

1 **ABSTRACT**

2 **Introduction:** Surgical site infection (SSI) remains a concern in shoulder surgery, especially
3 during arthroplasty. While many studies have explored the characteristics and efficacy of
4 different sterilizing solutions, no study has evaluated the method of application. The purpose of
5 this study was to compare two popular pre-surgical preparatory applications (two 4 x 4 cm gauze
6 sponges and applicator stick) in their ability to cover the skin of the shoulder.

7 **Methods:** Two orthopedic surgeons simulated the standard pre-surgical skin preparation on 22
8 shoulders of volunteer subjects. Each surgeon alternated between an applicator stick and two
9 sterile 4x4 cm gauze sponges. Skin preparation was performed with a commercially available
10 solution that can be illuminated under UV-A light. Advanced image-analysis software was
11 utilized to determine un-prepped areas. A two-tailed paired t-test was performed to compare
12 percentage of un-prepped skin.

13 **Results:** The applicator stick method resulted in a significantly higher percentage of un-prepped
14 skin (27.25%, Range 10-49.3) than the gauze sponge method (15.37%, Range 5-32.8, p=0.002).
15 Based on image evaluation, most un-prepped areas were present around the axilla.

16 **Conclusion:** Based on our findings, the use of simple gauze sponges for pre-surgical preparatory
17 application of sterilization solution may result in a lower percent of un-prepped skin than
18 commercially available applicator stick. Orthopaedic surgeons and operating room staff should
19 be careful during the pre-surgical sterile preparation of the shoulder, especially the region around
20 the axilla, in order to reduce the potential risk of surgical site infection.

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Gauze sponge vs applicator stick

22 **Level of Evidence: Diagnostic Level III**

23 **Keywords: shoulder; infection; sterile preparation; gauze sponge; applicator stick; surgical**

24 **site infection**

25

26 **Introduction**

27 Surgical site infection (SSI), although relatively infrequent, can be a devastating
28 complication after shoulder surgery. The rate of infection has been reported up to 3.9% in
29 primary shoulder arthroplasty and up to 15% in revision procedures (1-4). Pre-surgical
30 sterilization of the shoulder is a routine procedure aimed at preventing SSI. While many studies
31 have explored the characteristics and efficacy of different sterilizing solutions, no study has
32 evaluated the method of application. Two popular methods for application of sterilization
33 solution to the shoulder are utilized at our institution, an applicator stick (Chloraprep applicator,
34 Carefusion, San Diego, CA) and 4 x 4 cm gauze sponges. Although the method of application
35 may be less critical in anatomic locations with limited contour and easy visibility such as the
36 abdomen or back, un-prepped skin around the shoulder is a major concern due to the surface
37 anatomy of the shoulder and limited direct visibility in the axilla. The purpose of this study was
38 to determine which application method of sterilization solution yields the best coverage of skin
39 on the shoulder. We hypothesized that the use of sterile gauze sponges would leave less un-
40 prepped skin compared to commercially available applicator sticks.

41

42 **Methods**

43 Twenty-two shoulders of healthy male volunteers were prepped by two shoulder fellowship
44 trained orthopedic surgeons (■■■■ and ■■■■) as 11 matched pairs. Volunteers were placed supine
45 in an operating room on an operating room table in a beach chair position to recreate a common
46 positioning for both shoulder arthroscopy and arthroplasty. Both shoulders were suspended off
47 an adjustable candy cane style stirrup to recreate the pre-operative sterilization environment
48 [Figure 1] with the shoulder in approximately 90 degrees of abduction and 45 degrees of external
49 rotation. The surgeons sterilized the shoulder to the same standards used in the operating room
50 setting and no maximum time limit was allotted to prepare each shoulder. The surgeons
51 alternated between the two methods of application using either 4 x 4 cm gauze sponges or an
52 applicator stick (Chloraprep applicator, Carefusion, San Diego, CA) immersed in a commercially
53 available mineral oil solution. Each subject was tested as a matched pair with one shoulder
54 sterilized using the 4 x 4 cm sponges and the contralateral shoulder using the applicator stick.

55 The solution used to assess methods of application is a commercially available mineral oil
56 (GloGerm, Moab UT) that can be illuminated under UV-A light. This solution is used
57 commercially as a visual training tool for hand washing and aseptic techniques. A new, unused
58 applicator stick or 4X4 cm gauze pads were used on each shoulder. Two UV-A lights (GE,
59 (Fairfield, CT), T12 Fluorescent Blacklight Lamp) were utilized, one placed postero-superior and
60 one placed anterior to the shoulder. Prior to the prep, the shoulders were cleaned and checked
61 under UV light to ensure no preexisting sites of illumination were present. Once the skin
62 preparation was complete, overhead and room lights were switched off and the UV-A lights were
63 turned on. A high-resolution digital camera (Nikon D3200, 24.2 MP) was used to document
64 digital photographs of the anterior and posterior aspect of the shoulder.

65 An independent evaluator (■) blinded to the preparation process evaluated the digital
66 photographs to determine areas of un-prepped skin, referred to as regions of interest (ROIs) with
67 the use of the NIS-Elements Advanced Research image-analysis software (Nikon Inc., Melville,
68 NY). The threshold was created to include only a range of colors corresponding to the ROIs.
69 This was done by visual evaluation of areas that did not illuminate under UV-A light. The
70 threshold settings were then applied to all analyzed pictures. The total surface areas of the
71 analyzed surfaces were defined by applying a separate hue threshold that isolated the shoulder
72 from the background [Figure 2]. The surface area of the ROIs was calculated for each shoulder
73 and then was expressed as the percentage of the total surface area of the shoulder. The resulting
74 percentages were statistically analyzed using a matched pair t-test.

75

76 **Results**

77 *Un-prepped Area*

78 The applicator stick method resulted in a significantly higher percentage of un-prepped skin
79 (27.25%, Range 10%-49.3%) compared the gauze sponge method (15.37%, Range 5%-32.8%).

80 This difference was statistically significant ($p=0.002$) [Table 1]. Based on visual evaluation of
81 the images, the majority of the un-prepped areas were present around the axilla region [Figure 1].

82 *Surgeon Comparison*

83 Comparing the percentage of un-prepped skin between the two surgeons applying the solution,
84 there were no differences with the applicator ($p=0.72$) or gauze sponges [Table 2, $p = 0.24$].

85 Additionally, there was no difference between the surgeons based on side of shoulder prepped
86 [Table 2, $p=0.93$].

87 **Discussion**

88 Surgical site infection, although rare, remains a serious concern in shoulder surgery.
89 Periprosthetic joint infections after shoulder arthroplasty have been reported from 0.7% to 3.9%
90 in primary procedures and up to 15% in revision procedures (4-10). The economic burden on
91 healthcare resulting from surgical site infection is significant (7). Numerous techniques have
92 been described that aim to reduce the risk of infection in the orthopaedic literature, ranging from
93 sterilization solutions and adjuvants, sterility of draping and surgical attire, antibiotic-coated
94 implants, prophylactic antibiotics, laminar flow, and pre-operative blood glucose monitoring in
95 patients undergoing arthroplasty (1-3, 11-13). Despite the abundance of literature describing
96 these techniques, there is paucity of studies investigating the mechanism of application of
97 sterilization solution. The goal of our study was to compare two popular methods of applying
98 sterilization solution to the shoulder that are used at our institution: applicator stick and 4 x 4 cm
99 gauze sponges.

100 The Chloraprep applicator or applicator stick theoretically enhances antiseptic technique by
101 reducing direct patient contact, which ultimately lowers the potential risk of cross contamination.
102 The application is quick and time efficient and does not require the use of sterile gloves.
103 However, due to the surface anatomy of the shoulder, it can be challenging to prep the joint,
104 especially the axilla region. Alternatively, while gauze sponges do not eliminate direct contact,
105 they can theoretically make it easier to thoroughly apply the sterilization solution around the
106 surgical site.

107 This study demonstrated that use of simple gauze sponges for application of sterilization solution
108 produces significantly less un-prepped skin than a commercially available applicator stick.

109 Although, we cannot comment on the reason for the higher percentage of un-prepped skin with
110 the applicator stick, one theory is that the rigidity of the applicator limits the application in
111 regions with contour, such as the axilla. While our results support the use of gauze sponges over
112 an applicator stick, we were quite surprised at the high percentage of un-prepped skin after
113 prepping using both methods.

114 The correlation between un-prepped areas and SSI still remains relatively unknown. A study
115 done by Saltzman et al demonstrated the superiority of using Chloraprep in reducing the
116 incidence of positive cultures of *Coagulase-negative Staphylococcus* and *Propionibacterium*
117 *acnes* (*P. Acnes*) while Phadnis et al demonstrated in their series of patients that despite surgical
118 preparation and prophylactic antibiotics, viable *P acnes* colonies persist (14-15). Since our study
119 did not explore the infection implication in the difference between the applicator stick and the
120 gauze sponges, we are unable to conclude on its clinical significance, as unprepped areas do not
121 necessarily correspond to infection. However, in our advanced healthcare environment, all
122 precautions should be taken to reduce the potential of SSI in total shoulder arthroplasty.

123 The strengths of the study include the use of a systematic approach to determine areas of un-
124 prepped skin in the surgical sterilization of the shoulder. In order to minimize human error, we
125 used a validated software technique to identify un-prepped areas (16). An independent evaluator
126 not involved in the preparation reviewed the images to determine un-prepped areas, which were
127 reported as a percentage of the total prepped area to reduce variability and allow for accurate
128 comparison between shoulders. Finally, the surgeon alternated application techniques for each
129 subject and there was no difference in either application method or side of extremity.

Gauze sponge vs applicator stick

130 There are several limitations to this study. First, we understand that the application technique is
131 user dependent and the results may not apply to other users; however, both surgeons involved
132 were fellowship trained in shoulder surgery and have extensive experience in surgical
133 preparation of the shoulder. Second, we acknowledge that GloGerm liquid is not a true
134 sterilization solution, but rather a mineral oil with the same specific gravity as chloraprep
135 ($\rho=0.88$) that can be illuminated under UV light. Finally, while we were able to determine areas
136 of un-prepped skin, we did not determine a relationship to bacteria colonization and/or surgical
137 site infection; thus, the clinical importance is unknown.

138

139 **Conclusion**

140 Based on our findings, use of gauze sponge produced a significantly lower percentage of un-
141 prepped skin than the use of a 'prep stick', though we were not able to determine whether this
142 translates to clinical significance. Orthopaedic surgeons and their staff should be mindful of their
143 application technique during the sterile preparation of the shoulder prior to surgery. Particular
144 attention should be paid to the region around the axilla in order to reduce the areas of un-prepped
145 skin and the potential risk of surgical site infection.

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147 **Disclosure**

148 The authors report no conflicts on interest concerning the materials or methods used in this study
149 or the findings specified in this paper.

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151 References

- 152 1. Boekel P, Blackshaw R, Van Bavel D, Riazi A, Hau R. Sterile stockinette in orthopaedic
153 surgery: a possible pathway for infection: Stockinette, infection and TKRs. *ANZ J. Surg.*
154 2012 Nov;82(11):838–843. doi:10.1111/j.1445-2197.2012.06208.x
- 155 2. Lee MJ, Pottinger PS, Butler-Wu S, Bumgarner RE, Russ SM, Matsen FA.
156 *Propionibacterium Persists in the Skin Despite Standard Surgical Preparation. J. Bone Jt.*
157 *Surg.* 2014 Sep 3;96(17):1447–1450. doi:10.2106/JBJS.M.01474
- 158 3. Savage JW, Weatherford BM, Sugrue PA, Nolden MT, Liu JC, Song JK, et al. Efficacy
159 of Surgical Preparation Solutions in Lumbar Spine Surgery. *J. Bone Jt. Surg. Am.*
160 [Internet]. 2012 Mar 21 [cited 2015 Oct 23];94(6). Available from:
161 <http://jbjs.org/cgi/doi/10.2106/JBJS.K.00471>doi:10.2106/JBJS.K.00471
- 162 4. Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty.
163 *Clin. Orthop.* 2001 Jan;(382):206–216.
- 164 5. Coste JS, Reig S, Trojani C, Berg M, Walch G, Boileau P. The management of infection
165 in arthroplasty of the shoulder. *J. Bone Joint Surg. Br.* 2004 Jan;86(1):65–69.
- 166 6. Dodson CC, Craig EV, Cordasco FA, Dines DM, Dines JS, DiCarlo E, et al.
167 *Propionibacterium acnes* infection after shoulder arthroplasty: A diagnostic challenge. *J.*
168 *Shoulder Elbow Surg.* 2010 Mar;19(2):303–307. doi:10.1016/j.jse.2009.07.065
- 169 7. Padegimas EM, Maltenfort M, Ramsey ML, Williams GR, Parvizi J, Namdari S.
170 *Periprosthetic shoulder infection in the United States: incidence and economic burden. J.*
171 *Shoulder Elb. Surg. Am. Shoulder Elb. Surg. Al.* 2015 May;24(5):741–746.
172 doi:10.1016/j.jse.2014.11.044

- 173 8. Singh JA, Sperling JW, Schleck C, Harmsen WS, Cofield RH. Periprosthetic infections
174 after total shoulder arthroplasty: a 33-year perspective. *J. Shoulder Elbow Surg.* 2012
175 Nov;21(11):1534–1541. doi:10.1016/j.jse.2012.01.006
- 176 9. Verhelst L, Stuyck J, Bellemans J, Debeer P. Resection arthroplasty of the shoulder as a
177 salvage procedure for deep shoulder infection: does the use of a cement spacer improve
178 outcome? *J. Shoulder Elbow Surg.* 2011 Dec;20(8):1224–1233.
179 doi:10.1016/j.jse.2011.02.003
- 180 10. Wirth MA, Rockwood CA. Complications of shoulder arthroplasty. *Clin. Orthop.* 1994
181 Oct;(307):47–69.
- 182 11. Ambrose CG, Clyburn TA, Mika J, Gogola GR, Kaplan HB, Wanger A, et al. Evaluation
183 of Antibiotic-Impregnated Microspheres for the Prevention of Implant-Associated
184 Orthopaedic Infections. *J. Bone Jt. Surg.* 2014 Jan 15;96(2):128–134.
185 doi:10.2106/JBJS.L.01750
- 186 12. Glen L, Scammell B, Ashraf W, Bayston R. How Sterile Is Patient’s Skin After
187 Preparation with Alcoholic Povidone Iodine? *J. Bone Joint Surg. Br.* 2012 May 1;94-
188 B(SUPP XVIII):34–34.
- 189 13. Ricciardi BF, Bostrom MP, Lidgren L, Ranstam J, Merollini KMD, W-Dahl A.
190 Prevention of Surgical Site Infection in Total Joint Arthroplasty: An International
191 Tertiary Care Center Survey. *HSS J. ®.* 2014 Feb;10(1):45–51. doi:10.1007/s11420-013-
192 9369-1
- 193 14. Phadnis J, Gordon D, Krishnan J, Bain GI. Frequent isolation of Propionibacterium
194 acnes from the shoulder dermis despite skin preparation and prophylactic antibiotics. *J.*
195 *Shoulder Elbow Surg.* [Internet]. [cited 2015 Oct 23];Available from:

196 <http://www.sciencedirect.com/science/article/pii/S1058274615004395>doi:10.1016/j.jse.2
197 015.08.002

198 15. Saltzman MD, Nuber GW, Gryzlo SM, Marecek GS, Koh JL. Efficacy of Surgical
199 Preparation Solutions in Shoulder Surgery. *J. Bone Jt. Surg.* 2009 Aug 1;91(8):1949–
200 1953. doi:10.2106/JBJS.H.00768

201 16. Szpinda M, Daroszewski M, Szpinda A, Woźniak A, Wiśniewski M, Mila-
202 Kierzenkowska C, et al. New quantitative patterns of the growing trachea in human
203 fetuses. *Med. Sci. Monit. Int. Med. J. Exp. Clin. Res.* 2012 Jun;18(6):PH63–70.

204

205 **Figure Legend**

206 Figure 1: Depicts our surgical preparation setting with the patient in the beach chair position with
207 the surgeons alternating between using the prep stick and the gauze sponge. preparation setting
208 with the patient in the beach chair position with the surgeons alternating between using the prep
209 stick and the gauze sponge.

210 Figure 2: An example of the digital photographs before and after evaluation with the NIS-
211 Element Advanced Research image analysis software. Notably, the region around the axilla
212 remains largely un-prepped with the applicator stick.