RESEARCH ARTICLE

The Use of a Novel Antiseptic Irrigant Solution in Combination with Vancomycin Powder Significantly Reduces the Risk of Surgical Site Infections in Orthopedic Trauma Patients

Robert S. Wood, DO; Elizabeth Herrera, MPH; Meghan E. Wood, DO; Greta Brown, BS; Maddie Vergun, BS; Jacqueline Krumrey, MD

Research performed at Good Samaritan Regional Medical Center, Corvallis, Oregon, USA

Received: 3 August 2024 *Accepted: 21 December 2024*

Abstract

Objectives: This study aims to evaluate whether using a novel antiseptic irrigant solution combined with vancomycin powder can effectively reduce the incidence of surgical site infections (SSIs) in orthopedic trauma patients. Specifically, we seek to determine if this combined approach significantly decreases SSI rates compared to using vancomycin powder alone. The study also aims to assess the safety and efficacy of the phosphate buffer solution, particularly its ability to reduce biofilm formation on surgical implants without causing cytotoxic effects. Ultimately, our goal is to provide insights into potential clinical practice changes that can enhance infection prevention strategies in orthopedic trauma surgeries.

Methods: This retrospective study analyzed 450 orthopedic trauma surgeries for lower extremity fractures at a Level Two hospital in Oregon, USA, between January 2021 and October 2023. Patients were stratified based on intraoperative irrigation with either vancomycin alone or vancomycin combined with a phosphate buffer irrigation solution. Data analysis included demographic characteristics, operative details, and occurrences of SSIs within 90 days postoperatively.

Results: Among the 450 surgeries analyzed, 18 (8.1%) SSIs occurred in the vancomycin cohort compared to 3 (1.3%) in the vancomycin and Phosphate buffer cohort. Adjusted logistic regression revealed an 89% reduction in the odds of SSIs in the vancomycin and Phosphate buffer cohort (OR: 0.11, 95% CI 0.02-0.35, P=0.001), adjusting for age, tobacco use, operative time, and procedure type.

Conclusion: This study underscores the promising role of combined vancomycin and Phosphate buffer irrigation in reducing SSI rates in orthopedic trauma surgeries. Further prospective studies are warranted to validate these findings and explore optimal infection prevention strategies in diverse surgical settings.

Level of evidence: IV

Keywords: Infection Prevention, Orthopedic trauma, Orthopedics, Surgical irrigation, Surgical site infection

Introduction

Surgical site infection (SSI) can be a devastating complication of any operative procedure; it can lead to subsequent hospitalizations, further surgical interventions, long courses of antibiotics, and significant morbidity to patients.[1] Despite preventative measures, such as preoperative antibiotic prophylaxis and sterile technique, orthopedic trauma patients often require osteosynthesis with nonbiologic materials, and therefore are at elevated risk of SSI.[2,3] Further, the efficacy of intravenous antibiotics relies on adequate blood supply to

Corresponding Author: Robert S. Wood, Samaritan Health Services Department of Orthopedic Surgery, OR, USA

Email: robertwood@samhealth.org

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

the region, which may be compromised in the event of trauma. Additionally, orthopedic trauma services frequently encounter open wounds, which further compound the risk of a patient developing a surgical site infection due to wound contamination.[4] A recent cross-sectional study showed that up to 4% of patients receiving osteosynthesis for closed fractures develop a surgical site infection requiring further treatment, which represents an average increase in treatment cost of 115%.[1] A different multicenter study revealed that up to 18% of patients who initially present with open fractures will develop postoperative surgical site infection after undergoing operative osteosynthesis.[5] As such, intraoperative measures should be utilized to reduce the likelihood of surgical site infection in orthopedic trauma patients.

One frequently reported methodology for reducing the risk of SSI is the intrawound administration of vancomycin powder. A systematic review and meta-analysis found that orthopedic application of intraoperative, intrawound vancomycin powder significantly protected against SSI.[6] Additionally, a retrospective review found that topical administration of vancomycin powder resulted in a significant reduction in the risk of SSI and significantly lower rates of MRSA development in surgically treated fractures.[7] To date, the use of vancomycin powder for SSI has primarily been featured in spine literature, but minimal studies exist on its use and effectiveness in orthopedic trauma patients.[8]

Biofilm production on orthopedic implants is a serious consequence that greatly increases the risk of SSI in osteosynthesis. Biofilms have been found on orthopedic implants within 6 hours of wound closure and can occur in 30-80% of orthopedic trauma cases and can lead to surgical site infections that are significantly more difficult to treat.[9] Therefore, intraoperative interventions must also be directed at preventing and eradicating biofilm from orthopedic implants. This is commonly done with intraoperative irrigation. Frequently utilized irrigation solutions include povidone iodine (PI), which has been shown to reduce the development of biofilm from Staphylococcus aureus and Staphylococcus epidermidis. However, PI has been shown to be chondrotoxic in concentrations required to be effective.[10]

Novel surgical irrigants have been developed to overcome the issues with PI chondrotoxicity while still maintaining biofilm-reductive abilities. Xperience is a phosphate buffer, no-rinse, surgical irrigation solution. Use of a phosphate buffer has been found to provide up to an 8-log reduction in planktonic bacteria biofilm in vitro with limited cytotoxic effects to host tissue, leading to reduced biofilm production for up to 5 hours postoperatively. Furthermore, a specific advantage of this solution is the ability to leave it on surgical sites without rinsing with normal saline, which allows for increased contact time with implants and surrounding tissues.[11]

This retrospective review aims to evaluate the efficacy of the combined intraoperative application of vancomycin powder and a phosphate buffer no rinse solution to prevent SSI in orthopedic trauma patients. The ultimate aim is to identify a potential strategy that can be easily employed to reduce the risk of postoperative infections in orthopedic trauma surgery and ultimately lead to lower reoperation rates and reduce the burden these infections place on the healthcare system.

Materials and Methods

This retrospective cohort study analyzed patients who underwent operative management for a lower extremity facture with the orthopedic trauma service between 01/01/2021 and 10/31/23 at a single Level Two hospital in Oregon, USA. Lower extremity fractures were chosen for analysis as these are the most common fractures treated by the Orthopedic Trauma Team at the participating institution. The study was approved by the Samaritan Health Institutional Review Board in December 2023. At our institution, one orthopedic trauma surgeon routinely irrigates surgical sites of the lower extremities with Phosphate buffer and Vancomycin, whereas the other orthopedic trauma surgeons irrigate with Vancomycin. All patients were irrigated at the end of surgery with either 1 liter of sterile saline or 1 liter of the novel phosphate buffer solution. Data was retrospectively collected from electronic medical records in January 2024 for all surgeries among patients with a lower extremity fracture that required surgical intervention. Only the index surgery was included for patients with more than one qualifying encounter in the study frame. Patients younger than 18, those who did not receive intraoperative vancomycin powder, and those who had no follow-up at the participating institution between the date of hospital discharge and post-op day 90 were excluded from analysis. In addition, patients with a diagnosed pre-operative infection and those who underwent hardware removal surgery were excluded.

Data related to patient's demographic and surgical characteristics were extracted using structured query language from the electronic health records. The six flags listed below were included in the query to identify patients with a suspected post-operative surgical site infection within 90 days post-op.

1. Antibiotics given postoperatively
2. A positive microbiology lab result
3. An encounter reason related to SSI (prosthetic joint infection, abscess, cellulitis, blood infection, post-op problem, wound infection)
4. An ICD-10 code related to SSI (based on Epic EDG Concept Grouper 1910000040)
5. A chief compliant related to SSI
6. A subsequent surgery related to SSI (CPT codes: 11042-11047 or had keyword I&D)

Study investigators (RW, MV, GB) manually reviewed flagged patient's charts to confirm if a surgical site infection occurred within 90-days post-op. SSIs were defined in accordance with PREP-IT master protocol.[12]

Patients were stratified into cohorts based on the type of wound irrigate used (Phosphate buffer and Vancomycin vs Vancomycin). R version 4.3.1 (USA) was utilized to clean and analyze the data. Pearson's Chi-square and Student's T-tests were utilized to determine independent predictors of SSI. A full adjusted logistic model was built using strong predictor variables identified in the univariate analysis (p-values <0.10) and factors that were deemed clinically plausible by study investigators. An alpha level of 0.05 was used for regression model results.

Results

523 orthopedic trauma surgeries of the lower extremities occurred among adult patients between January 2021 and October 2023. Seventeen patients did not have any follow-up care between hospital discharge and post-op day 90 and 5 surgeries occurred in pediatric patients. An additional 39 surgeries were excluded due to being a non-index surgery (N=26) or a hardware removal procedure (N=13). To avoid cross-over between treatment type and primary surgeon, patients who did not receive the standard irrigation protocol per surgeon were excluded (N=15).

450 surgical patents met the study eligibility criteria and were included in the final analysis. The clinical characteristics of included patients are shown in [Table 1]. The mean age and BMI of the entire cohort was 64 years old and 29, respectively. 56.2% of participants were female and 18.7% have been diagnosed with diabetes. Approximately 17.6% of participants used tobacco products. Participants in the Phosphate buffer group were younger (*P*-value: <0.01) and had shorter operating times (*P*-value: <0.01). Hemiarthroplasty of the hip was the most common surgery in the Vancomycin only cohorts, whereas open reduction and internal fixation of the ankle was the most common surgery in the Phosphate buffer group.

Table 1. Demographic Characteristics of Study Participants

	Vancomycin Only (N=222)	Vancomycin & Phosphate buffer (N=228)	P-value
Patient Age			
Mean (SD)	67.8 (17.3)	60.4 (22.1)	<0.01
Median [Min, Max]	71.5 [18.0, 98.0]	67.0 [18.0, 97.0]	
Patient BMI			
Mean (SD)	28.3 (7.25)	28.7 (7.37)	0.62
Median [Min, Max]	27.1 [15.5, 54.9]	27.5 [14.5, 64.4]	
Missing	13 (5.9%)	18 (7.9%)	
Patient Sex			
Female	124 (55.9%)	129 (56.6%)	0.95
Male	98 (44.1%)	99 (43.4%)	
Operative Time (minutes)			
Mean (SD)	178 (50.8)	158 (70.6)	<0.01
Median [Min, Max]	170 [89.0, 412]	146 [59.0, 541]	
History of DM			
No	177 (79.7%)	189 (82.9%)	0.46
Yes	45 (20.3%)	39 (17.1%)	
Tobacco Use			
Non-Tobacco User	177 (79.7%)	194 (85.1%)	0.17
Current Tobacco User	45 (20.3%)	34 (14.9%)	
Primary Procedure			
ORIF Ankle	48 (21.6%)	76 (33.3%)	
Hemiarthroplasty Hip	75 (33.8%)	36 (15.8%)	
ITST Intramedullary Nail	26 (11.7%)	36 (15.8%)	
IM Rodding of Tibia†	13 (5.9%)	17 (7.5%)	
ORIF Tibia and Fibula†	16 (7.2%)	17 (7.5%)	
ORIF Distal Femur†	13 (5.9%)	10 (4.4%)	
ORIF of the Pilon†	9 (4.1%)	6 (2.6%)	
Percutaneous Pinning Hip†	4 (1.8%)	9 (3.9%)	<0.01
ORIF Patella†	3 (1.4%)	8 (3.5%)	
IM Rodding of Femur†	4 (1.8%)	4 (1.8%)	
Fusion Ankle†	4 (1.8%)	1 (0.4%)	
ORIF Foot†	0 (0%)	5 (2.2%)	
Quadricep Tendon Repair†	2 (0.9%)	1 (0.4%)	
DHS Hip†	2 (0.9%)	0 (0%)	
ORIF Femur†	1 (0.5%)	1 (0.4%)	

Table 1. Continued		
Patellar Tendon Repair†	1 (0.5%)	1 (0.4%)
ORIF Calcaneus†	1 (0.5%)	0 (0%)

DM: Diabetes Mellitus, ITST: inter-trochanteric/sub-trochanteric, ORIF: Open reduction and internal fixation
P-values for continuous variables calculated with Student's T-test. P-values for categorical variables calculated with Pearson's Chi-square tests or Fisher's Exact Tests when cell sizes <5. Statistically significant p-values are bolded
† Categorized as other in regression modeling

The overall surgical site infection rate among included surgeries was 4.7%. Study investigators identified 18 (8.1%) surgical site infections in the vancomycin cohort and 3 (1.3%) surgical site infections in the Phosphate buffer cohort [Figure 1]. A post-hoc power analysis revealed that 302 patients would be required to give the study 80% power at an alpha level of 0.05 to detect a statistically significant difference in surgical site infection rates assuming a SSI rate of 8.1% among the vancomycin group and a SSSI rate of 1.3% in the phosphate buffer group. An adjusted logistic regression model was fit to control for potential confounding variables. The regression analysis showed a 89% reduction in the odds of surgical site infections in the Phosphate buffer cohort (OR: 0.11, 95% CI 0.02-0.36, *P*-value: 0.001), adjusting for patient age, tobacco use, operative time, diabetic status, and procedure type [Table 2].

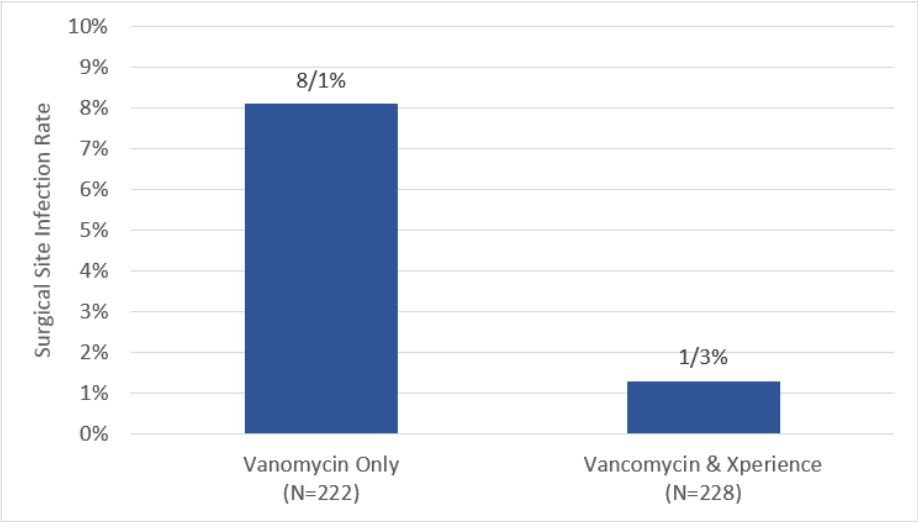

Figure 1. Surgical Site Infection Rates among Orthopedic Lower Extremity Trauma Patients (p-value: <0.001)*
***P-value calculated with Fisher's Exact Test**

Table 2. Adjusted Multi-Variable Logistic Regression Model Predicting Surgical Site Infections		
Variable	**OR (95% CI)**	**P-value**
Irrigation Solution Used		
Vancomycin Only	Ref	-
Vancomycin & Phosphate Buffer	0.11 (0.02-0.36)	0.001
Age at surgery (years)	0.97 (0.94-0.99)	0.03
Operative time (minutes)	0.99 (0.99-1.01)	0.64
Current Tobacco Use		
No	Ref	-
Yes	1.48 (0.50-4.04)	0.46
History of DM		
No	Ref	
Yes	1.78 (0.53-5.25)	0.31
Procedure Type		
Hemiarthroplasty hip	Ref	-

Table 2. Continued		
ITST intramedullary nail	0.95 (0.12-5.38)	0.96
ORIF Ankle	0.70 (0.13-3.75)	0.67
Other	1.07 (0.26-4.79)	0.93

Discussion

Surgical site infections (SSI) pose significant challenges in orthopedic trauma surgeries, necessitating effective preventive measures to mitigate their occurrence. The findings of this study suggest a substantial reduction in the odds of developing SSI among patients who received the combination of vancomycin powder and Phosphate buffer irrigation compared to those who received vancomycin alone. Specifically, the Phosphate buffer cohort demonstrated an 89% reduction in the odds of SSI after adjusting for potential confounders such as patient age, tobacco use, operative time, and procedure type.

Orthopedic surgeries often involve complex procedures with inherent risks of SSI, necessitating meticulous attention to infection prevention strategies. Intraoperative irrigation is a cornerstone in infection prevention protocols, yet the optimal irrigation solution remains debated due to a lack of consensus and concrete data supporting a universally effective agent. Historically, isotonic normal saline has been favored for its safety and cost-effectiveness, but recent research has highlighted the need for solutions with optimal antimicrobial properties and low cytotoxic effects.[13]

In the context of orthopedic implant-related infections, biofilm formation emerges as a significant challenge, contributing to the pathogenesis of SSIs. Rozis et al. highlight the prevalence of biofilm-associated infections in orthopedic implants, underscoring the need for strategies targeting biofilm eradication.[14] The efficacy of vancomycin powder and Phosphate buffer irrigation in reducing biofilm formation aligns with the imperative to address this critical aspect of infection prevention and may represent a mechanism for the effective reduction of surgical site infections observed in this study.

A systematic review and network meta-analysis of 41 randomized clinical trials involving 17,188 patients found that both antiseptic and antibiotic solutions were associated with a reduction in SSIs compared to no irrigation, with antiseptic solutions showing a higher level of certainty in their effectiveness. However, antibiotic solutions demonstrated a lower level of certainty, prompting caution due to concerns regarding global antimicrobial resistance. Saline irrigation did not show a statistically significant difference in preventing SSIs compared to no irrigation.[15] These findings underscore the importance of selecting appropriate irrigation solutions in surgical settings to mitigate the risk of SSIs effectively. The findings of this current study represent a promising approach with the potential for phosphate buffer solutions to reduce SSIs in orthopedic trauma surgeries.

There remains a paucity of level I evidence to identify the ideal intraoperative irrigation solution. One proposed solution has been dilute polyhexanide for intraoperative irrigation. An RCT involving 689 patients from 12 hospitals were randomized to receive polyhexanide 0.04% irrigation, saline irrigation, or no irrigation before wound closure. The primary outcome, SSIs within 30 days postoperatively, was observed in 11.8% of participants overall, with no statistical superiority observed for polyhexanide irrigation compared to saline or no irrigation.[16] These results stand in contrast to the effect seen with the phosphate buffer solution and further emphasizes the need for more RCTs to identify the ideal intraoperative irrigation solution.

The observed reduction in SSI rates with the combined use of vancomycin powder and Phosphate buffer irrigation underscores the potential synergistic effects of these interventions. While vancomycin powder targets bacterial colonization at the surgical site, Phosphate buffer irrigation offers sustained antimicrobial activity and biofilm reduction without compromising tissue viability. The retrospective study's findings align with the call for evidence-based standardization of surgical irrigation practices, as advocated by many infection prevention experts.[17]

However, several considerations warrant attention. The retrospective nature of the study may introduce biases and limits causal inference. Surgical technique and degree of operative contamination differs among surgeons, and as such are important independent variables when predicting surgical site infection rates. This was a non-randomized design with all patients in the Phosphate buffer group being treated by a single surgeon and patients in the control group being treated by two other surgeons. We were unable to control for surgeon characteristics in our regression model, significantly limiting our results. However, all surgeons have over 15 years of experience and have been practicing together since 2015. In addition, differential misclassification could have occurred in patients without SSI. It is possible that patients experienced a SSI and sought care outside the system or did not have documentation that flagged investigators to conduct manual chart review. Ensuring that patients had at least one documented out-patient encounter in post-operative period reduces the likelihood of misclassification occurring. Prospective randomized controlled trials are warranted to validate the observed outcomes and elucidate the mechanisms underlying the combined efficacy of vancomycin powder and Phosphate buffer irrigation. Additionally, the generalizability of findings to diverse patient populations and surgical contexts merits further investigation.

Conclusion

This study does show a potential advantage for the potential use of combined vancomycin powder and

phosphate buffer irrigation as a strategy for reducing surgical site infection risk. However, the study was limited by its size and retrospective nature. Thus, larger scale and prospective randomized studies should be conducted in order to validate these initial findings.

Acknowledgement

N/A

Authors Contribution: Authors who conceived and designed the analysis: Robert Wood, DO; Jacqueline Krumrey, MD/ Authors who collected the data: Robert Wood, DO; Elizabeth Herrera, MPH; Meghan Wood, DO; Greta Brown, BS; Madeline Vergun, BS/ Authors who contributed data or analysis tools: Elizabeth Herrera, MPH/ Authors who performed the analysis: Elizabeth Herrera, MPH/ Authors who wrote the paper: Robert Wood, DO; Elizabeth Herrera, MPH; Meghan Wood, DO; Greta Brown, BS; Madeline Vergun, BS; Jacqueline Krumrey, MD

Declaration of Conflict of Interest: The authors does NOT have any potential conflicts of interest for this manuscript.

Declaration of Funding: The author received NO financial support for the preparation, research, authorship, and publication of this manuscript.

Declaration of Ethical Approval for Study: Approval for this study was obtained from the Samaritan Health Services IRB. The IRB approval number is IRB23-062.

Declaration of Informed Consent: There is no information that can be used to identify patients included in the manuscript.

Robert S. Wood DO [1]
Elizabeth Herrera MPH [1]
Meghan E. Wood DO [2]
Greta Brown BS [3]
Maddie Vergun BS [1]
Jacqueline Krumrey MD [1]

1 Samaritan Health Services Department of Orthopedic Surgery, OR, USA

2 Samaritan Health Services Department of Family Medicine, OR, USA

3 Western Univeristy of Health Sciences, Corvallis, OR, USA

References

1. Motififard M, Teimouri M, Shirani K, Hatami S, Yadegari M. Prevalence of Bacterial surgical site infection in traumatic patients undergoing orthopedic surgeries: a cross-sectional study. Int J Burns Trauma. 2021; 11(3):191-196.
2. Katsikogianni MG, Missirlis YF. Interactions of bacteria with specific biomaterial surface chemistries under flow conditions. Acta Biomater. 2010; 6(3):1107-1118. doi:10.1016/j.actbio.2009.08.006.
3. Ribeiro M, Monteiro FJ, Ferraz MP. Infection of orthopedic implants with emphasis on bacterial adhesion process and techniques used in studying bacterial-material interactions. Biomatter. 2012; 2(4):176-194. doi:10.4161/biom.22905.
4. Dong X. Surgical site infection in upper extremity fracture: Incidence and prognostic risk factors. Medicine (Baltimore). 2022; 101(35):e30460. doi:10.1097/MD.0000000000030460.
5. Hu Q, Zhao Y, Sun B, Qi W, Shi P. Surgical site infection following operative treatment of open fracture: Incidence and prognostic risk factors. Int Wound J. 2020; 17(3):708-715. doi:10.1111/iwj.13330.
6. Sadigursky D, Sousa MD, Cajaíba YGL, Martins RR, Lobão DMV. Infectious Prophylaxis with Intrawound Vancomycin Powder in Orthopedic Surgeries: Systematic Review with Meta-Analysis. Rev Bras Ortop (Sao Paulo). 2019; 54(6):617-626. doi:10.1016/j.rbo.2017.12.003.
7. Qadir R, Costales T, Coale M, Zerhusen T Jr, Joshi M, O'Toole RV. Topical Vancomycin Powder Decreases the Proportion of Staphylococcus aureus found in Culture of Surgical Site Infections in Operatively Treated Fractures. J Orthop Trauma. 2021; 35(1):17-22. doi:10.1097/BOT.0000000000001855.
8. Horii C, Yamazaki T, Oka H, et al. Does intrawound vancomycin powder reduce surgical site infection after posterior instrumented spinal surgery? A propensity score-matched analysis. Spine J. 2018; 18(12):2205-2212. doi:10.1016/j.spinee.2018.04.015.
9. Hrynyshyn A, Simões M, Borges A. Biofilms in Surgical Site Infections: Recent Advances and Novel Prevention and Eradication Strategies. Antibiotics (Basel). 2022; 11(1):69. doi:10.3390/antibiotics11010069.
10. Edmiston CE Jr, Spencer M, Leaper D. Antiseptic Irrigation as an Effective Interventional Strategy for Reducing the Risk of Surgical Site Infections. Surg Infect (Larchmt). 2018; 19(8):774-780. doi:10.1089/sur.2018.156.
11. Bashyal RK, Mathew M, Bowen E, James GA, Stulberg SD. A Novel Irrigant to Eliminate Planktonic Bacteria and Eradicate Biofilm Superstructure With Persistent Effect During Total Hip Arthroplasty. J Arthroplasty. 2022; 37(7S):S647-S652. doi:10.1016/j.arth.2022.01.045.
12. PREP-IT Investigators, Sprague S, Slobogean G, et al. Skin Antisepsis before Surgical Fixation of Extremity Fractures. N Engl J Med. 2024; 390(5):409-420. doi:10.1056/NEJMoa2307679.
13. Papadakis M. Wound irrigation for preventing surgical site infections. World J Methodol. 2021; 11(4):222-227. doi:10.5662/wjm.v11.i4.222.
14. Rozis M, Evangelopoulos DS, Pneumaticos SG. Orthopedic Implant-Related Biofilm Pathophysiology: A Review of the Literature. Cureus. 2021; 13(6):e15634. doi:10.7759/cureus.15634.
15. Groenen H, Bontekoning N, Jalalzadeh H, et al. Incisional Wound Irrigation for the Prevention of Surgical Site Infection: A Systematic Review and Network Meta-Analysis. JAMA Surg. doi:10.1001/jamasurg.2024.0775.
16. Mueller TC, Kehl V, Dimpel R, et al. Intraoperative Wound Irrigation for the Prevention of Surgical Site Infection after Laparotomy: A Randomized Clinical Trial by CHIR-Net. JAMA Surg. 2024; 159(5):484-492. doi:10.1001/jamasurg.2023.7985.
17. Barnes S, Spencer M, Graham D, Johnson HB. Surgical wound irrigation: a call for evidence-based standardization of practice. Am J Infect Control. 2014; 42(5):525-529. doi:10.1016/j.ajic.2014.01.012.