SURGICAL INFECTIONS
Volume 19, Number 00, 2018

DOI: 10.1089/sur.2018.156

Review Article

Antiseptic Irrigation as an Effective Interventional Strategy for Reducing the Risk of Surgical Site Infections

Charles E. Edmiston, Jr,[1] Maureen Spencer,[2] and David Leaper[3]

Abstract

A surgical site infection (SSI) can occur at several anatomic sites related to a surgical procedure: Superficial or deep incisional or organ/space. The SSIs are the leading cause of health-care–associated infection (HAI) in industrialized Western nations. Patients in whom an SSI develops require longer hospitalization, incur significantly greater treatment costs and reduction in quality of life, and after selective surgical procedures experience higher mortality rates. Effective infection prevention and control requires the concept of the SSI care bundle, which is composed of a defined number of evidence-based interventional strategies, because of the many risk factors that can contribute to the development of an SSI. Intra-operative irrigation has been a mainstay of surgical practice for well over 100 years, but lacks standardization and compelling evidence-based data to validate its efficacy. In an era of antibiotic stewardship, with a widespread prevalence of bacterial resistance to multiple antibiotic agents, there has emerged an interest in using intra-operative antiseptic irrigation to reduce microbial contamination in the surgical site before closure and possibly reduce the need for antibiotic agents. This approach has gained added appeal in an era of biomedical device implantation, especially with the recognition that most, if not all, device-related infections are associated with biofilm formation. This review focuses on the limited, evidence-based rationale for the use of antiseptic agents as an effective risk reduction strategy for prevention of SSIs.

Keywords: antibiotic irrigation; antibiotic stewardship; antiseptic; chlorhexidine gluconate; intra-operative wound irrigation; povidone iodine; surgical site infection

HISTORICALLY, THE PRIMARY ROLE of intra-operative wound irrigation was to remove tissue debris, metabolic waste, and tissue exudate from the surgical field before site closure. It has been proposed that intra-operative wound irrigation (IOWI) represents an economical approach to reducing the risk of SSI [1]. Unfortunately, the technique of operative site is highly variable in relation to the volume of fluid used to irrigate the surgical site and to the type of supplements, such as antimicrobial agents, added to traditional saline lavage. Intra-operative irrigation commonly is practiced by all surgical practitioners because it is reasonable to reduce possible microbial contamination, clearing the site of blood and removing necrotic tissue or purulent material, before closure. While a recent systematic review and meta-analysis suggests that IOWI has a significant beneficial effect in reducing the risk of post-operative SSI in selected surgical disciplines, the process clearly lacks standardization [2,3].

While intra-operative irrigation is common surgical practice, the 2016 recommendations from both the World Health Organization (WHO), WHO Global Guidelines for the Prevention of Surgical Site Infections, and the American College of Surgeon/Surgical Infection Society Surgical Site Infection Guidelines offer little insight or recommendations on the practice [4,5]. The 2017 Centers for Disease Control and Prevention Guidelines for the Prevention of Surgical Site Infection, however, and the online publication of the Wisconsin Division of Public Health Supplemental Guidance for the Prevention of Surgical Site Infection published online in January 2017 both recommend the use of an antiseptic agent as an additive to intra-operative lavage (irrigation) [6,7].

Traditionally, warmed physiologic saline has been accepted universally as the irrigation fluid of choice, because it was widely available and safe for all surgical site surfaces including the peritoneal and pleural cavities (serosal mesothelium).

[1]Department of Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin.
[2]Accelerate Diagnostics, Inc., Tucson, Arizona.
[3]Institute of Skin Integrity and Infection Prevention University of Huddersfield, Huddersfield, United Kingdom.

Copious quantities (up to 10 L) were often used for peritoneal lavage [3,8,9]. Over the ensuing years, multiple combinations of antimicrobial agents including antibiotic agents, surfactants, and antiseptics have been have used to further minimize the risk of bioburden before closure. In 2018, however, there is no established clinical standard for the practice of intra-operative irrigation, which is surprising given the current focus on evidence-based practice guidelines.

Intra-Operative Antibiotic Irrigation in the Era of Antibiotic Stewardship

It was not long after the discovery of penicillin that surgical practitioners proposed the addition of an antibiotic agent to intra-operative peritoneal lavage (IOPL) [10]. Antibiotic agents were viewed as ''wonder drugs'' or ''silver bullets'' and a panacea for all serious infectious processes, and little consideration was given to the concept of antibiotic resistance or whether or not the concentration within the irrigation fluid was sufficient to eradicate the bacterial pathogen. The practice of adding an antibiotic agent to an irrigation fluid is still widespread and persists in many surgical disciplines. A recent survey suggests that >50% of general surgeons, including colorectal surgeons, and orthopedic surgeons still request antibiotic irrigation fluid for their cases, followed by neurosurgical and spinal (30%–39%), and cardiothoracic surgeons (26%), with the lowest by obstetrics-gynecology and plastic surgeons (22%–23%) [11].

The fundamental flaw in the justification of that usage is a failure to appreciate the mechanistic nature of how antibiotic agents actually work; antimicrobial activity necessitates sufficient contact time to allow the antibiotic agent to bind to its target site within the cell membrane (i.e., beta-lactams, glycopeptides) or internal cytoplasmic structures (i.e., aminoglycosides, quinolones). Further, effective antimicrobial activity is dependent on a persistent drug concentration that is above the MIC^{90}, the concentration of the antibiotic agent that is required to kill 90% of the targeted microbial population. Neither of these requirements is met during the process of antibiotic irrigation, because the irrigating fluid is evacuated rapidly from the cavity. The pharmacokinetics/pharmacodynamics of the irrigation process is essentially unknown.

The mechanistic failure of antibiotic irrigation was addressed in a laboratory study published in 1990. A series of Sprague-Dawley rats underwent cecal ligation and puncture (CLP) to stimulate fecal peritonitis. The investigators found that gram-negative Enterobacteriaceae rapidly colonized the serosal mesothelium and were the predominant flora harvested at four hours post-CLP. After eight hours, anaerobic bacteria, specifically *Bacteroides fragilis*, represented the predominant microbial population adherent to the serosal mesothelium (5.6 $\log_{10}$ cfu/mg tissue). At 24 hours, the aerobic and anaerobic microbial populations adherent to the serosal mesothelial surfaces were 7.1 and 9.1 $\log_{10}$ cfu/mg tissue, respectively. Extended serial peritoneal saline lavage (100-ml$\times$10) was effective in significantly reducing microbial counts in the peritoneal fluid. Saline lavage, however, had no impact on dislodging the adherent aerobic/anaerobic microbial populations from the surface of the serosal mesothelium.

In a parallel series of studies, the addition of cefazolin, kanamycin, or metronidazole alone or in combination failed to significantly reduce (or dislodge) the microbial populations adherent to the mesothelial surface at 48 hours post-CLP compared with saline controls. This series of experiments found that after injury to the bowel, there is a rapid, stable colonization of the peritoneal mesothelium that is resistant to multiple lavage, with or without antibiotic agents [9]. Cultures from serial saline or antibiotic irrigation fluids did document a reduced microbial burden, but those results are misleading because they represented a reduction in the number of non-adherent microbial populations within the peritoneal fluid, justifying the old adage, *''The solution to pollution is dilution.''* Further, the study revealed that limited exposure (contact time) of an adherent microbial population to a normal saline-antibiotic concentration exceeding the MIC^{90} was of itself insufficient to reduce the microbial burden on the surface of the serosal mesothelium.

Several clinical studies, reported in general and orthopedic research communications, have documented the futility of adding antibiotic agents as an adjunctive strategy for reducing the risk of post-operative infection [12–15]. There is also compelling evidence that suggests that not only does antibiotic irrigation lack efficacy but may pose a potential threat. Reported cases of severe anaphylaxis after the use of irrigation fluids containing bacitracin have been reported after cardiac, neurosurgical, general, and orthopedic surgical procedures [16]. Additional reports have suggested that neomycin or vancomycin, used as an additive to irrigation fluid, has been associated with tissue irritation or systemic toxicity [17].

In the current era of antibiotic stewardship, which is tasked with promoting the appropriate use of antibiotic agents, the use of antibiotic agents for intra-operative irrigation along with the topical application of antibiotic into the surgical site would be viewed as inappropriate. The reason is that most clinical studies purporting benefit are of poor quality, and there exists a probably of risk of exerting selective pressure among gram-positive and gram-negative microbial populations, potentiating the emergence of antimicrobial resistance [11,18–22]. Finally, a recent systematic review and meta-analysis found that the addition of antibiotic agents to irrigation fluid provided no benefit in reducing the risk of incisional site infection in the abdomen or mediastinum [23].

Intra-Operative Irrigation in the Presence of an Implantable Biomedical Device

Device-related infections are preceded by biofilm formation, and the presence of an acute biofilm on the surface of an implantable device makes organisms (gram-positive or negative) recalcitrant to traditional antibiotic irrigation or therapy [24]. An effective intra-operative irrigation strategy would then entail selection of an agent that can be delivered to the tissues in a safe and effective concentration and that is rapidly cidal in the presence of a biofilm mediated device-associated infection. As reported in an earlier publication, the concept of using an antiseptic agent for intra-operative site irrigation is not new and harkens back to the Listerian concept of antiseptic surgical practice.

Both in vitro and animal studies suggest that adding an antiseptic agent, often with surfactant properties, to intra-operative irrigation fluid may assist in preventing the adherence of biofilm-forming bacteria to the surface of the biomedical device. Two recent in vitro studies have investigated the benefits of using an antiseptic agent as an additive to

physiologic saline irrigation. A laboratory biofilm-forming strain of *Staphylococcus epidermidis* was allowed to propagate in 96-well plastic dishes, followed by exposure to chlorhexidine gluconate (CHG) (0.025%, 0.05%, and 0.1%), povidone iodine (PI) (0.35%, 1.0%, 3.5%, and 10%), sodium hypochlorite (0.125%, 0.25%, and 0.5%), and a triple antibiotic solution (bacitracin 50,000 U/L, gentamicin 80 mg/L, and polymyxin 500,000 U/L) for one, five and 10 minutes.

The CHG 0.05% and 0.1% at all three exposure times, 10% PI at all three exposure times, and 3.5% PI at 10 minutes were effective at eradicating the staphylococcal biofilm, whereas all concentrations and exposure time for sodium hypochlorite and triple antibiotic solution were not effective at resolving the staphylococcal biofilm. The study suggests that a concentration of 0.05% CHG was effective at killing biofilm-based *S. epidermidis* with a short exposure time (one minute or less). Alternatively, PI was capable of killing a sessile biofilm-forming strain of *Staphylococcus* but required a 30-fold increase in concentration at a clinically relevant exposure period (10% PI for 1 min) or a 10-fold increased concentration at triple the exposure time (3.5% PI for 10 min). Unfortunately, a 10-minute irrigation interval is not clinically realistic because most intra-operative irrigations last less than 1–2 minutes. Further, a 10% solution of PI is recommended for external use only [25].

Aqueous CHG is a cationic-chlorinated biguanide with broad spectrum activity and has been documented to disrupt the bacterial cell membrane within 20–30 seconds. In vitro, time-kill kinetics document a greater than six-log reduction in 60 seconds for most health-care–associated pathogens, including multiple drug resistant (MDRO) gram-positive/negative pathogens [8]. In a separate analysis, a concentration of 0.05% CHG was effective (<five-log reduction) in preventing a biofilm-forming strain *of S. aureus* (MRSA) from colonizing the surface of four distinct synthetic surgical mesh segments compared with a saline control ($p < 0.01$). In a follow-up animal study, intra-operative irrigation with 0.05% was effective in resolving polypropylene mesh infections. Surgical mesh was used to repair a 1×2 cm abdominal defect in Sprague-Dawley rats, followed by inoculation with 3.0-$\log_{10}$ cfu/mL of MRSA recovered from a clinical incisional hernia infection. After 15 minutes, the mesh segments were irrigated for 60 seconds with either physiologic saline or aqueous 0.05% CHG, followed by closure with polypropylene. At 7 days the animals were sacrificed.

All physiologic saline-irrigated mesh segments ($N = 8$) were infected with a microbial biofilm (mean, 6.3-$\log_{10}$ cfu/cm^2 mesh segment), while one of eight mesh segments that had been irrigated with 0.05% CHG demonstrated a staphylococcal biofilm (2.3-$\log_{10}$ cfu/cm^2 mesh segment), resulting in an 82.5% reduction in the risk of a MRSA biofilm-mediated mesh infection compared with physiologic saline controls ($p < 0.001$) [8].

Clinical Efficacy of Intra-Operative Irrigation with Antiseptic Additives

Various concentrations of PI have been shown to be effective in vitro against resistant *S. aureus* (MRSA), and a systematic review of PI found a reduction of the incidence of SSI in various surgical applications [23,26]. As part of an evidence-based surgical care bundle, PI was shown to be an effective inclusive strategy to reduce the risk of infection after spinal instrumentation operation [27]. In a separate study, intra-operative irrigation with PI plus the administration of vancomycin powder before site closure was deemed to be an effective strategy for preventing SSI after spine operation. The level of evidence for this study was poor, however [28].

While PI irrigation has gained clinical favor, especially within orthopedic surgical procedures, a recognized side effect of PI irrigation is chrondrotoxicity on articular cartilage. The extent of superficial chondrocyte death appears to be significantly greater at higher concentrations of PI solutions. While 0.35% PI solution was the least chondrotoxic of all concentrations, it has been observed to reduce cell viability significantly if applied for longer than one minute [29]. In addition to chondrocyte toxicity, the antimicrobial activity of PI is diminished in the presence of blood or tissue protein, which may marginalize its antimicrobial activity as an intra-operative lavage additive [17,20,29].

Chlorhexidine gluconate has been used as both a pre-operative and intra-operative surgical site irrigation fluid, documenting a faster onset of cidal activity compared with PI [30,31]. In a recent study of the use of 0.05% CHG intra-operative irrigation in hip and knee arthroplasty, 411 total knee arthroplasty (TKA) and 253 total hip arthroplasty (THA) patients served as a historic control while 248 TKA and 138 THA patients were enrolled in a CHG irrigation group. A single surgeon performed all of the operations.

The control THA patients underwent an intra-operative irrigation with 0.9% saline followed by a two-minute wash with dilute PI. The TKA control patients underwent intra-operative irrigation with 0.9% saline as the only interventional treatment. In the CHG group, the intra-operative irrigation protocol involved a primary lavage with 0.9% saline followed by a one-minute soak with 0.05% CHG. There was no statistically significant difference observed between the two interventional groups. A post-hoc analysis, however, suggested that the study was significantly underpowered [31].

It is obvious from laboratory and animal studies that 0.05% CHG offers some unique advantages over PI, especially in terms of its ability to penetrate and disrupt microbial biofilms on the surface of biomedical devices. In light of the low rate of infection in total joint replacement operations ($\sim 2.0\%$), however, future efforts to validate the efficacy of 0.05% CHG will require a robust multi-center, randomized clinical trial.

Does Intra-Operative Antiseptic Irrigation Pose a Risk for Development of Resistance?

Bacterial cells can express intrinsic or acquired resistance to selective antimicrobial agents; currently, the primary concern among the advocates of antibiotic stewardship is the probable risk that selective antiseptic agents may increase the risk of antibiotic resistance, which is then transferable to other microbial populations [32–35]. While there is some similarity to the mechanisms of resistance between antibiotic and antiseptic agents, antibiotic agents usually have a singular mechanism of action, whereas antiseptic agents such as triclosan and chlorhexidine have primary and secondary mechanisms that involve the outer bacterial membrane and other membrane-like structures associated with organelles within the cytoplasm. Antiseptic (biocidal) activity is rapid, occurring within 30–60 seconds of contact with the bacterial

cell. Antibiotic agents require a longer contact time with the bacterial cell, which under optimal conditions results in an inhibitory or cidal activity several hours after continuous antibiotic exposure.

Intra-Operative Irrigation: Volume and Delivering Strategies

The optimal volume of fluid used for abdominal irrigation that will prevent incisional SSIs (both deep and superficial), dehiscence, and fistula formation and improve 30-day death in trauma patients is unknown. A three-arm parallel clinical superiority randomized controlled trial, comparing different volumes of effluent (5, 10, and 20 L), has been conducted in trauma patients (both blunt and penetrating). A total of 204 patients were randomized to one of three groups; 5 L (Group 1), 10 L (Group 2), or 20 L (Group 3). Patients were comparable with respect to age, gender distribution, admission Injury Severity Score, and mechanism of injury, estimated blood loss, and degree of contamination. The mortality rate overall was 1.96% (4/204). No differences were noted with respect to contamination, wound infection, fistula formation, or dehiscence.

The 20 L group (Group 3) documented a trend toward increased incidence of deep incisional SSI, compared with the 5 L (Group 1) ($p = 0.051$) and 10 L (Group 2) ($p = 0.057$) groups. This did not reach statistical significance, however. The result of this study clearly suggests that using more irrigation fluid in the presence of excessive surgical site contamination does not reduce post-operative complications or affect death; and it may actually predispose patients to increased incidence of abscess formation [36].

In orthopedic operations, bone and polymethyl methacrylate (PMMA) debris and particles generated during TKA may cause third-body wear (abrasive wear when hard particles such as bone or PMMA fragments embed in soft surfaces, such as polyethylene). The volume of saline lavage used during these procedures is highly variable and not standardized. In an investigation to assess the optimal volume of intra-operative saline lavage to remove PMMA fragments, subjects underwent cemented TKA and pulse lavage with 8 L of sterile saline using a pulsatile irrigator. Aspirated fluid was collected in a 1 L aliquot, and the number and size of bone and PMMA particles quantified.

Image analysis revealed that the number of particles peaked at first lavage and gradually decreased over the eight consecutive lavages. Significant differences were found between the first compared with second, second compared with third, and third compared with fourth lavage. No significant differences were found beyond the fourth lavage, however. This study found that that a total volume of 4 L was effective at removing residual PMMA particles during TKA arthroplasty [37].

Pulsed irrigation has been used for more than 50 years, especially in orthopedic and trauma procedures. In selective surgical procedures such as spine operations, however, there has been no study validating the efficacy of pulsed irrigation compared with bulb syringe irrigation. In a recent study, consecutive patients undergoing posterior lumbar inter-body fusion were investigated. Those who underwent procedures during the first three months were irrigated by bulb syringe (Group 1) and those who underwent procedures during the next three months were irrigated using a pulsatile irrigator with 17 psi (Group 2). Gender, age, surgical time, amount of blood loss, whether associated with diabetes mellitus, smoking, and amount of irrigation solution were comparable between the two groups. Physiologic saline was used as the lavage fluid.

Intra-operative irrigations were performed three times, and after final irrigation, culture specimens were obtained from muscle layers and inter-vertebral spaces and the microbial recovery compared between the two groups. There were 79 cases in Group 1 and 59 cases in Group 2. Operative time was longer ($p = 0.011$), and the amount of irrigation saline was larger ($p = 0.042$) in Group 2. Bacteria were recovered from the posterior muscle layer in 8/79 cases (10.1%) in Group 1 and 1/59 cases (1.6%) in Group 2. This was statistically significant ($p = 0.046$). Cultures obtained from the inter-vertebral space were positive in 6/79 cases (7.6%) in Group 1 and 5/59 cases (8.5%) in Group 2. There was no difference between the two groups ($p = 0.546$). *S. epidermidis*, *S. aureus, S. hominis*, and *S. saprophyticus* were obtained in decreasing order of frequency. The investigators found that pulsed irrigation was more effective compared with bulb syringe irrigation in the posterior muscle layer. In the inter-vertebral space, however, both methods were found to be insufficient to eradicate microbial contamination [38].

Peri-prosthetic joint infections (PJI) are representative of a biofilm-mediated infection. In acute PJI, irrigation and debridement with component retention has a high failure rate in some studies. A recent investigation found that pulse lavage irrigation is ineffective at removing biofilm from TKA components. The *S. aureus* biofilm mass and location were visualized on arthroplasty materials using a photon collection camera and laser scanning confocal microscopy. While continuous pulse lavage with saline resulted in substantial reduction in biofilm signal intensity, the reduction was less than a 10-fold decrease. These results suggest that saline pulse-irrigation was not effective in removing the biofilm mass below a necessary bioburden level to prevent recurrence of acute infection in TKA [39]. This study clearly documents the need to look beyond the use of traditional saline irrigation and investigate the role of antiseptic pulse lavage with CHG as an effective strategy for eliminating biofilm formation on implantable biomedical devices.

A recent review has explored the experimental and clinical evidence associated with the use of pressure irrigation, and while experimental evidence demonstrates a benefit for this technology to eliminate bacteria and foreign debris in soft tissue surgical sites, there is no standard of practice associated with this technology. Further, clinical trials that document a benefit are usually underpowered and often retrospective [40].

The theoretical benefit behind power or pulse-lavage is based on the forcible removal of bacteria and debris using a ''jet'' of fluid—in most cases, saline. After traumatic injury to the skin, the inflammatory phase is responsible for the extravasation of fibrinogen, which is rapidly converted to fibrin. The fibrin creates a weblike structure within the wound; on one hand, it offers a protective coating to the surface of the wound but it can also entrap bacteria within the weblike matrix. The bacterial contamination of the wound most likely originates at the time of traumatic injury or contamination may occur at the time of operation. The use of conventional gravity irrigation that is delivered under low pressure is unlikely to alter the fibrin web or sufficiently

remove bacteria entrapped within the mesh. Pulse irrigation, however, is thought to produce shear forces sufficient to dislodge contaminating organisms from within the fibrin sheath by overcoming the adhesive force between the bacteria and host tissues.

While the theoretical principle behind the perceive benefit of power irrigation is sound, the question of whether this irrigation process effectively removes bacteria from the wound or drives the organisms deeper into the tissues continues to be debated. Failure to adequately remove acute biofilm adds to the risk of infection, promoting delayed healing, which may be associated with a delay in the inflammation component of healing, or promotes inappropriate excessive inflammatory responses through delay or disorganization of the wound healing cascades. Persisting biofilm enhances nitric oxide production, free radial oxygen species, matrix metalloproteinases, and excessive white cell activation [41].

This question was addressed partially in an experimental study involving a porcine surgical site model that was contaminated with *Serratia marcescens*. The investigators irrigated the site by either a piston syringe using eight psi or pulse lavage using 70 psi. The lavage fluid penetrated deeper into the tissues under the higher pressure; the rate of infection was equivalent in both experimental models but higher in a ''no-lavage'' control group. It was the authors' opinion that bacteria were not displaced (driven deeper) into the tissues by the increased pressure irrigation but did suggest that the process may damage host tissues, thereby exacerbating the infectious process [42].

In a separate analysis using ex vivo ovine muscle, investigators found that lower lavage pressure (three psi) was more effective at removing bacteria than high pulse lavage rates (6–19 psi). The higher psi rates were associated with displacement (sequestering) of bacteria into the deeper tissues [43]. The debate is likely to continue with advocates on both sides, championing the use or either low or high psi for site cleansing or debridement before closure at the end of a surgical procedure.

What is actually lacking in this discussion is the question, ''What is the optimal lavage solution?'' The historic control has been physiologic saline, but it offers no residual activity; an antibiotic lavage solution for pressure irrigation is fraught with the same criticism that was discussed in an earlier section (increased risk of resistant organisms); contact time is too limited to have any residual activity. Use of an antiseptic agent that has a high tissue binding potential, however, such as afforded by CHG, would provide a measure of residual activity sufficient for a wide range of gram-positive or gram-negative surgical site pathogens. Povidone iodine is less likely to afford any sufficient residual activity because of its potential to be inactivated by blood or tissue protein [20,30].

Melding Intra-Operative Lavage while Protecting the Surgical Site

Preventing contamination of the surgical site or reducing the bacterial burden within the site at the time of closure through the use of barrier protectors in addition to intra-operative lavage may have promise and is an ongoing strategic focus to reduce the risk of post-operative infection [15,44,45], Two recent studies, however—a meta-analysis and well conducted trial— found that surgical site protector devices provide little risk reduction and economic benefit after laparotomy [46,47].

Another possible approach could be to integrate site protection with continuous intra-operative lavage. A prospective multi-center pilot study was conducted in 86 eligible patients undergoing elective colorectal resections that utilized a novel incision retractor-protector sleeve that combines continuous irrigation and barrier protection [48]. Bacterial culture swabs were collected from the incision edge before device placement and from the exposed and protected incision edge before device removal. The primary and secondary end-points were the rate of enteric and overall bacterial contamination on the exposed incision edge compared with the protected incision edge, respectively.

At the time of operation, the device was placed by inserting the bottom ring into the abdomen and expanding the upper retraction ring. The device was connected to the operating room's standard suction mechanism and a bag of sterile irrigation solution. Before placing the device within the surgical site, incisional wall cultures were obtained. The continuous irrigation fluid rate was 5–16 mL/min. Incisional site cultures were obtained after the operation was completed. The innovative wound retractor-protector device was associated with a 66% reduction in overall bacterial contamination at the protected incision edge compared with the exposed incision edge (11.9% vs. 34.5%, $p < 0.001$), and 71% reduction in enteric bacterial contamination (9.5% vs. 33.3%, $p < 0.001$). The investigators found no adverse events attributed to device use.

The results of the study suggest that a novel wound retractor-protector that combines continuous irrigation and barrier protection was associated with a significant reduction in bacterial contamination in patients undergoing colorectal surgery. The primary end-points of this pilot study were a reduction in site contamination and device safety and not the reduction in SSI. While the choice of irrigation fluids was left to individual surgeons, 97% of the patients received an aminoglycoside combined with metronidazole, clindamycin, or bacitracin, again reflecting the continued bias toward using an antibiotic agent for intra-operative irrigation. In the development of future randomized, controlled trials using this technology, the study protocol should include an antiseptic agent, the most effective antiseptic agent being 0.05% aqueous CHG.

Moving Forward

For the past 100 years, the practice of surgical site irrigation has taken a pragmatic, if not dogmatic pathway. Most studies supporting the benefit of selective irrigation fluids for intra-operative lavage have been hindered by haphazard design, institutional bias, and have been poorly powered. The development of ''antibiotic cocktails'' for intra-operative lavage represents a fundamental lack of knowledge of the pharmacokinetic and pharmacodynamic nature of antibiotic agents. They ignore that exposure of contaminating flora within the surgical site to sub-therapeutic concentrations fosters the emergence of resistance. The benefits of using an antiseptic agent such as CHG rather than saline or an antibiotic agent are obvious: Rapid bactericidal activity (multiple mechanisms of action), residual activity, sustained activity in the presence of blood or tissue protein, tissue safety, and a

low risk for the emergence of resistance. In addition, ''the potential for surgical irrigation with an antiseptic agent to play a key role involves not only reducing the risk of SSI but also mitigating the risk of bacterial resistance, avoiding the need for more aggressive post-SSI interventions (implant removal), and containment of overall healthcare costs (fewer procedures, shortened hospital stays) is undeniable'' [3].

There is currently a void of evidence-based science and standardization for the practice of intra-operative irrigation across the spectrum of surgical services. The current peer published evidence and SSI prevention protocols are insufficient to guide surgical practitioners toward the optimal standard of practice. While more and more well-designed clinical studies are published embracing the concept of an evidence-based (and standardized) surgical care bundle, the science of intra-operative irrigation (lavage) remains ''the odd man out,'' trapped within the hallowed halls of tradition and dogma, lacking a clear evidence-based pathway.

Author Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Dr. Charles E. Edmiston, Jr
Department of Surgery
Medical College of Wisconsin
8701 Watertown Plank Road
Milwaukee, WI 53226

E-mail: edmiston@mcw.edu