). 2020; 162(4): 729–736. [PubMed: 31940095]
14. Lietard C, Thébaud V, Besson G, Lejeune B. Risk factors for neurosurgical site infections: an 18-month prospective survey. J Neurosurg. 2008; 109(4): 729–734. [PubMed: 18826362]
15. Choi SY, Yoon SM, Yoo CJ, et al. Necessity of surgical site closed suction drain for pterional craniotomy. J Cerebrovasc Endovasc Neurosurg. 2015; 17(3): 194–202. [PubMed: 26523255]
16. Cassir N, De La Rosa S, Melot A, et al. Risk factors for surgical site infections after neurosurgery: a focus on the postoperative period. Am J Infect Control. 2015; 43(12): 1288–1291. [PubMed: 26300100]
17. Kim T, Han JH, Kim HB, et al. Risk factors of surgical site infections after supratentorial elective surgery: a focus on the efficacy of the wound-drain-tip culture. Acta Neurochir (Wien). 2013; 155(11): 2165–2170. [PubMed: 23917745]
18. Buchanan IA, Donoho DA, Patel A, et al. Predictors of surgical site infection after nonemergent craniotomy: a nationwide readmission database analysis. World Neurosurg. 2018; 120: e440–e452. [PubMed: 30149164]
19. Abode-Iyamah KO, Chiang HY, Winslow N, et al. Risk factors for surgical site infections and assessment of vancomycin powder as a preventive measure in patients undergoing first-time cranioplasty. J Neurosurg. 2018; 128(4): 1241–1249. [PubMed: 28498056]
20. Martin ET, Kaye KS, Knott C, et al. Diabetes and risk of surgical site infection: a systematic review and meta-analysis. Infect Control Hosp Epidemiol. 2016; 37(1): 88–99. [PubMed: 26503187]
21. Jiménez-Martínez E, Cuervo G, Hornero A, et al. Risk factors for surgical site infection after craniotomy: a prospective cohort study. Antimicrob Resist Infect Control. 2019; 8(1): 69. [PubMed: 31073400]
22. Schipmann S, Akalin E, Doods J, et al. When the infection hits the wound: matched case-control study in a neurosurgical patient collective including systematic literature review and risk factors analysis. World Neurosurg. 2016; 95: 178–189. [PubMed: 27506410]
23. Fang C, Zhu T, Zhang P, et al. Risk factors of neurosurgical site infection after craniotomy: a systematic review and meta-analysis. Am J Infect Control. 2017; 45(11): e123–e134. [PubMed: 28751035]
24. Sherrod BA, Johnston JM, Rocque BG. Risk factors for unplanned readmission within 30 days after pediatric neurosurgery: a nationwide analysis of 9799 procedures from the American College of Surgeons National Surgical Quality Improvement Program. J Neurosurg Pediatr. 2016; 18(3): 350–362. [PubMed: 27184348]
25. Han C, Song Q, Ren Y, et al. Dose-response association of operative time and surgical site infection in neurosurgery patients: a systematic review and meta-analysis. Am J Infect Control. 2019; 47(11): 1393–1396. [PubMed: 31296347]
26. Bydon M, Abt NB, De la Garza-Ramos R, et al. Impact of resident participation on morbidity and mortality in neurosurgical procedures: an analysis of 16,098 patients. J Neurosurg. 2015; 122(4): 955–961. [PubMed: 25574567]
27. Lim S, Parsa AT, Kim BD, et al. Impact of resident involvement in neurosurgery: an analysis of 8748 patients from the 2011 American College of Surgeons National Surgical Quality Improvement Program database. J Neurosurg. 2015; 122(4): 962–970. [PubMed: 25614947]
28. Hayek LJ, Emerson JM, Gardner AMN. A placebo-controlled trial of the effect of two preoperative baths or showers with chlorhexidine detergent on postoperative wound infection rates. J Hosp Infect. 1987; 10(2): 165–172. [PubMed: 2889770]

29. Ayliffe GAJ, Noy MF, Babb JR, et al. A comparison of pre-operative bathing with chlorhexidine-detergent and nonmedicated soap in the prevention of wound infection. J Hosp Infect. 1983; 4(3): 237–244. [PubMed: 6195236]
30. Hekman KE, Michel E, Blay E Jr, et al. Evidence-based bundled quality improvement intervention for reducing surgical site infection in lower extremity vascular bypass procedures. J Am Coll Surg. 2019; 228(1): 44–53. [PubMed: 30359836]
31. Prabhu AS, Krpata DM, Phillips S, et al. Preoperative chlorhexidine gluconate use can increase risk for surgical site infections after ventral hernia repair. J Am Coll Surg. 2017; 224(3): 334–340. [PubMed: 28017808]
32. Kestle JRW, Riva-Cambrin J, Wellons JC III, et al. A standardized protocol to reduce cerebrospinal fluid shunt infection: the Hydrocephalus Clinical Research Network Quality Improvement Initiative. J Neurosurg Pediatr. 2011; 8(1): 22–29. [PubMed: 21721884]
33. Gupta A, Nair RR, Moorthy RK, Rajshekhar V. Effect of staphylococcal decolonization regimen and change in antibiotic prophylaxis regimen on incidence of postcraniotomy aseptic meningitis. World Neurosurg. 2018; 119: e534–e540. [PubMed: 30075267]
34. Humphreys H, Becker K, Dohmen PM, et al. *Staphylococcus aureus* and surgical site infections: benefits of screening and decolonization before surgery. J Hosp Infect. 2016; 94(3): 295–304. [PubMed: 27424948]
35. Lefebvre J, Buffet-Bataillon S, Henaux PL, et al. *Staphylococcus aureus* screening and decolonization reduces the risk of surgical site infections in patients undergoing deep brain stimulation surgery. J Hosp Infect. 2017; 95(2): 144–147. [PubMed: 28081909]
36. Shuman AG, Shuman EK, Hauff SJ, et al. Preoperative topical antimicrobial decolonization in head and neck surgery. Laryngoscope. 2012; 122(11): 2454–2460. [PubMed: 22865589]
37. Chan AK, Bisson EF, Fu KM, et al. Sexual dysfunction: prevalence and prognosis in patients operated for degenerative lumbar spondylolisthesis. Neurosurgery. 2020; 87(2): 200–210. [PubMed: 31625568]
38. Guzel A, Ozekinci T, Ozkan U, et al. Evaluation of the skin flora after chlorhexidine and povidone-iodine preparation in neurosurgical practice. Surg Neurol. 2009; 71(2): 207–210. [PubMed: 18291465]
39. Patel KS, Goldenberg B, Schwartz TH. Betadine irrigation and post-craniotomy wound infection. Clin Neurol Neurosurg. 2014; 118: 49–52. [PubMed: 24529229]
40. Chan AK, Mummaneni PV. In Reply: Chlorhexidine showers are associated with a reduction in surgical site infection following spine surgery: an analysis of 4266 consecutive surgeries. Neurosurgery. 2020; 86(6): E581–E582. [PubMed: 32022231]
41. Chen Y, Zhang L, Qin T, et al. Evaluation of neurosurgical implant infection rates and associated pathogens: evidence from 1118 postoperative infections. Neurosurg Focus. 2019; 47(2): E6.
42. Ho AL, Cannon JGD, Mohole J, et al. Topical vancomycin surgical prophylaxis in pediatric open craniotomies: an institutional experience. J Neurosurg Pediatr. 2018; 22(6): 710–715. [PubMed: 30141749]
43. Haines SJ. Randomized clinical trials in the evaluation of surgical innovation. J Neurosurg. 1979; 51(1): 5–11. [PubMed: 376786]
44. Grady D, Parks M. Why is nonadherence to cancer screening associated with increased mortality? JAMA Intern Med. 2019; 179(2): 143–144. [PubMed: 30592474]

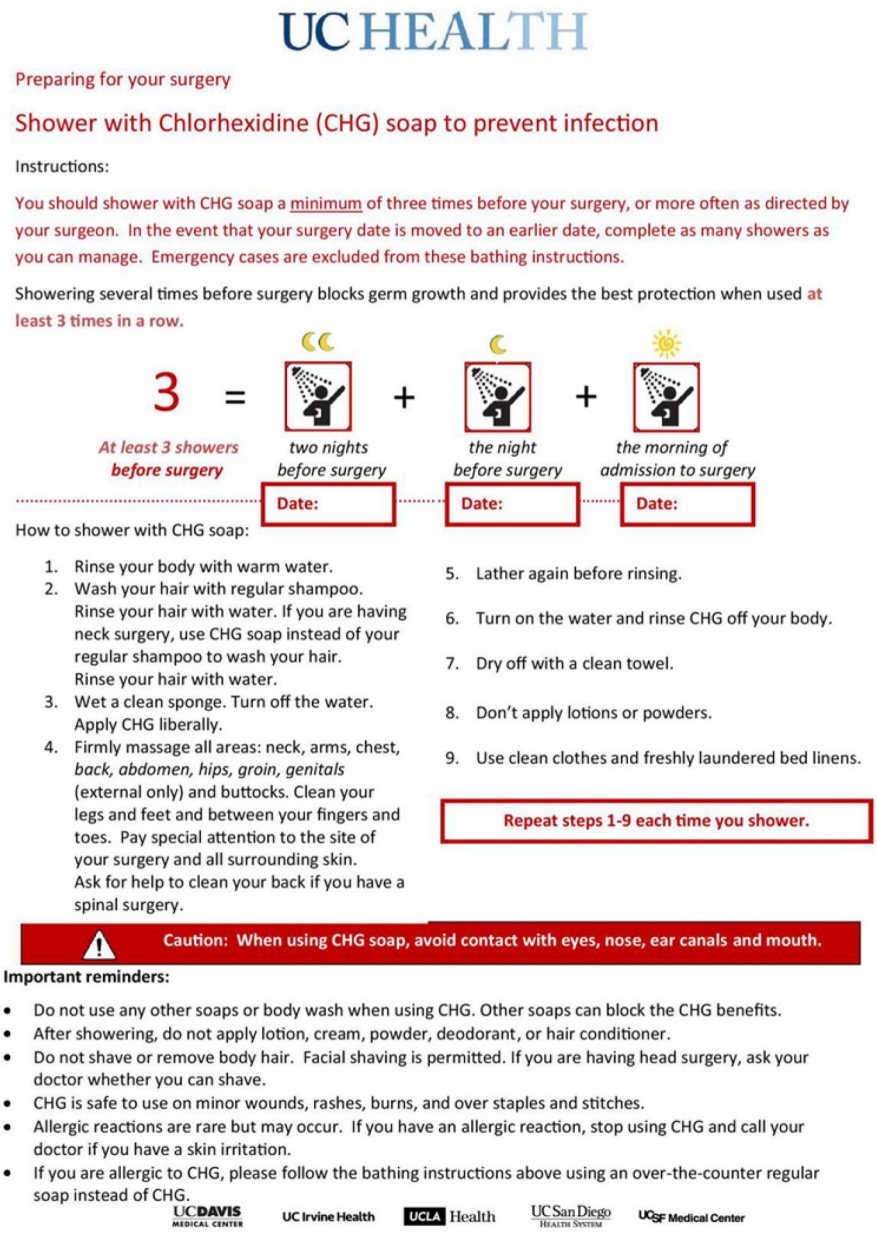

FIG. 1.

University of California Health protocol for preoperative CHG showering. Reprinted from Chan et al: *Neurosurgery* 85(6):817–826, 2019.[5] Image credit: 2013–2016 University of California, Office of the President (PI: Torriani). Developing standardized operative bundles to decrease surgical site infections (SSI). All rights reserved. Copyright UC Health. Published with permission.

TABLE 1.

Patient and surgical characteristics of the overall cohort and patients with and those without SSI

Characteristic	Overall Cohort (n = 3126)	w/o Infection (n = 3106)	w/ Infection (n = 20)	p Value
Age, yrs	51.40 ± 0.29	51.40 ± 0.29	50.70 ± 3.43	0.84
Male sex	1554 (49.7)	1546 (49.8)	8 (40.0)	0.52
BMI, kg/m^2	27.59 ± 0.12	27.59 ± 0.12	28.47 ± 1.60	0.59
Length of stay, days	5.91 ± 0.13	5.92 ± 0.13	4.45 ± 0.78	0.08
Preop period, days	1.19 ± 0.05	1.19 ± 0.05	0.90 ± 0.49	0.56
Postop period, days	4.72 ± 0.11	4.73 ± 0.11	3.55 ± 0.41	0.12
Hypertension	867 (27.7)	863 (27.8)	4 (20.0)	0.60
Diabetes mellitus	284 (9.1)	283 (9.1)	1 (5.0)	0.81
History of non-CNS malignancy	332 (10.6)	331 (10.7)	1 (5.0)	0.65
History of chemotherapy	355 (11.4)	353 (11.4)	2 (10.0)	>0.99
History of radiation therapy	461 (14.7)	458 (14.7)	3 (15.0)	>0.99
ASA score >II	1420 (45.4)	1410 (45.4)	10 (50.0)	0.85
Smoker	483 (15.6)	479 (15.4)	4 (20.0)	0.80
Prior cranial procedure	1060 (33.9)	1056 (34.0)	4 (20.0)	0.28
Surgical pathology				
Tumor	1883 (60.2)	1866 (57.6)	17 (85.0)	0.38
Vascular	392 (12.5)	392 (12.6)	0 (0.0)	
Functional	371 (11.9)	369 (11.9)	2 (10.0)	
Epilepsy	237 (7.6)	236 (7.6)	1 (5.0)	
Hematoma	100 (3.2)	100 (3.2)	0 (0.0)	
Repair	72 (2.3)	72 (2.3)	0 (0.0)	
Other	71 (2.3)	71 (2.3)	0 (0.0)	
Preop CHG shower	2234 (71.5)	2216 (71.3)	18 (90.0)	0.11
Preop steroids	549 (17.6)	547 (17.7)	2 (10.0)	0.55
Intraop steroids	2547 (81.5)	2529 (81.4)	18 (90.0)	0.49
Postop steroids	2531 (81.0)	2514 (80.9)	17 (85.0)	>0.99
Intraop antibiotics	3062 (98.0)	3042 (97.9)	20 (100)	>0.99

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Characteristic	Overall Cohort (n = 3126)	w/o Infection (n = 3106)	w/ Infection (n = 20)	p Value
Postop antibiotics	2721 (87.0)	2701 (87.0)	20 (100)	0.09
Resident involvement	2241 (71.7)	2222 (71.5)	19 (95.0)	**0.04**
>2 surgeons	955 (30.6)	944 (30.4)	11 (55.0)	**0.03**
Site of craniotomy				
Frontal	1118 (38.0)	1110 (38.0)	8 (40.0)	0.057
Parietal	575 (18.4)	572 (18.4)	3 (15.0)	
Temporal	665 (21.3)	663 (21.3)	2 (10.0)	
Pterional	119 (3.8)	117 (3.8)	2 (10.0)	
Retrosigmoid	115 (3.7)	112 (3.6)	3 (15.0)	
Occipital	464 (14.8)	462 (14.9)	2 (10.0)	
Implants	2770 (88.6)	2750 (88.5)	20 (100.0)	0.21
Sealant	2385 (76.3)	2367 (76.2)	18 (90.0)	0.24
Drains	1269 (40.6)	1266 (40.8)	3 (15.0)	**0.04**
CSF drains	553 (17.7)	539 (17.4)	14 (70.0)	**<0.001**
Op time, mins	235.72 ± 2.13	235.46 ± 2.13	276.90 ± 22.80	0.08
Estimated blood loss, ml	203.47 ± 6.20	203.69 ± 6.24	182.00 ± 27.12	0.45
CSF leak	62 (2.0)	59 (1.9)	3 (15.0)	**0.001**

Values are shown as mean ± SD or number (%). Boldface type indicates statistical significance ($p < 0.05$).

TABLE 2.

Patient and surgical characteristics of the pre- and postimplementation CHG shower cohorts

Characteristic	Preimplementation (n = 892)	Postimplementation (n = 2234)	p Value
Age, yrs	51.75 ± 0.52	51.26 ± 0.34	0.43
Male sex	466 (52.2)	1088 (48.7)	0.08
BMI, kg/m^2	27.38 ± 0.23	27.67 ± 0.14	0.26
Length of stay, days	6.01 ± 0.23	5.87 ± 0.16	0.61
Preop period, days	1.19 ± 0.08	1.19 ± 0.06	0.99
Postop period, days	4.82 ± 0.20	4.68 ± 0.13	0.55
Hypertension	256 (28.7)	611 (27.4)	0.47
Diabetes mellitus	103 (11.5)	181 (8.3)	**0.003**
History of non-CNS malignancy	107 (12.0)	225 (10.1)	0.13
History of chemotherapy	114 (12.8)	241 (10.8)	0.13
History of radiation therapy	145 (16.3)	316 (14.1)	0.15
ASA score >II	439 (49.2)	981 (43.9)	**0.008**
Smoker	153 (17.2)	330 (14.8)	0.11
Prior cranial procedure	311 (34.9)	749 (33.5)	0.50
Surgical pathology			
Tumor	557 (62.4)	1326 (59.4)	0.07
Vascular	89 (10.0)	303 (13.6)	
Functional	119 (13.3)	252 (11.3)	
Epilepsy	58 (6.5)	179 (8.0)	
Hematoma	28 (3.1)	72 (3.2)	
Repair	21 (2.4)	51 (2.3)	
Other	20 (2.2)	51 (2.3)	
Preop steroids	139 (15.6)	412 (18.4)	0.07
Intraop steroids	712 (79.8)	1835 (82.1)	0.15
Postop steroids	709 (79.5)	1882 (81.6)	0.20
Intraop antibiotics	871 (97.6)	2191 (98.1)	0.53
Postop antibiotics	797 (89.3)	1924 (86.1)	**0.02**

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Characteristic	Preimplementation (n = 892)	Postimplementation (n = 2234)	p Value
Resident involvement	607 (68.0)	1634 (73.1)	**0.01**
>2 surgeons	213 (23.9)	742 (33.2)	**<0.001**
Site of craniotomy			
Frontal	342 (38.3)	846 (37.6)	
Parietal	161 (18.0)	414 (18.5)	
Temporal	208 (23.3)	457 (20.5)	0.10
Pterional	29 (3.3)	90 (4.0)	
Retrosigmoid	39 (4.4)	76 (3.4)	
Occipital	113 (12.7)	351 (15.7)	
Implants	805 (90.2)	1965 (88.0)	0.08
Sealant	682 (76.5)	1703 (76.2)	0.93
Drains	406 (45.5)	38.6 (38.6)	**0.001**
CSF drains	159 (17.8)	394 (17.6)	0.94
Op time, mins	243.79 ± 4.29	232.50 ± 2.42	**0.02**
Estimated blood loss, ml	203.55 ± 9.53	203.43 ± 7.79	0.99
CSF leak	21 (2.4)	41 (1.8)	0.43

Values are shown as mean ± SD or number (%). Boldface type indicates statistical significance ($p < 0.05$).

TABLE 3.

ORs and 95% CIs from binary multivariate logistic regression analysis of SSI

Variable	OR	95% CI	p Value
Preop CHG shower	2.96	0.67–13.1	0.15
Diabetes mellitus	0.49	0.06–3.76	0.49
ASA score >II	1.36	0.56–3.34	0.50
Resident involvement	6.79	0.90–51.5	0.06
No. of surgeons	1.72	0.66–4.48	0.27
Drains	0.24	0.07–0.84	**0.03**
Op time	1.002	0.99–1.01	0.19

Boldface type indicates statistical significance ($p < 0.05$).

TABLE 4.

Causative microorganisms of SSIs in the pre- and postimplementation CHG shower cohorts

Preimplementation, 2/892 patients w/ SSI (0.2%)
Resistant *Propionibacterium acnes* (1)
Methicillin-resistant *Staphylococcus epidermidis* & *Enterobacter aerogenes* (1) *
Postimplementation, 18/2234 patients w/ SSI (0.8%)
Methicillin-sensitive S. *aureus* (6)
Methicillin-resistant S. *aureus* (2)
Pseudomonas aeruginosa (2)
Methicillin-sensitive S. *epidermidis* & *P. acnes* (1) *
Methicillin-resistant S. *epidermidis* & *P. acnes* (1)
E. aerogenes (1)
Rhizopus species (1)
P. acnes (1) *
Salmonella group D (1)
Proteus mirabilis (1)
Unknown (1)

The number of patients is shown in parentheses.

* Patient underwent skull base surgery.