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General Assembly, Prevention, Antiseptic Irrigation Solution: Proceedings of International Consensus on Orthopedic Infections

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Question 1: Which antiseptics can be used to prevent biofilm formation?

Recommendation:

Although several studies have demonstrated the ability of certain antiseptic agents to prevent biofilm formation in vitro, the ability of antiseptics to provide prevention of biofilm formation in vivo is uncertain. They may have use in the context of revision surgery due to existing infection, but this issue has not been adequately studied.

Level of evidence: limited

Delegate vote: Agree: 93%, Disagree: 2%, abstain: 5% (Super Majority, Strong Consensus).

Rationale:

It has not been established whether a specific antiseptic or a combination of agents is better to eradicate biofilms from an implant surface in vivo [1]. So far, almost all of the studies focused on the abilities of antiseptics to inhibit biofilm formation have been demonstrated in in vitro studies [2–5].

Santos et al performed a crossover, randomized, double-blind clinical trial to evaluate the effects of two chlorhexidine solutions (alcohol-containing 0.12% chlorhexidine solution and alcohol-free 0.12% chlorhexidine solution) against supragingival and subgingival biofilm formation. The group found that both the solutions had similar inhibitory effects on the formation of biofilms [6]. In addition, Quintas et al performed an observer-masked, crossover, randomized clinical trial to evaluate the in situ antiplaque effect after 4 days of using 2 commercial antimicrobial agents (essential oils and 0.2% chlorhexidine) in short term on undisturbed plaque-like biofilm [7]. Although the 0.2% chlorhexidine showed better results with regard to reducing the thickness and covering grade by the biofilm, both antiseptics had great and similar antiplaque effects.

The ability of acetic acid and polyhexanide to prevent biofilm formation has also been mentioned in the literature. Halstead et al demonstrated that acetic acid at low concentrations of 0.16% to 0.31% was able to inhibit biofilm formation in vitro [8]. Lenselink and Andriessen performed a cohort study to evaluate the clinical efficacy of the polyhexanide-containing bio cellulose dressing for the eradication of biofilms in nonhealing wounds [9]. They suggested that continuous application of polyhexanide, using a bio cellulose wound dressing, reduced biofilm in the stagnating wounds treated, thus promoting healing.

Regarding the clinical use of povidone-iodine to prevent the formation of biofilms, there are limited studies in vitro. Hill et al used a sophisticated in vitro biofilm model that was designed to closely mimic chronic wound biofilms and demonstrated the complete

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[1] Question 2.
[2] Question 4.
[3] Question 3.
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destruction of an established 7-day mixed *Pseudomonas* and *Staphylococcus* biofilm by iodine-based dressings [10]. Kanno et al suggested that irrigation of wounds with 1% povidone-iodine was an effective way to reduce bacterial counts on the wound surface and prevent new biofilm formation by using a rat model of chronic wound biofilm infection [11]. However, Presterl et al found that povidone-iodine was inferior to hydrogen peroxide and alcohol for the eradication of *Staphylococcus epidermidis* biofilms [12].

It is worth noting that many biofilm infections occur much later in the postoperative period, often due to the hematogenous dissemination of bacteria to the site of an implanted device from a breach in surface structures [13]. Indeed, this can occur months or even years after implantation, and it is unlikely to prevent this mode of infection development with the use of antiseptic agents at the time of perioperative period. The role of antiseptics in various debridement protocols for the treatment of established periprosthetic joint infections remains controversial. Each clinical scenario is unique in terms of causative pathogen, host factors, local tissue viability, as well as the duration and virulence of the infection. If the surgeon is attempting to salvage the existing prosthesis through a debridement, antibiotics, and implant retention protocol, it is imperative that all biofilms should be removed through mechanical and chemical disruption [14–16]. If a one-stage revision including component explantation, debridement, and reimplantation of a new prosthesis is to be undertaken in a single surgical setting, the importance of debriding all infected tissue is vital. The role of antiseptics, in this case, is not to treat existing biofilm, as all prosthetic components will have been removed; instead, the purpose is to aggressively treat the remaining bone and its soft tissue envelope to prevent recolonization. Antiseptics used for this purpose include acetic acid, Dakin's solution (NaOCl), povidine-iodine, and hydrogen peroxide [17]. In this situation, the volume of antiseptic solution may be more important than the combination and sequence of agents [17,18].

The use of antiseptic agents during the perioperative period has the potential to reduce the rates of surgical infection early in the postoperative period. In addition, the use of certain antiseptic solutions for lavage, during primary and revision total joint arthroplasty operations, has the potential to reduce infection rates [19]. However, validated protocols do not exist for the use of such solutions in terms of concentration, volume, and duration of exposure. More in vivo studies are needed to evaluate the use of various antiseptic agents for this purpose such that direct comparisons between agents can be made.

Ultimately, although several studies have demonstrated the ability of certain antiseptic agents to prevent biofilm formation in vitro, the ability of antiseptics to provide protection against biofilm formation in vivo is uncertain. They may have use in the context of revision surgery due to existing infection, but this issue has not been adequately studied.

Question 2: What is the optimal irrigation solution (i.e., type, volume, frequency) to be used during clean elective orthopedic procedures?

Recommendation:

There is ample evidence to support the WHO and CDC recommendations that advocate the use of dilute betadine for the irrigation of wounds during surgical procedures. The optimal volume of irrigation solution is not known.

Level of Evidence: Strong

Delegate Vote: Agree: 75%, Disagree: 16%, Abstain: 9% (Super Majority, Strong Consensus)

Rationale:

Intraoperative irrigation during clean elective orthopedic procedures is one aspect of the operative protocol to reduce surgical site infections (SSIs), and there is generally consensus that this technique in some form should be performed. Recently released guidelines by the Centers for Disease Control and World Health Organization recommend intraoperative irrigation with dilute betadine before closure [20,21]. Betadine contains aqueous iodophor in the form of povidone-iodine, which becomes chemically toxic to microorganisms when released as free iodine [22,23].

Povidone-iodine irrigation initially garnered support from studies in other fields, such as general, urologic, cardiovascular, and spine surgeries [24–33]. A meta-analysis of seven randomized control trials demonstrated a statistically significant benefit for incisional wound irrigation with aqueous betadine compared with normal saline solution (odds ratio: 0.31; $P = .007$) [21]. In a larger meta-analysis of 15 level I or II studies in various surgical fields, 10 studies demonstrated that povidone-iodine irrigation was more effective than the control method that included irrigation with saline, water, or no irrigation [34].

Although well studied in other specialties, only one retrospective cohort study addresses intraoperative betadine irrigation in primary joint arthroplasty [35]. Brown et al demonstrated a statistically significant reduction in SSI from 0.97% to 0.15% with the use of 0.35% povidone-iodine. Kokavec et al studied betadine irrigation in a pediatric population undergoing surgery on the proximal femur, hip, and pelvis [26]. In this study, two superficial wound infections were identified in the nonbetadine group (2/73, 2.7%), and no infections were identified in the betadine group (0/89; 0%) (Table 1).

In addition to isotonic saline and Ringers lactate, several solutions, such as antiseptics and antibiotic solutions, have also been proposed as potential irrigation fluids in orthopedic surgery. However, there is no consensus on a “gold standard” because of lack of clinical studies on the topic. Chlorhexidine is an antiseptic that alters the osmotic equilibrium of bacterial cells by binding to negatively charged molecules on the cell wall [36,37]. Chlorhexidine has a broad spectrum of activity [38] and can be bacteriostatic or bactericidal depending on its concentration [39]. Frisch et al compared 0.05% chlorhexidine to normal saline irrigation in total knee arthroplasty (TKA) and 0.05% chlorhexidine to <2% dilute betadine in total hip arthroplasty [40]. There was no significant difference in the rate of superficial or deep SSI between groups, which suggest that chlorhexidine may be comparable to normal saline in reducing infection rates.

Although there is some evidence for the optimal irrigation solution, few studies have demonstrated an optimal volume or method for performing irrigation [41,42]. In addition, there is little support for the benefits of adding antibiotics to irrigation solution, which was shown to be ineffective on metal surfaces in vitro, and thus this practice is not currently recommended by the World Health Organization [41,43]. However, a single surgeon has reported beneficial results when vancomycin and polymyxin were added to irrigation solution in 2293 total joint arthroplasties [44].

Overwhelming evidence from published randomized controlled trials (RCTs) on the use of irrigation solutions for clean, elective orthopedic procedures or surgeries suggests that both normal isotonic saline and Ringers lactate solutions are safe and effective irrigation fluids. However, the majority of these studies were based on shoulder arthroscopic surgery [45–51], with limited studies on TKAs [50,52,53]. Whether Ringers lactate is better than normal saline or vice versa is not known. However, in a laboratory-based study on surgically resected menisci from patients who underwent arthroscopic knee surgery, investigators aimed to determine whether there was a difference in the effect on cell morphology and function between isotonic saline and Ringers lactate solutions. The findings showed that Ringers lactate maintained better meniscal cell integrity than isotonic saline [54].

Emerging and consistent evidence suggests that warming of irrigation fluids (whether normal isotonic saline or Ringers lactate)

Table 1
Summary of Orthopedic Literature Comparing the Efficacy of Irrigation Solutions With Respect to Prevention of SSI.

Author	Category	N	Intervention	Comparison	Study Design	Analysis	Outcome	Incidence of SSI	*P* Value
Brown et al	TJA	2550 (1862 pre/688 post)	Betadine	Saline	Retrospective; Pre-post	Univariate	D	0.15% vs 0.97%	.04
Cheng et al	Spine	414 (206 control/208 intervention)	Betadine	Saline	RCT	Multivariate	S and D	0% vs 3.4%	.01
Cheng et al	Spine	244 (124 control/120 intervention)	Betadine	Saline	RCT	Univariate	S and D	0% vs 4.8%	.03
Kokavec et al	Ortho	162 (73 control/89 intervention)	Betadine	Saline	RCT	NA	S	0% vs 2.7%	NA
Frisch et al	THA	391 (253 pre/138 post)	Chlorhexidine	Betadine	Retrospective; Pre-post	Multivariate	S and D	S—0% vs 1.2%; D—0% vs 1.6%	.56; .30
Frisch et al	TKA	659 (411 pre/248 post)	Chlorhexidine	Saline	Retrospective; Pre-post	Multivariate	S and D	S—0.8% vs 0.7%; D—1.2% vs 0.7%	.91; .53

S, superficial infection, D, deep infection; THA, total hip arthroplasty; TKA, total knee arthroplasty; SSI, surgical site infection.

to temperatures of 32°C to 40°C compared with room temperature decreases the risk of peroperative hypothermia and reduces inflammatory response in patients undergoing shoulder, hip, or knee arthroscopy [47,50,55–57]. Only two RCTs have, to our knowledge, reported that warmed irrigation fluids were not superior to room temperature fluids in reducing the occurrence of perioperative hypothermia [49,58].

Results from three RCTs provided evidence that the addition of epinephrine to irrigation fluids improved the clarity of the visual field of surgery, reduced intraoperative bleeding, and reduced total operating time compared with plain irrigation fluids [46,48,51]. The benefits of using chilled irrigation solutions in orthopedic procedures were uncertain until recently. Li et al performed an randomized controlled trial (RCT) and compared the effects of continuous irrigation of 4000 mL cold saline plus 0.5% epinephrine vs 4000 mL normal saline at room temperature in patients undergoing TKAs [52]. Irrigation with cold saline was demonstrated to be associated with decreased postoperative pain, reduced intraoperative blood loss, and improved quality of life.

Though commonly used isotonic solutions such as normal saline or Ringers lactate have been reported to be safe for joint irrigation in orthopedic procedures, rare adverse events from excessive fluid irrigation have been documented. It has been reported that hyperosmolar solutions may have the potential to minimize these problems. However, their benefits have only so far been demonstrated in animal models. In a recent RCT, hyperosmolar irrigation was shown to decrease periarticular fluid retention in shoulder arthroscopy compared with standard of care irrigation fluid [45].

The role of continuous irrigation or pulse lavage in orthopedic surgery has progressed from open fractures and contaminated wounds to being used in clean elective procedures. Furthermore, the optimum volume of irrigation solution used during orthopedic procedures varies from one surgery to the other. In studies of patients undergoing shoulder arthroscopy, average volume of fluid used for irrigation ranged from 3.7 to 11.4 L, and this was based on continuous irrigation with a pressure-control pump maintained at pressure settings of 30 to 60 mmHg [45–51].

For hip arthroscopy, evidence was based on an observational prospective study [57]. Median volume of irrigation solution was 27 L, using an infusion pump, with pressure between 45 and 65 mmHg. In the RCT by Kelly et al investigating patients undergoing knee arthroscopy, the average volume of irrigation fluid used was 11.7 L [58]. In two studies of TKA (one RCT and one case series), continuous irrigation with 4 L of normal saline solution was used during surgery in each study [52,53]. In an RCT of hip hemiarthroplasty, 2 L of normal saline administered by pulse lavage was associated with a 30-day lower infection rate than 2 L of normal saline washout by jug or syringe [29]. No data were reported on the pressure settings of the infusion pump in these studies.

Question 3: Does the pressure of the pulsatile delivery mechanism for irrigation fluid influence the efficacy of the irrigation solution to eradicate infecting organisms in the wound?

Recommendation:

A series of clinical studies were unable to observe differences in clinical outcomes or reoperation rates between high-pressure vs low-pressure wound irrigation. Tangential hydrosurgery is an emerging irrigation method that, though promising, still requires further investigation.

Level of Evidence: moderate

Delegate Vote: Agree: 90%, Disagree: 4%, Abstain: 6% (Super Majority, Strong Consensus)

Rationale:

There has been a combination of in vitro models, animal models, and clinical studies that have investigated the efficacy of irrigation pressure in wounds. The majority of the in vitro and in vivo studies have been completed in regard to traumatic wound debridement. These studies have looked at the ability of irrigation methods to remove bacteria, inorganic contaminate, tissue damage induced from irrigation, and possible differences in distribution of contaminate in the wound after irrigation. A series of clinical studies have been completed which do not demonstrate any difference in clinical efficacy between high-pressure and low-pressure irrigation.

High- and low-pressure lavage has mixed results in removing contaminants from the wound. In vitro studies have shown an increased ability of pulsatile lavage to remove inorganic debris [59,60] and bacteria [61]. Animal models have had indeterminate results. In a rabbit animal model, high-pressure irrigation and bulb syringe irrigation were equally effective at removing debris. In an animal model using bioluminescent bacteria, high-pressure lavage demonstrated an increased ability to remove bacteria [62].

Concerns have been raised that high-pressure irrigation may distribute contaminates deeper into soft tissues. Paradoxical results that high-pressure irrigations have fewer contaminants removed support these results [42,63]. These data are supported by luminescent bacteria in wound animal models in which high-pressure irrigation has improved or has an equivalent ability to initially remove bacteria, but there is a higher rebound of bacteria several hours after completion of the procedure [64]. In an in vitro model of a contaminated human tibial fracture, high-pressure pulsatile lavage followed by cultures of serial sections at increasing distance from the fracture site revealed a reproducible pattern of bacterial propagation into the intramedullary canal [65]. In addition, bone destruction was found to vary proportionally with the depth into the canal.

There have been a large number of in vitro studies demonstrating possible increased levels of microscopic and macroscopic bone and tissue destruction after high-pressure pulse lavage as compared with low-pressure irrigation. On bone specimens, high-pressure pulse lavage was associated with more fissures and defects in cancellous bone [61], bone structure, and fracture healing [61,66]. Similar results have been seen with high-pressure irrigation having increased gross damage to soft tissue as compared with low-pressure irrigation [59,63,67]. These results show that high-pressure pulsatile lavage penetrates and disrupts soft tissue to a deeper level than low-pressure lavage, causing considerable gross and microscopic tissue disruption [63].

Animal models support the findings from these in vitro models. High-pressure lavage can inhibit early new bone formation in an intraarticular fracture rabbit model. There was a direct relationship between irrigation pressures and the amount of cellular materials removed from the trabeculae at the irrigation site [68]. Animal models have shown that high-pressure pulsatile lavage of musculoskeletal wounds can cause injury to tissue, resulting in myonecrosis and dystrophic calcification [69]. High-pressure pulsatile lavage has also been shown to significantly decrease the mechanical strength of fracture callus (peak bending force and stiffness) during the early phases of healing (three weeks) as compared with bulb syringe techniques in a noncontaminated diaphyseal femoral fracture model in rats [70].

Multiple clinical studies have demonstrated that high or low irrigation pressure results in similar clinical outcomes. The largest of these was the Fluid Lavage of Open Wounds (FLOW) study [71]. This was a large, well-designed, prospective, randomized, 2-by-3 factorial design clinical study comparing three irrigation pressures and two irrigation solutions (normal saline and castile soap). A total of 2551 patients were enrolled, and the primary endpoints were reoperation in 12 months from the index procedure or treatment of a wound infection. The FLOW study demonstrated that the rates of reoperation were similar regardless of irrigation pressure (ClinicalTrials.gov NCT00788398) [71].

These findings are supported by several smaller studies. The FLOW study design was based on pilot data that suggested that low-pressure irrigation of open wounds may decrease reoperation rates for infection, although the pilot study did not observe any statistically significant differences between high- and low-pressure irrigation groups (ClinicalTrials.gov NCT01069315) [72]. In a small prospective randomized clinical study of acute periprosthetic joint infection, there were no differences seen with the use of high- vs low-pressure irrigation with outcomes defined by retention of prosthesis or elevation of ESR and CRP at one year [73].

Irrigation pressures may have difficulty removing bacteria from the wound because biofilm acts as a viscous fluid. Biofilms are viscoelastic and resist detachment from increased fluid flow and shear by deformation. This allows the biofilm to remain attached to the surface or roll along a surface in response to a shear stress from fluid [74]. Given this limitation of pulsatile irrigation as well as the concerns for bone destruction discussed previously, there has been a recent interest in exploring novel delivery mechanisms of the irrigation fluid. In a prospective randomized control study, tangential hydrosurgery was compared with standard surgical debridement of grade IIIA and IIIB open tibia fractures in 40 patients, and it was found that when hydrosurgery was used, significantly fewer debridement procedures were required before final wound closure [75]. Hydrosurgery debridement was also evaluated as a method for removing bacteria from fracture implants. Specifically, when comparing the use of hydrosurgery, pressurized pulsatile lavage, and bulb syringe to deliver the same volume of saline to debride *Staphylococcus aureus*–contaminated stainless steel fracture plates, residual bacterial loads were found to be significantly lower in the hydrosurgery group [76].

Question 4: Does the addition of topical antibiotics (polymyxin and/or bacitracin) to irrigation solution offer additional antibacterial properties?

Recommendation:

Guidelines from the WHO and National Institute for Health and Care Excellence advise against the addition of topical antibiotics to irrigation solutions. Recent CDC recommendations suggest an uncertain trade-off between the benefits and risks of intraoperative antimicrobial irrigation for the prevention of SSIs. Although data regarding the antimicrobial efficacy of irrigation solutions containing antibiotics, such as polymyxin-bacitracin, are conflicting and largely based on nonorthopedic studies, we advocate against its intraoperative usage in the face of growing antimicrobial resistance concerns, costs, and hypersensitivity implications.

Level of Evidence: Moderate

Delegate Vote: Agree: 92%, Disagree: 4%, Abstain: 4% (Super Majority, Strong Consensus).

Rationale:

Although the intraoperative use of irrigation solutions is an important strategy for mitigation of surgical site infections (SSIs) and periprosthetic joint infections in patients undergoing orthopedic procedures [35,77,78], the optimal irrigation solution remains unknown. Surgeons worldwide continue to add topical antibiotics to irrigation fluid [79], assuming that this solution has local activity that can help eliminate bacteria. However, published literature suggests that the addition of antibiotics to irrigation confers no added benefits [80–82] and may even be deleterious [82–84].

Two clinical practice guidelines issued by the World Health Organization and National Institute for Health and Care Excellence advise that antibiotic incisional wound irrigation before closure should not be used for the purposes of preventing SSIs, although these were based on generally low-quality evidence [80,85–87]. Furthermore, using available data from five randomized controlled trials [88–92], the Centers for Disease Control concluded that antibiotic irrigation of the incisional wound conferred neither benefits nor harms in reducing SSIs when compared with no irrigation or saline irrigation [87]. In addition, the World Health Organization guideline development group highlighted the risks of emergence of antimicrobial resistance with the use of antibiotics for wound irrigation.

Moreover, in vitro studies have raised concerns about the bactericidal efficacy of adding antimicrobials to irrigation fluids [43,93]. Anglen et al found that the addition of antibiotic drugs, including bacitracin and polymyxin/neomyxin, to irrigation solutions had no significant effects on bacterial removal. None of the antibiotic solutions tested were statistically different from saline alone in the amount of bacteria removed from a *Staphylococcus*-coated stainless steel screw model [43]. In a series of breakpoint experiments, Goswami et al showed that polymyxin-bacitracin solution was significantly less efficacious ($P < .001$) in eradicating *Staphylococcus aureus* vs other tested irrigation solutions, including 0.3% povidone-iodine, 0.05% chlorhexidine, and 0.125% sodium hypochlorite [93]. Similarly, using a rat model of a contaminated paravertebral wound containing a wire implant, Conroy et al found no significant benefit with respect to the rates of positive wound cultures after bacitracin antibiotic irrigation over normal saline [94].

In addition to the questionable efficacy and perpetuating antimicrobial resistance, concerns have been raised about the harmful effects of bacitracin-containing irrigation solutions on wound healing, as have been reported in a prospective randomized clinical trial [82]. The study recruited 400 patients with a lower extremity open fracture who received irrigation with either a bacitracin antibiotic solution or a nonsterile castile soap solution. No differences in infection rates were seen between the two study arms ($P = .2$), but wound healing problems were found to be significantly higher in the bacitracin group (9.5% vs 4%; $P = .03$).

An increased risk of hypersensitivity and the potential for anaphylactic reactions have also been cited [82–84]. Bacitracin is a polypeptide antibiotic effective against a variety of gram-positive bacteria, and its pharmacological activity is exerted by the inhibition of prokaryotic cell wall synthesis. Polymyxins are a group of cyclic nonribosomal polypeptide antibiotics that have gram-negative activity. Studies have reported that these antibiotics may produce serious systemic effects. Damm reported three cases with a severe anaphylactic reaction after prophylactic bacitracin irrigation in the setting of pacemaker insertion [95]. Similarly, Antevil et al attributed the use of bacitracin irrigation to anaphylactic shock during a case of revision TKA [83]. Furthermore, in a multi-institutional study by the North American Contact Dermatitis Group (NACDG) involving patients with suspected allergic contact dermatitis, bacitracin was noted as the sixth most common allergen with 9.2% positive on patch testing [96].

Efficacy data from largely historical studies suggest some use for polymyxin-bacitracin irrigation. Savitz et al investigated the addition of polymyxin-bacitracin to saline lavage in 50 spinal procedures [97]. They reported that the incidence of bacterial growth reduced from 64% to 4% with the addition of antibiotics to irrigation, and no wound infections were reported in postoperative phase. Similarly, in 1972, Scherr et al showed a significant in vitro decrease in local bacterial concentrations after topical administration of bacitracin and other antimicrobials [98]. Rosenstein et al also showed that irrigation with 50 mL of bacitracin solution into the intramedullary canal of canine femora inoculated with *Staphylococci* decreased the number of positive cultures one week later [99]. A single surgeon series also reported beneficial results when vancomycin and polymyxin were added to irrigation solution in 2293 total joint arthroplasties [44]. Despite these reports, data within the orthopedic literature remain unconvincing because of poor study design or limitations with defining appropriate endpoints for efficacy in musculoskeletal wounds [84].

More recent data from five non-orthopedic RCTs comparing irrigation of the incisional wound with an antibiotic solution to irrigation with normal saline or no irrigation showed limited efficacy [88–92]. A meta-analysis of these trials demonstrated no significant differences between antibiotic irrigation and no irrigation or irrigation with only saline solution (odds ratio, 1.16; 95% confidence interval, 0.64-2.12; $P = .63$). The overall quality of evidence in this meta-analysis was cited as low, however, due to the risk of bias and imprecision [81].

Although the cost-effectiveness of polymyxin-bacitracin has not been formally evaluated, one operative orthopedic procedure typically uses 150,000 units of bacitracin (50,000 units per liter of saline), which adds a cost of $150.00 according to estimates by Anglen [84].

In conclusion, two clinical practice guidelines based on a review of the evidence recommend against antimicrobial wound irrigation to reduce the risk of SSIs [80,85,86]. The efficacy of irrigation solutions with supplemental topical antibiotics in orthopedic procedures remains controversial because of the paucity of available evidence. Future well-designed randomized controlled trials using current standard of care protocols for SSI prevention are needed to evaluate commonly used irrigation practices with a special emphasis on the agents used and a focus on orthopedic procedures [44,100]. Trials should also address cost-effectiveness and adverse events associated with the agents used for irrigation. In the interim, given the lack of proven efficacy and the potential for harm, we advise against the addition of topical antibiotics to irrigation solution.

Question 5: Is there a role for nonantibiotic natural antiseptic agents (e.g., honey, vinegar) as an irrigation solution during surgical debridement for periprosthetic joint infections (PJIs)?

Recommendation:

There may be a role for nonantibiotic antiseptic agents (e.g., honey, vinegar, and so forth) as an irrigation solution during surgical debridement.

Level of Evidence: Limited

Delegate Vote: Agree: 39%, Disagree: 43%, Abstain: 18% (No Consensus)

Rationale:

As multiantibiotic-resistant organisms become more prevalent, the need for nonantibiotic antimicrobial therapy becomes important again (as it was in the preantibiotic era). Several options are readily available for use as a local chemical debriding agent for local irrigation of periprosthetic joint infections (PJI) wounds, after surgical and mechanical debridement has been completed [101]. Among these options are vinegar (acetic acid), honey, hydrogen peroxide, and local anesthetic. Other options include iodine and chlorhexidine. There are no randomized control trials of deep wound irrigation using any of these substances in PJIs. The evidence is limited and often inferred from chronic wound management [102,103].

Vinegar

Vinegar has been in use for millennia as an antibacterial agent [104]. The only case series reporting its use as a deep, wound irrigant in orthopedics was by Williams et al in 2015 [17]. This study showed that the use of 3% acetic acid soak, as part of a debridement protocol, was safe in patients. Although the exact mechanism of action is yet to be determined, acetic acid concentrations as low as 0.19% vol/vol in vitro are sufficient to completely inhibit bacterial growth. It is postulated that pH change is a potential mechanism of action.

Honey

Honey has a long history of use in topical wound management [105]. There is only a small, case series showing honey as a topical agent for deep PJI wounds at the time of reimplantation [106]. In this series, sterile, industrially manufactured SurgiHoney (SurgiHoney RO, Southmoor, Abingdon, United Kingdom) was used in salvage cases. No adverse effects were reported, but no conclusions regarding efficacy can be drawn.

Hydrogen Peroxide

Dental publications are a resource that orthopedic surgeons should review for parallel implant experience. One such paper is by Gustumhaugen et al [107] who found that hydrogen peroxide (H_2O_2) was an effective biofilm-debriding agent, especially in combination with mechanical debridement.

Local Anesthetic

Indirect evidence comes from an experimental study of peritonitis in a rat model. Lavage with normal saline and bupivacaine prolonged survival [108]. Studies on ropivacaine have also proved encouraging [109].

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