Surgical Site Irrigation in Plastic Surgery

Olga Zhadan, MD, MS; and Hilton Becker, MD, FACS

Abstract

Background: The incidence of infection following breast implant reconstruction remains high at the level of 24%. Surgical site irrigation is commonly used for its prevention. However, the lack of evidence-based guidelines for antibiotic prophylaxis in breast implant surgery necessitates research for optimal irrigation technique.

Objectives: Define the optimal composition and exposure time of irrigation solution for surgical site infection (SSI) prophylaxis using an in vitro model of a surgical site.

Methods: The study design was an in vitro model to assess antibiotic irrigation of a surgical site. Strains of Staphylococcus aureus, Methicillin-resistant Staphylococcus aureus, Group A Streptococcus, and Pseudomonas aeruginosa were seeded on blood agar growth medium and irrigated with various antibiotic and antiseptic solutions under different exposure times. The presence and quantity of the colonies grown were estimated after 24-hour incubation. Repetition of the studies for 5 times with each investigated irrigation solution and microorganism was performed. Optimal irrigation agents were chosen based on the ability to achieve sterility with minimal tissue toxicity.

Results: The optimal wound irrigation agents for SSI prophylaxis in our study were found to be 0.05% chlorhexidine or triple antibiotic solutions. Adding of vancomycin to the irrigation solutions did not show an increase in their effectiveness. Prolonged irrigation exposure time was necessary to achieve sterility of the in vitro model of a surgical site.

Conclusions: We recommend 0.05% chlorhexidine or triple antibiotic solution for topical SSI prophylaxis in breast implant surgery. Sufficient time of irrigation can be achieved by maintaining some of the solution in the pocket and delaying drainage for at least 30 minutes.

Level of Evidence: 5

Infection following implant breast reconstruction is one of the most concerning complications as it can lead to implant removal and development of sepsis. The most common causative microorganisms are coagulase-negative staphylococci which can be isolated in 53% of cases. Alpha-hemolytic streptococci, enterococci, diphtheroids, and lactobacilli are found in less than 10% of specimens.1 As little as 100 colony-forming units (CFU) are required to cause infection with Staphylococcus aureus in the presence of a foreign body in animal models, as opposed to known 100,000 CFU needed in the pathophysiology of infectious process without implants. Among the main causes of the increased risk is the absence of microcirculation in foreign bodies, such as implants and surgical scaffolds, which is critical for neutrophil migration and antibiotic delivery.2,3 This confirms the fact that infectious complication rate is significantly higher after reconstruction than cosmetic breast augmentation: 24% vs 1.9% to 2.5% as reported from the Charles E. Schmidt College of Medicine, Florida Atlantic University, Boca Raton, FL.

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in serial studies. Therefore, the elimination of even minimal bacterial contamination is crucial for the success of implant/expander based breast reconstruction.

The situation is complicated with the absence of convincing data and clinical guidelines of antibiotic prophylaxis in plastic surgery as opposed to general surgery and other subspecialties. Current literature contains controversial facts regarding the optimal way of administration (systemic or topical) and duration of antibiotic prophylaxis after breast reconstruction. Prolonged (more than 24 hours) postoperative antibiotic use is not supported and can even increase the infection rate and severity as well as lead to evolvement of resistant organisms.

Surgical site irrigation is commonly used intraoperatively when performing reconstructive and cosmetic breast implant surgery. The antibiotics and antiseptics used for wound irrigation have bactericidal mechanisms of action. The time of local exposure is important for their effectiveness and has not been studied before.

The purpose of our study was to investigate the efficacy of various intraoperative pocket irrigation solutions that have been popularized against common causative agents of breast implant infections under different exposure times. An in vitro model was developed which simulated a contaminated surgical pocket. Irrigation with various antiseptic and antibacterial solutions was performed followed by assessment of bacterial survival.

**METHODS**

The most common microorganisms involved in surgical site infections were seeded on the blood agar growth medium (Figure 1). Methicillin-resistant *Staphylococcus aureus* (MRSA) ATCC 43300, methicillin-sensitive *Staphylococcus aureus* (MSSA) ATCC 29293, Group A *Streptococcus* ATCC 19615 strains were studied for Gram-positive, and *Pseudomonas aeruginosa* ATCC 27853 for Gram-negative sensitivity.

The cups with seeded blood agar were subsequently irrigated with antimicrobial agents (Figure 2). To exclude the antagonism of the microorganisms on a growth medium, we used separate agar cups for every strain. Antiseptic irrigation solutions consisted of 0.05% chlorhexidine or 5% povidone-iodine. High concentrations of aqueous solution of povidone-iodine (Betadine) are known to cause toxic effect on fibroblasts so the lower concentrations were used. We studied the triple antibiotic solution described by Adams et al as well as the solutions of its separate components: 50,000 units of bacitracin, 1 g cefazolin, and 80 mg gentamicin in 500 cc normal saline. PCG solution consisted of 50 cc of 5% povidone-iodine (50% Betadine), 1 g cefazolin, 80 mg gentamicin in 500 cc of normal saline (Table 1). Addition of Betadine to triple antibiotic irrigation agent yielded BPCG solution (50,000 U of bacitracin, 50 cc of 5% povidone-iodine, 1 g cefazolin, 80 mg gentamicin, in 500 cc of normal saline). We also compared the efficacy of the solutions after changing cefazolin to vancomycin in triple antibiotic and BPCG solutions (having received BVG and BPVG solutions).

Antimicrobial agent exposure was 5, 10, 15, and 30 minutes. At the completion, the antibiotic solution was poured out of the agar plates and the plates were then rinsed with lactated Ringer's solution for 30 seconds. Lactated Ringer's solution was chosen because its composition resembles plasma. After the irrigation session, the cups were closed and incubated at 37°C for 24 hours. The effectiveness of the irrigation was estimated by comparison of the numbers of the colonies which had grown (Figure 3). Irrigation of the seeded agar plates with lactated Ringer's solution for 30 minutes was used as a control. The reliability of the results was achieved with repetition of the
studies: 5 times for each investigated irrigation solution and microorganism.

RESULTS

In our study an in vitro model of a surgical site was irrigated with various antiseptic and antibiotic solutions. The estimation of the irrigation efficacy was based on the microorganism sensitivity and the time of the antimicrobial agent exposure. A satisfactory antimicrobial effect was accepted when no growth of microorganisms was found.

Single agent irrigation with cefazolin revealed at least one colony grown after 30 min of irrigation. Both cefazolin and bacitracin left abundant growth of *Pseudomonas* with all the exposure times. Gentamicin solution covered all the seeded strains at 30 min exposure (Table 2).

Combined solutions (triple antibiotic, BPCG, BVG, and BPVG) required 15 to 30 min to eliminate MRSA and 5 min to work against Group A *Streptococcus*. Triple antibiotic, BPCG, and BPVG were effective against MSSA in 15 to 30 min. BVG covered MSSA after 10 min irrigation. (Table 3). PCG solution covered Group A *Streptococcus* after 5 min, *Pseudomonas* after 10 min, and MSSA after 30 min exposure. It was ineffective against MRSA.

All the control plates revealed abundant growth of microorganisms confirming viability of the seeded strains and the absence of washing out bias.

DISCUSSION

Surgical site infection (SSI) is defined as an infection that occurs postoperatively in the part of the body where the surgery took place. It poses a significant burden on the healthcare system with delay in wound healing, increase in patient morbidity, and additional treatment costs due to prolonged hospital stay.

Capsular contracture remains an ongoing problem in cosmetic and reconstructive breast surgery. Its incidence is variable and ranges from 8% to 30% in the case series. There is a number of factors that significantly increase the risk of capsular contracture (implant type, delayed hematoma, pregnancy), and infection is the most common among them. The relationship between subclinical infection and capsular contracture was confirmed in multiple studies silicone implant infection with *S. epidermidis* in a rabbit model resulted in Baker grade III or IV capsular contracture. Accelerated fibrous capsule formation was detected around silicone implants after contamination with *S. aureus* in a guinea pig model. Virden et al cultured 55 removed silicone implants and tissue expanders. 56% (15 of 27) of implants surrounded by contracted capsules revealed bacterial growth (predominantly *S. epidermidis*) vs 18% (5 of 28) of those without capsular contracture (P < 0.05). Positive bacterial culture and presence of biofilms correlated with the degree of capsular contracture in a multicenter observational study from six plastic and reconstructive surgery clinics which included 121 breast implants from 84 patients. The most frequent organisms isolated were Propionibacterium acnes and coagulase-negative Staphylococci.

In a prospective clinical study of 139 implants from 72 symptomatic patients (91% had capsular contracture), 47% had positive culture. The bacterial isolates were

<table>
<thead>
<tr>
<th>Irrigation solution</th>
<th>Composition</th>
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<tbody>
<tr>
<td>Triple Antibiotic</td>
<td>50,000 U bacitracin 1 g cefazolin 80 mg gentamicin 500 cc normal saline</td>
</tr>
<tr>
<td>PCG</td>
<td>50 cc 5% povidone-iodine 1 g cefazolin 80 mg gentamicin 500 cc normal saline</td>
</tr>
<tr>
<td>BPCG</td>
<td>50,000 U bacitracin 50 cc 5% povidone-iodine 1 g cefazolin 80 mg gentamicin 500 cc normal saline</td>
</tr>
<tr>
<td>BVG</td>
<td>50,000 U bacitracin 1 g vancomycin 80 mg gentamicin 500 cc normal saline</td>
</tr>
<tr>
<td>BPVG</td>
<td>50,000 U bacitracin 50 cc 5% povidone-iodine 1 g vancomycin 80 mg gentamicin 500 cc normal saline</td>
</tr>
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</table>
Among thick capsule implants 49% were culture positive and 36% negative, statistical significance was not achieved however ($P = 0.17$). In a similar analysis of 150 explanted silicone breast implants from 87 patients, cultures were positive in 54%, predominantly with *S. epidermidis* (84%). Microorganisms were revealed on 76% of implants with capsular contracture and on 28% of those without it ($P < 0.05$).

In a recent multi-institutional multisurgeon study analyzed a large cohort of patients undergoing cosmetic surgical procedures the following were found to be the risk factors of major SSIs: age, female gender, increased BMI, smoking, preexisting diabetes mellitus, and trunk and extremity procedures as opposed to breast and face procedures. Performance of the procedures in the accredited surgical centers or hospitals were associated with higher risk of wound infections compared to office-based surgical suites, which was explained with the difference in patient populations. The patients with comorbidities requiring higher level of care undergo surgery in hospital settings.

It is believed that indwelling drain use in breast reconstruction can be a source of bacteria. In our practice we use the following features to eliminate this possibility: creating of a long subcutaneous tunnel with a trocar during the drain placement, which acts as a barrier against microbial entry. In addition, chlorhexidine gluconate-impregnated sponge (BIOPATCH protective disk with chlorhexidine, Ethicon US, LLC, Somerville, NJ) is placed around the drain to reduce the risk of the infection.

Despite being the most bothersome complication in plastic surgery, SSI, and hence, the capsular contracture, is the most preventable one. Up to 60% of SSI can be prevented with well-described measures: preoperative skin cleansing, proper hair removal, thermoregulation, good surgical technique, perioperative glucose control, and smoking cessation. The most disputable component of SSI prevention at the present time is the use of prophylactic intravenous and topical antibiotics. Antibiotic prophylaxis most commonly refers to the systemic (intravenous) administration of antibiotics given to the patient within 1 hour before the incision. Numerous studies and recommendations exist regarding the choice of intravenous antibiotics, timing, and duration of their administration. But the use of topical antibiotic prophylaxis agents in plastic surgery is not specified and nonstandardized.

Various antibacterial solutions have been described for the irrigation of breast implant pockets to decrease the risk of contamination. The effectiveness of antibiotic/antiseptic irrigation is supported by a wealth of clinical data. Burkhardt et al were pioneers of topical antibiotic use in breast surgery. They applied a variety of local antibacterial agents around breast implants in the prospective randomized double-blind study involving 124 patients undergoing augmentation mammoplasty. The rate of class III and IV capsular contracture was reduced significantly (by 50%). Betadine-irrigated implants also had a lower incidence of contracture than the saline-irrigated devices in their following study. Irrigation with a 5% povidone-iodine (50% Betadine) solution was the procedure of choice. In another study wound irrigation produced higher local cefazolin concentrations for longer periods of time in 24 breast reduction patients (5 vs 24 hours in patients who received intravenous cefazolin). These properties of local antibiotic use allow avoidance of potential adverse systemic effects and development of antibiotic resistance.

Adams et al studied the effect of various combinations of topical antibiotics that will eliminate bacteria commonly cultured around breast implants. They compared the
efficacy of in vitro serial dilutions of povidone-iodine and two double antibiotic solutions: gentamicin/polymyxin B and gentamicin/cefazolin against S. epidermidis, S. aureus, E. coli, P. aeruginosa, and P. acnes. The bacteria were mixed with the irrigant for 2 minutes and then cultured in agar plates. Although povidone-iodine was effective against most organisms, its efficacy was present only at concentrations well above cytotoxic levels. It also required full undiluted stock strength to control Pseudomonas. Gentamicin/polymyxin B, gentamicin/cefazolin, and cefazolin controlled P. acnes and E. coli. However, none of them suppressed the growth of S. epidermidis, the most frequently cultured organism from the implant biofilms. They concluded that neither povidone-iodine nor a polymyxin B/gentamicin antibiotic alone were effective separately, but their combination worked synergistically with improved efficacy. The authors recommended 50 mL of povidone-iodine, 1g of cefazolin, and 80 mg of gentamicin in 500 mL of sterile saline for irrigation of breast pockets with incomplete evacuation of the solution before implant placement.\(^\text{15}\)

After the 2000 US Food and Drug Administration decree on avoiding contact of the implant with povidone-iodine, Adams et al replaced povidone-iodine in irrigation solution with 50,000 U of bacitracin.\(^\text{43}\) They found the four- to five-fold decrease in incidence of contracture in the augmentation group and threefold in the reconstruction group in patients after triple antibiotic breast irrigation.\(^\text{44}\)

Dilute povidone-iodine (Betadine is 10% povidone-iodine in an aqueous solution) is cytotoxic to normal tissue, as shown in the in vitro and in vivo studies. Lineaweaver et al reported the cytotoxic effect of 0.05% povidone-iodine
on wound healing in rats and lower tensile strength after irrigation with 1% povidone-iodine solution.45 Full strength solution of povidone-iodine destroyed 100% of in vitro human fibroblasts. The 1:1000 dilution, however, did not reveal human fibroblast toxicity with persistence of full bactericidal activity.14 In a more recent study on in vitro human fibroblast cells 1% povidone-iodine solution was effective in killing Gram-positive and Gram-negative bacteria and did not show toxicity against normal fibroblasts.46 The duration of wound irrigation necessary to eliminate the microbial contamination is an important issue. It needs to be sufficient to obtain sterility of the pocket. Earlier studies showed the effectiveness of various antibiotic and antiseptic agents but did not address the necessary time of exposure.15,40,41,43,44 Also, there is not enough data in the literature about optimal time of wound irrigation taking into consideration direct toxic effects of prolonged irrigation and its interfering with early stages of wound healing. Our study is the first report of the effectiveness of different antibiotic solutions depending on the exposure time of the irrigation agents.

We compared the effects of multiple agents on wound irrigation. Reliable antimicrobial effect was not reached after minimal time (5 min) of irrigation with different solutions. Irrigation with the separate components of triple antibiotic solution (50,000 units of bacitracin, 1 g cefazolin, or 80 mg gentamicin in 500 cc normal saline) was not effective. Cefazolin and bacitracin did not cover P. aeruginosa. Overall, the single agent solution able to cover both Gram-negative and Gram-positive bacteria was gentamicin, but only under extra-long 30 minute exposure. A 0.05% chlorhexidine solution was effective against the studied organisms starting at 15 min exposure. The results with P. aeruginosa were inconsistent however: repeating the experiment with different strains did not show any coverage in 40% of the cases. This corresponded with known chlorhexidine resistance of P. aeruginosa seen in up to 84% of the strains in the literature.47,48 We used P. aeruginosa as a representative of Gram-negative agents as there are reports of the increasing proportion of Gram-negative bacterial infectious complications after implant-based breast reconstruction.49,50 MSSA and group A Streptococcus were covered with 5% povidone-iodine with minimal irrigation time, but complete sterility of experimental surgical site was achieved only under 30 min exposure.

We exchanged cefazolin component to vancomycin in the triple antibiotic and BPCG solutions to detect possible superior Gram-positive coverage. Interestingly, the effectiveness of the triple antibiotic solution against MRSA was not inferior: it was suppressed within 15 min, compared to 30 min exposure necessary for BVG. Conversely, BVG required only 10 min irrigation to cover MSSA. In the case of triple antibiotic solution, extra-long exposure (30 minutes) was needed to eradicate this microorganism. Group

<table>
<thead>
<tr>
<th>Antimicrobial agent/exposure</th>
<th>5 min</th>
<th>10 min</th>
<th>15 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triple antibiotic</td>
<td>MRSA +</td>
<td>MRSA +</td>
<td>MRSA -</td>
<td>MRSA -</td>
</tr>
<tr>
<td></td>
<td>MSSA +</td>
<td>MSSA +</td>
<td>MSSA +</td>
<td>MSSA -</td>
</tr>
<tr>
<td></td>
<td>Strep A</td>
<td>Strep A</td>
<td>Strep A</td>
<td>Strep A</td>
</tr>
<tr>
<td></td>
<td>P. aerug +++</td>
<td>P. aerug +++</td>
<td>P. aerug ++</td>
<td>P. aerug -</td>
</tr>
<tr>
<td>PCG</td>
<td>MRSA +</td>
<td>MRSA +</td>
<td>MRSA +</td>
<td>MRSA +</td>
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<tr>
<td></td>
<td>MSSA +</td>
<td>MSSA +</td>
<td>MSSA +</td>
<td>MSSA -</td>
</tr>
<tr>
<td></td>
<td>Strep A</td>
<td>Strep A</td>
<td>Strep A</td>
<td>Strep A</td>
</tr>
<tr>
<td></td>
<td>P. aerug +</td>
<td>P. aerug -</td>
<td>P. aerug -</td>
<td>P. aerug -</td>
</tr>
</tbody>
</table>

MRSA, Methicillin-resistant Staphylococcus aureus; MSSA, Methicillin-sensitive Staphylococcus aureus; Strep A, Group A Streptococcus; P. aerug, Pseudomonas aeruginosa. −, no microorganism growth; +, 1 to 2 colonies; ++, 3 to 5 colonies; +++; 6 to 9 colonies; ++++; abundant growth with 10 and more colonies.

A Streptococcus was covered under minimal time of irrigation with both solutions. The efficiency of BPCG and BPVG were comparable to the strengths of the triple antibiotic and BVG solutions.

In an attempt to broaden the spectrum of coverage and reduce efficient exposure time, bacitracin was replaced with povidone-iodine in the triple antibiotic solution. The obtained PCG solution was similar in efficacy regarding MSSA and Group A Streptococcus in the in vitro surgical site model. However, it did not cover MRSA. It required less time for anti-Gram-negative effect: 10 min vs 30 min exposure needed in the case of triple antibiotic solution (Table 4).

The possibility of residual antibiotic effect due to its absorption by blood agar was a concern in our surgical site model which needed to be ruled out. To evaluate this feature as possible bias, we irrigated sterile blood agar cups with the irrigation solutions for 30 min, rinsed the cups with lactate Ringer’s solution, and seeded the microorganisms. Abundant growth comparable with control cups was present after 24 hours which excluded agar absorption bias. Estimating the effectiveness of the studied irrigation agents from the perspective of the coverage of separate microorganisms, we received the following results. MRSA was optimally covered with 0.05% chlorhexidine and triple antibiotic solutions. The former was effective within 5 min of irrigation time, the latter required longer exposure (at least 15 min). The most efficient agent for MSSA eradication was shown to be 5% povidone-iodine solution which covered it in 5 min, the rest of the studied agents needed longer periods of time. Group A Streptococcus was the most sensitive to all types of the antimicrobial and antiseptic agents we used. It was eradicated in minimal irrigation time.
The situation with *P. aeruginosa* was not that straightforward. Chlorhexidine was effective at 10 min exposure in 60% of the seedings. In other 40% of the cases the growth of *Pseudomonas*-resistant strains was suppressed but still present under extra long exposure times. Triple antibiotic solution required 30 min to take effect. PCG and BPCG solutions were effective against *P. aeruginosa* in 10 and 15 min of irrigation respectively. Vancomycin-containing agents worked during the intermediate exposure times: 10 to 15 min.

It was shown in our study that 0.05% chlorhexidine and triple antibiotic solutions are effective wound irrigation agents for SSI prophylaxis directed against Gram-positive and Gram-negative microorganisms. Attempt to involve vancomycin in the irrigation solutions did not reveal a superior suppressive antimicrobial effect both at short and long exposure times. Therefore, there is no need to increase the cost of the irrigation solution, and we recommend using more economically efficient antimicrobial agents.

The FDA issued a warning regarding rare allergic reaction to chlorhexidine in February 2017. Fifty-two cases of anaphylaxis with the use of chlorhexidine gluconate products applied to the skin have been identified between January 1969 and June 2015. We acknowledge that caution needs to be taken when using chlorhexidine solution.

Prolonged irrigation with antibiotic solutions was shown to completely suppress the organisms of contamination in the *in vitro* model of the surgical site. However, the 30 min window of the open wound irrigation in the operating room will not be convenient for surgeons, as well as not economically justified from the OR time use point of view. Adequate time of exposure can be achieved by delaying the activation delaying the activation of the Jackson-Pratt drains till the patient is brought to the postanesthesia care unit.

We acknowledge the limitations of our *in vitro* study: further in vivo research is necessary to confirm the effectiveness of the irrigation agents in the clinical setting, and the range of studied microorganisms needs to be broadened including atypical mycobacteria. The incidence of nontuberculous mycobacteria periprosthetic breast infections are increasing worldwide. Wound management in those patients is challenging and recovery time is prolonged. Absence of clinical data and recommendations regarding its prophylaxis necessitate further studies.

Intraoperative wound irrigation with an optimal antimicrobial regimen is an effective SSI prophylaxis as it allows to achieve complete or almost complete sterile wound after its closure, which is very important in the case of breast implant placement. Given the proper use, wound irrigation may negate the necessity of intravenous antibiotic prophylaxis.

### CONCLUSIONS

Wound irrigation is an effective SSI prophylaxis method in breast reconstruction surgery supported by an abundance of clinical data. The choice of optimal antimicrobial solution is based on the combination of antimicrobial effect against the most common SSI causative organisms and its impact on wound healing. We recommend 0.05% chlorhexidine and triple antibiotic solutions for topical SSI prophylaxis in breast reconstruction surgery. Caution needs to be taken when using chlorhexidine solution.

Sufficient irrigative antibiotic agent exposure allows for the suppression of the usual intraoperative contamination, thereby avoiding systemic effects and potential toxicity of intravenous antibiotic prophylaxis.

### Disclosures

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### REFERENCES


