Evidence-Based Wound Irrigation: Separating Fact from Fiction

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PATIENT SAFETY

Summary: The relationship between wound irrigation and healing has been recognized for centuries. However, there is little evidence and no official recommendations from any health care organization regarding best wound irrigation practices. This is the first review of wound irrigation that systematically summarizes the literature using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and distills the evidence into a practical format. In this comprehensive review, the authors outline the irrigation fluids and delivery methods used in the identified studies, analyze reported treatment outcomes, summarize irrigation effectiveness, and propose evidence-based guidelines to improve wound healing outcomes and enhance the consistency of wound irrigation. Thirty-one high-quality studies with a combined total of 61,808 patients were included. Based on the current evidence provided by this review, the authors propose the following guidelines: (1) acute soft-tissue wounds should receive continuous gravity flow irrigation with polyhexanide; (2) complex wounds should receive continuous negative-pressure wound therapy with instillation with polyhexanide; (3) infected wounds should receive continuous negative-pressure wound therapy with instillation with silver nitrate, polyhexanide, acetic acid, or povidone-iodine; (4) breast implant wounds should receive gravity lavage with povidone-iodine or antibiotics; and (5) surgical-site infection rates can be reduced with intraoperative povidone-iodine irrigation. (*Plast. Reconstr. Surg.* 148: 601e, 2021.)

The use of salt solutions for wound care dates back to the Edwin Smith Papyrus of 1650 BC.[1,2] For nearly a century, wound irrigation and débridement have been the most important means of preventing infection and promoting healing.[3] Although the utility of débridement is well established, there is little evidence and no official recommendations from any health care organization regarding wound irrigation.

Wound irrigation involves the use of a fluid to lift and remove loosely attached debris. This standard practice has been shown to reduce bacterial load and the overall infection rate.[3,4] Furthermore, by reducing the biological burden and delaying the development of a biofilm, débridement and irrigation have been shown to improve the wound environment and accelerate healing.[5–7]

This review will investigate the evidence to support intraoperative irrigation fluids and techniques to improve treatment outcomes and reduce complication rates. The four specific objectives of this review are to (1) conduct a comprehensive search of the published literature on wound irrigation, (2) outline the types of irrigation fluids and delivery methods used in the identified studies, (3) analyze outcomes, and (4) propose evidence-based guidelines.

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PATIENTS AND METHODS

For a high standard of reporting, procedures indicated by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed.

Literature Search

The PubMed and Embase databases were searched for all publications from January of 2000 through March of 2020 containing the following terms: "plastic surgery" AND "irrigation" OR "washing" OR "cleansing" OR "cleaning" OR "rinsing." (**See Appendix, Supplemental Digital Content 1**, which shows the search strategy and Medical Subject Headings terms, ***http://links.lww.com/PRS/E605***.)

Selection Criteria

English-language publications that met the following criteria were included: randomized controlled trials, meta-analyses, systematic reviews, prospective studies, and retrospective studies with at least 20 subjects. We excluded nonhuman studies, case reports, case series, and studies lacking a control group. This search was supplemented by a reference list review for potentially eligible studies. Two reviewers independently screened and extracted data in two steps: (1) titles and abstracts and (2) full-text articles.

Outcomes

Our primary outcome of interest was efficacy of irrigation solution and delivery method on time to definitive wound closure. Our secondary outcome of interest was the incidence of wound complications.

Data Extraction

A standardized data abstraction form recorded the following information regarding each relevant study: (1) article author, (2) study design, (3) level of evidence, (4) number of patients, (5) irrigation evaluated, (6) irrigation technique evaluated, and (7) study outcomes.

RESULTS

Study Selection

The identification, screening, eligibility, and inclusion processes are demonstrated in Figure 1. We initially identified 419 publications. After duplicates were removed, 381 articles were screened for exclusion criteria in the title and abstract. Two hundred fifty-five articles were irrelevant. Full-text review and application of our inclusion criteria to the remaining 126 publications produced 31 relevant articles with a total of 61,808 patients undergoing wound irrigation.

Description of Included Studies

Among the 31 included studies, there are three studies with a total of 1981 patients receiving acute soft-tissue wound treatment, eight studies with 2980 patients receiving treatment for complex wounds (defined as open fractures, pressure ulcers, diabetic foot ulcers, and nonhealing or chronic postoperative dehiscence wounds), five studies with 397 patients receiving treatment of infected wounds, two studies with 148 patients receiving treatment of burn wounds, 11 studies with 51,222 patients undergoing aesthetic or reconstructive breast augmentation, one study with 75 patients receiving treatment of tenosynovitis, and one study with 5004 patients investigating the effect of intraoperative povidone-iodine irrigation on the incidence of surgical-site infections (Table 1). The Jadad scale was used for quality assessment of included trials and is described in Table 2. Mean Jadad scale score was 3.2 ± 1.3, with the distribution of all included articles illustrated in Figure 2. A summary of effectiveness is provided in Table 3, and evidence-based guidelines are listed in Table 4.

Acute Soft-Tissue Wounds

Tap Water versus Normal Saline Irrigation

Huang et al. reviewed 1885 patients undergoing gravity flow (very low-pressure, poured or administered with a bulb syringe) irrigation for treatment of acute soft-tissue wounds. Group A patients received tap water irrigation. Group B received normal saline. The authors concluded that infection rates did not significantly differ between tap water and normal saline.[8]

Polyhexanide or Nitrofurazone versus Normal Saline Irrigation

Becerro et al. performed a randomized controlled trial with 71 patients receiving intraoperative gravity flow irrigation and debridement for treatment of nail avulsion. Twenty-four patients received normal saline, 22 patients received 0.2% nitrofurazone, and 25 patients received 0.1% polyhexanide (Prontosan; B. Braun, Melsungen, Germany). The authors reported significant reduction in bacterial load and subsequent infections in patients receiving 0.1% polyhexanide but

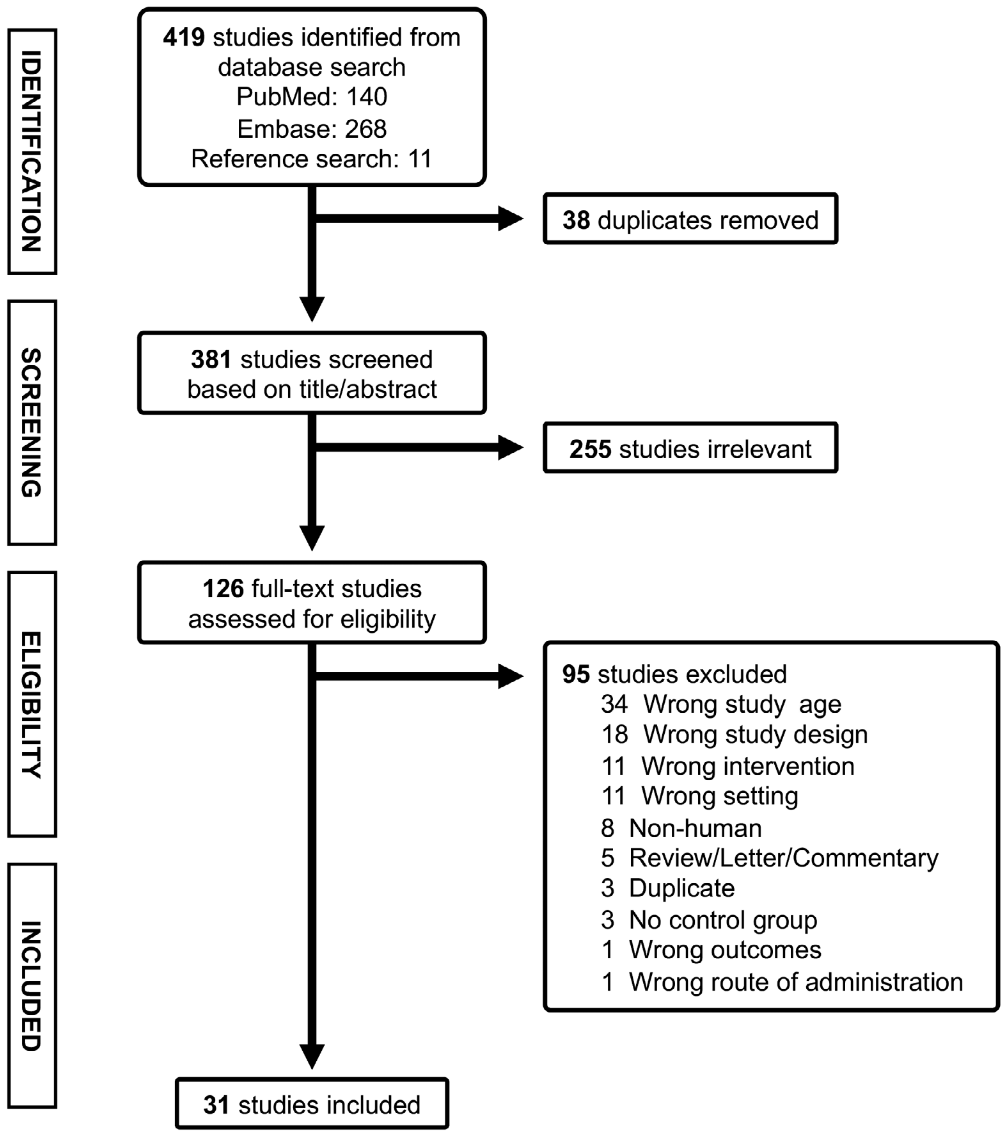

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram describing the screening and selection process for included studies.

not 0.2% nitrofurazone when compared with normal saline alone.[9]

High-Pressure Parallel Water Jet versus High-Pressure Pulsatile Lavage

Granick et al. performed a randomized controlled trial with 25 patients to compare wound bacterial counts after high-pressure parallel water jet (Versajet; Smith & Nephew, Inc., Largo, Fla.) (pressure range, 5025 to 7360 psi) hydrosurgical débridement versus high-pressure pulsatile lavage (40 psi) of contaminated traumatic wounds. The authors reported that pulsatile lavage with pressure of 15 psi sufficiently reduces bacterial counts compared with high-pressure parallel water jet.[10]

Summary of Results

Three studies provided appropriate data for analysis. One thousand nine hundred eighty-one patients with acute soft-tissue wounds underwent irrigation with tap water, normal saline, 0.2% nitrofurazone, or 0.1% polyhexanide solutions delivered by gravity flow, high-pressure parallel water jet, or high-pressure pulsatile lavage. Our review demonstrated the following:

- No difference in infection rate when comparing tap water with saline delivered by gravity flow.
- Significantly reduced infection rate with polyhexanide versus saline delivered by gravity flow.

Table 1. Summary of Articles

First Author and Year	Study Type (Jadad Scale Score*)	LOE	No. of Patients	Irrigant(s) Evaluated	Technique(s) Evaluated	Study Outcome
Acute-soft tissue wounds						
Huang, 2013	Meta-analysis	I	1885	Tap water, NS	Gravity flow	Infection rates were not statistically significant
Becerro De Bengoa Vallejo, 2011	RCT (4)	I	71	NS, 0.2% nitrofurazone, 0.1% polyhexanide	Gravity flow	Intraoperative irrigation with 0.1% polyhexanide significantly reduced the bacterial load and subsequent infections compared to saline
Granick, 2007	RCT (5)	I	25	NS	High-pressure parallel water jet (5000–7000 psi), high-pressure pulsatile lavage (40 psi)	Wound bacterial counts were not significantly reduced using high-pressure parallel water jet vs. high-pressure pulsatile lavage
Complex wounds†						
Bhandari, 2015	RCT (5)	I	2551	NS, 0.45% castile soap	High- (>20 psi), low- (5-10 psi), very low- (1–2 psi) pressure lavage	Reoperation rates were similar regardless of irrigation pressure; reoperation rate was higher in the soap group than in the saline group (HR, 1.32; 95% CI, 1.06–1.66; $p = 0.01$)
Kokavec, 2008	Prospective (2)	II	162	3.5% PVI	Gravity flow	3.5% PVI irrigation reduces rates of postoperative infections of the femur, hip, and pelvis
Shetty, 2014	RCT (5)	I	30	NS	Gravity flow, pulsatile lavage (10–15 psi; flow rate, 1025 ml/min)	Wounds treated with pulsatile lavage system significantly reduced in size, had better control of bacterial contamination, and had overall faster healing rates ($p < 0.001$)
Gabriel, 2014	Retrospective	III	82	NS, 0.1% polyhexanide	NPWT, NPWT-i (dwell 1–60 sec, followed by 1–2 hr continuous NPWT, 12 or 24 times daily)	NPWT-i with polyhexanide significantly reduced mean time to wound closure (4.1 days vs. 20.9 days), mean hospital stay (8.1 days vs. 27.4 days), and average therapy cost ($799 vs. $2217) compared with NPWT ($p < 0.001$)
Brinkert, 2013	Prospective (1)	II	131	NS	NPWT, NPWT-i (dwell 10 min, followed by 4–12 hr continuous NPWT, 2–6 times daily)	NPWT-i showed improved granulation tissue production compared with NPWT
Fluieraru, 2013	Retrospective	III	24	NS	NPWT, NPWT-i (dwell 10 min, followed by 4 hr continuous NPWT, 6 times daily)	NPWT-i for 10.1 ± 4.0 days (range, 6–15 days) improved granulation tissue formation and filling of undermined cavities compared with NPWT
Gupta, 2016	Systematic review	II	—	Varied	NPWT, NPWT-i	NPWT with instillation may improve overall wound outcomes
Anghel, 2016	Systematic review	II	—	NS, 0.1% polyhexanide	NPWT, NPWT-i	Outcomes were heterogeneous; overall, NPWT-i may significantly improve outcomes in patients with comorbidities
Infected wounds						
Davis, 2019	RCT (3)	I	90	NS	NPWT, NPWT-i (15 ml/hr)	NPWT-i with saline irrigation does not improve wound healing
Lavery, 2019	RCT (3)	I	150	0.1% polyhexanide-betaine	NPWT, NPWT-i (30 ml/hr)	NPWT-i with 0.1% polyhexanide-betaine irrigation did not improve wound healing
Gabriel, 2008	Prospective (2)	II	30	NS, 0.5% silver nitrate	Wet-to-moist, NPWT-i (instill 50–75 ml over 30–45 sec, hold for 1 sec, followed by 2 hr cont NPWT, 12 times daily)	NPWT-i required fewer days of treatment (9.9 vs. 36.5, $p < 0.001$), cleared clinical infection earlier (6.0 vs. 25.9, $p < 0.001$), decreased days to wound closure (13.2 vs. 29.6, $p < 0.001$) and had fewer in-hospital stay days (14.7 vs. 39.2, $p < 0.001$)

(*Continued*)

Table 1. *Continued*

First Author and Year	Study Type (Jadad Scale Score*)	LOE	No. of Patients	Irrigant(s) Evaluated	Technique(s) Evaluated	Study Outcome
Kim, 2014	Retrospective	II	142	NS, 0.1% polyhexanide	NPWT, NPWT-i (dwell 6 min, followed by 3.5 hr continuous NPWT, 8 times daily), NPWT-i (dwell 20 min, followed by 2 hr continuous NPWT, 12 times daily)	Compared with NPWT, NPWT-i (6- and 20-min dwell) required shorter hospital stays (11.4 vs. 14.9, $p = 0.034$), and had a significantly higher percentage of wounds: (1) closed before discharge (94% vs. 62%) and (2) culture improvement for Gram-positive bacteria (90% vs. 63%, $p < 0.001$)
Back, 2013	Systematic review	II	—	NS, 0.1% polyhexanide, 0.25% acetic acid, 10% PVI	NPWT-i (soak 20 min, 4–8 times daily)	Prophylactic use of NPWT-i with polyhexanide, acetic acid or PVI is recommended in contaminated and/or noninfected wounds which cannot be closed primarily with surgical means
Burn wounds						
Tan, 2014	Retrospective	II	99	Tap water	Continuous gravity flow, soaked gauze	Continuous tap water significantly reduced time to recovery compared with soaking with gauze ($p = 0.021$)
Mohammadi, 2013	RCT (3)	I	49	NS, 2% hydrogen peroxide	5-min soaked gauze followed by NS gravity flow	2% hydrogen peroxide improves rate of graft take in chronic colonized burn wounds compared with NS
Breast implant wounds						
Platt, 2003	RCT (2)	I	30	NS	Bulb syringe lavage (300 ml)	NS irrigation had no significant effect on bilateral breast reduction outcomes
Yalanis, 2015	Meta-analysis	I	5153	NS, 10% PVI	Gravity lavage	PVI irrigation reduces risk of capsular contracture compared with NS (2.7% vs. 8.9%, $p < 0.001$)
Giordano, 2013	Retrospective	II	330	25 ml 10% PVI plus 750 mg cefuroxime plus 80 mg gentamicin plus 15 ml normal saline	Gravity lavage	PVI with antibiotic irrigation yielded lower capsular contracture rate compared with no irrigation (0.6% vs. 6%, $p = 0.006$)
Horsnell, 2017	Systematic review	I	11,772	NS, 10% PVI	Gravity lavage	PVI irrigation reduces risk of capsular contracture
Blount, 2013	Retrospective	II	856	NS, triple antibiotic (bacitracin, cefazolin, gentamicin)	Gravity lavage	Triple antibiotic irrigation reduces capsular contracture rate compared with NS (0.4% vs. 3.9%, $p = 0.04$)
Pfeiffer, 2009	Retrospective	II	436	NS/epinephrine, NS/epinephrine plus 1000 mg cephalothin	Gravity lavage	Antibiotic irrigation significantly reduced rates of infection (6.7% vs. 12.8%, $p = 0.044$) and seroma formation (2.9% vs. 7.6%, $p = 0.036$) but not capsular contracture (5.9% vs. 8.1%, $p = 0.393$) compared with NS/epinephrine
Campbell, 2018	Systematic review	I	8050	NS, PVI, triple antibiotic	Gravity lavage	Outcomes were heterogeneous; overall, infection and capsular contracture rates were not significantly reduced with PVI or triple antibiotic compared with NS
Drinane, 2017	Meta-analysis	I	10,923	NS, antimicrobial (iodine or antibiotic)	Gravity lavage	Antimicrobial irrigation associated with increased risk of capsular contracture (OR, 2.60; 95% CI, 2.3–2.94; $p < 0.001$)
Drinane, 2016	Retrospective	II	55	NS, triple antibiotic	Gravity lavage (250 ml)	No difference between triple antibiotic and NS irrigation on incidence and severity of capsular contracture
Samargandi, 2018	Systematic review	I	8892	NS, antibiotic	Gravity lavage	Outcomes were heterogeneous; overall, rates of capsular contracture were not significantly reduced with antibiotic irrigation

(*Continued*)

Table 1. *Continued*

First Author and Year	Study Type (Jadad Scale Score*)	LOE	No. of Patients	Irrigant(s) Evaluated	Technique(s) Evaluated	Study Outcome
Lynch, 2018	Meta-analysis	I	4725	NS, antibiotic	Gravity lavage	Antibiotic irrigation showed significant reduction in clinical infection (RR, 0.52; 95% CI, 0.33–0.81) and capsular contracture (RR, 0.36; 95% CI, 0.16–0.83) compared with NS
Tenosynovitis						
Lille, 2000	Retrospective	II	75	NS	Postoperative catheter irrigation (continuous 24–48 hr)	Outcomes were not significantly different with 24–48 hr of continuous postoperative NS irrigation
Surgical-site infections						
Fournel, 2010	Meta-analysis	I	5004	NS, 10% PVI	Gravity lavage	Intraoperative PVI irrigation significantly reduced the rate of SSI (RR, 0.58; 95% CI, 0.40–0.83, $p = 0.003$) compared with NS

LOE, level of evidence; NS, normal (0.9%) saline; RCT, randomized controlled trial; HR, hazard ratio; PVI, povidone-iodine; NPWT, negative pressure wound therapy; NPWT-i, negative pressure wound therapy with instillation; RR, relative risk; SSI, surgical-site infection.
*Jadad scale, a 0–5 scale, with a higher score representing a higher quality of randomized controlled trial.
†Open fracture, pressure ulcer, diabetic foot ulcer, and nonhealing postoperative dehiscence wounds.

Table 2. Methodologic Quality Assessment of Included Trials

First Author and Year	Randomization	Blinding	Account of All Patients	Jadad Scale Score*	Comments
Acute soft-tissue wounds					
Huang, 2013	—	—	—	—	Meta-analysis
Becerro De Bengoa Vallejo, 2011	1	2	1	4	
Granick, 2007	2	2	1	5	
Complex wounds					
Bhandari, 2015	2	2	1	5	
Kokavec, 2008	1	0	1	2	
Shetty, 2014	2	2	1	5	
Gabriel, 2014	—	—	—	—	Retrospective
Brinkert, 2013	0	0	1	1	
Fluieraru, 2013	—	—	—	—	Retrospective
Gupta, 2016	—	—	—	—	Systematic review
Anghel, 2016	—	—	—	—	Systematic review
Infected wounds					
Davis, 2019	2	0	1	3	
Lavery, 2019	2	0	1	3	
Gabriel, 2008	1	0	1	2	
Kim, 2014	—	—	—	—	Retrospective
Back, 2013	—	—	—	—	Systematic review
Burn wounds					
Tan, 2014	—	—	—	—	Retrospective
Mohammadi, 2013	1	1	1	3	
Breast implant wounds					
Platt, 2003	1	0	1	2	
Yalanis, 2015	—	—	—	—	Meta-analysis
Giordano, 2013	—	—	—	—	Retrospective
Horsnell, 2017	—	—	—	—	Systematic review
Blount, 2013	—	—	—	—	Retrospective
Pfeiffer, 2009	—	—	—	—	Retrospective
Campbell, 2018	—	—	—	—	Systematic review
Drinane, 2017	—	—	—	—	Meta-analysis
Drinane, 2016	—	—	—	—	Retrospective
Samargandi, 2018	—	—	—	—	Systematic review
Lynch, 2018	—	—	—	—	Meta-analysis
Tenosynovitis					
Lille, 2000	—	—	—	—	Retrospective
Surgical-site infections					
Fournel, 2010	—	—	—	—	Meta-analysis

*Jadad scale, a 0–5 scale with a higher score representing a higher quality of randomized controlled trial. The Jadad scale assesses a randomized controlled trial's reported methodologic quality by incorporating appropriateness of randomization, blinding, and account of all patients. A point is given for each of the above safeguards against bias. An additional point is given or deducted if the reported method of randomization or blinding is appropriate or inappropriate, respectively. [Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: Is blinding necessary? *Control Clin Trials* 1996;17:1–12. 10.1016/0197-2456(95)00134-4]

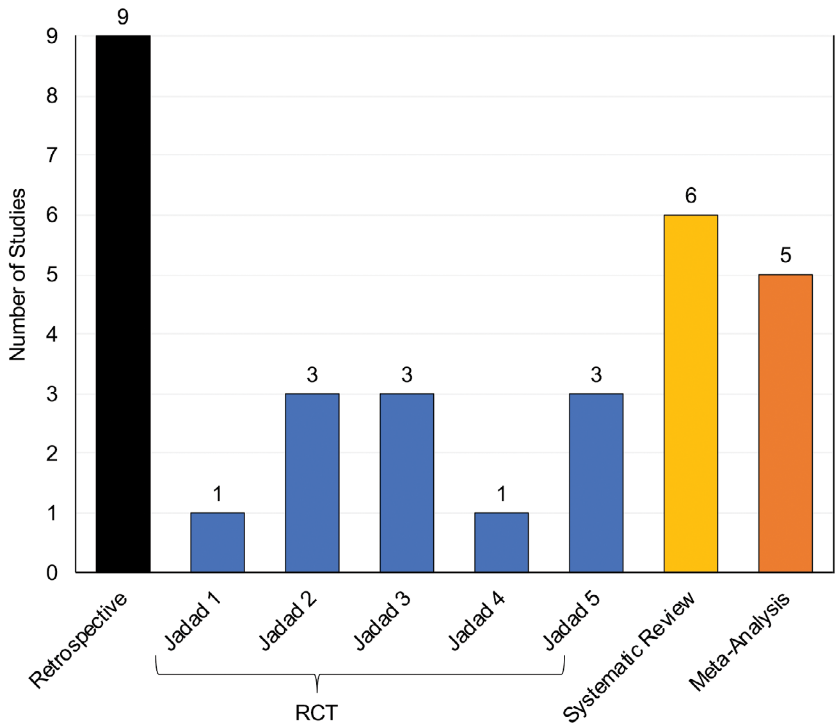

Fig. 2. Histogram of articles with Jadad scores for randomized controlled trials (*RCT*). Mean Jadad score for included randomized controlled trials was 3.2 ± 1.3.

- No difference in bacterial load when comparing high-pressure parallel water jet with high-pressure pulsatile lavage.
- **Evidence-based guideline: Acute soft-tissue wounds should receive continuous gravity flow polyhexanide irrigation.**

Complex Wounds

Castile Soap versus Normal Saline Irrigation

In 2015, Bhandari et al. performed a randomized controlled trial with 2551 patients receiving treatment for complex open fracture wounds. The authors compared reoperation rates between 0.45% castile soap and normal saline delivered by means of continuous high- (>20 psi), low- (5 to 10 psi), or very low- (1 to 2 psi) pressure irrigation in addition to débridement. Among the 2447 patients, 1229 patients received irrigation with a 0.45% solution of castile soap and 1218 patients received normal saline. The authors reported reoperation rates to be higher with castile soap than with normal saline (hazard ratio, 1.32; 95 percent CI, 1.06 to 1.66; $p = 0.01$).[11]

3.5% Povidone-Iodine versus No Irrigation

Kokavec and Fristáková performed a prospective study of 162 patients undergoing surgical procedures in the proximal femur, hip, and pelvis regions. Among the 162 patients, 89 patients received intraoperative irrigation with 3.5% povidone-iodine before wound closure. In this study, the authors reported a reduced infection rate with intraoperative 3.5% povidone-iodine irrigation (0 percent versus 2.74 percent).[12]

High- versus Low-Pressure Continuous Irrigation

Bhandari et al. reported similar reoperation rates, defined as surgery that occurred within 12 months after the initial procedure to treat an infection, manage a wound healing problem, or promote bone healing at the operative site, between high (>20 psi), low- (5 to 10 psi), or very low- (1 to 2 psi) pressure continuous irrigation ($n = 826$, $n = 809$, and $n = 812$, respectively). Hazard ratios for the three pairwise comparisons were as follows: for low- versus high-pressure, 0.92 (95 percent CI, 0.70 to 1.20; $p = 0.53$), for high- versus very low-pressure, 1.02 (95 percent CI, 0.78 to 1.33; $p = 0.89$), and for low- versus very low-pressure, 0.93 (95 percent CI, 0.71 to 1.23; $p = 0.62$).[11]

Pulsatile Lavage versus Gravity Flow Irrigation

Shetty et al. performed a randomized controlled trial with 30 patients receiving normal saline lavage and débridement for treatment of chronic wounds. Group A patients received

Table 3. Summary of Effectiveness

Intervention Evaluated	No. of Patients	LOE	Outcome Measured	Effect on Outcome	First Author and Year
Acute soft-tissue wounds					
Tap water vs. NS	1885	I	Infection rate	No difference	Huang, 2013
0.1% polyhexanide vs. NS	71	I	Infection rate	Improves	Becerro De Bengoa Vallejo, 2011
HPPWJ vs. pulsatile lavage	25	I	Wound bacterial count	No difference	Granick, 2007
Complex wounds*					
0.45% castile soap vs. NS	2447	I	Reoperation rate	Worsens	Bhandari, 2015
3.5% PVI vs. no irrigation	162	I	Infection rate	Improves	Kokavec, 2008
0.1% polyhexanide vs. NS	82	II	Healing time	Improves	Gabriel, 2008
High- vs. low-pressure vs. gravity lavage	2447	I	Reoperation rate	No difference	Bhandari, 2015
Pulsatile vs. gravity lavage	30	I	Healing time	Improves	Shetty, 2014
NPWT-i vs. NPWT	155	II	Tissue production	May improve	Brinkert, 2015; Flui-eraru, 2017
Infected wounds					
0.5% silver nitrate vs. NS	30	II	Healing time	Improves	Gabriel, 2008
0.1% polyhexanide vs. NS	292	I–II	Healing time	May improve	Kim, 2014; Lavery, 2019
0.25% acetic acid vs. NS	—	II	Infection rate	May improve	Back, 2013
10% PVI vs. NS	—	II	Infection rate	May improve	Back, 2013
NPWT-i vs. wet-to-moist wound care	30	II	Healing time	Improves	Gabriel, 2008
Burn wounds					
Gravity flow vs. soaked gauze	99	II	Healing time	Improves	Tan, 2014
2% hydrogen peroxide vs. NS	49	I	Graft take	Improves	Mohammadi, 2013
Breast implant wounds					
10% PVI vs. NS	16,925	I	Risk of CC	Improves	Yalanis, 2015; Horsnell, 2017
10% PVI plus cefuroxime plus gentamicin vs. no lavage	330	II	Risk of CC	Improves	Giordano, 2013
Triple antibiotic vs. NS	8961	I–II	Risk of CC	May improve	Blount, 2013; Campbell, 2018; Drinane, 2016
Antimicrobials vs. NS	10,923	I	Risk of CC	Worsens	Drinane, 2017
NS/epinephrine plus 1000 mg cephalothin vs. NS/epinephrine	436	II	Infection rate, seroma rate	Improves	Pfeiffer, 2009
Antibiotic vs. NS	4725	I	Infection rate	Improves	Lynch, 2018
Antibiotic vs. NS	13,617	I	Risk of CC	May improve	Lynch, 2018; Samargandi, 2018
NS bulb syringe lavage vs. no lavage	30	I	Healing time	No difference	Platt, 2003
Tenosynovitis					
Intraoperative vs. intraoperative and postoperative continuous irrigation	75	II	Healing time	No difference	Anghel, 2016
Surgical-site infections					
10% PVI vs. NS	5004	I	Infection rate	Improves	Fournel, 2010

LOE, level of evidence; NS, normal (0.9%) saline; HPPWJ, high-pressure pulsatile water jet; PVI, povidone-iodine; NPWT-i, negative pressure wound therapy with instillation; NPWT, negative pressure wound therapy; CC, capsular contracture.
*Open fracture, pressure ulcer, diabetic foot ulcer, and nonhealing postoperative dehiscence wounds.

pulsatile lavage at 10 to 15 psi with a flow rate of 1025 ml/minute. Group B patients received gravity flow. The authors concluded that pulsatile lavage significantly reduced wound size, bacterial load, and time to definitive wound closure ($p < 0.001$) compared with gravity flow irrigation.[13]

Negative-Pressure Wound Therapy with Instillation versus Negative-Pressure Wound Therapy Alone

In 2016, Anghel et al. and Gupta et al. independently reviewed complex wound patients receiving surgical débridement and negative-pressure wound therapy with instillation. Compared with negative-pressure wound therapy alone, these studies concluded that negative-pressure wound therapy with instillation may only improve wound outcomes in comorbid patients.[14,15] The benefits of negative-pressure wound therapy with instillation have been reported by numerous studies.[16–18] Brinkert et al. and Fluieraru et al. reviewed a combined 155 patients undergoing wound débridement and negative-pressure wound therapy with instillation for treatment of complex lower extremity wounds and independently reported a significant increase in granulation tissue production[16,17] and rate of filling of undermined cavities[17] compared with negative-pressure wound therapy alone. In 2014, Gabriel et al. reported that negative-pressure wound therapy with instillation significantly reduced time to wound closure (4.1 days versus 20.9 days), hospital stay (8.1 days versus 27.4 days), and average therapy cost ($799 versus $2217) compared with negative-pressure wound therapy alone ($p < 0.001$).[18]

Table 4. Evidence-Based Irrigation Guidelines

Acute soft-tissue wounds
• Gravity flow irrigation with tap water is as effective as NS in reducing infection rate
• Gravity flow irrigation with 0.1% polyhexanide more effective than NS at reducing infection rate
• High-pressure (40 psi) pulsatile lavage is as effective as HPPWJ at reducing wound bacterial load
• **Evidence-based guideline: Acute soft-tissue wounds should receive continuous gravity flow irrigation with a 0.1% solution of polyhexanide.**
Complex wounds*
• Irrigation with 0.45% castile soap solution more likely than NS to result in reoperation
• Gravity flow irrigation with 3.5% PVI is more effective than no irrigation at reducing infection rate
• NPWT-i with 0.1% polyhexanide is more effective than NPWT-i with NS at reducing healing time
• Gravity flow is as effective as continuous high-pressure (>20 psi) lavage at reducing reoperation rate
• Pulsatile (10–15 psi) lavage is more effective than gravity flow at reducing healing time
• NPWT-i may be more effective at promoting tissue production than NPWT alone
• **Evidence-based guideline: Complex wounds should receive continuous NPWT-i with 0.1% polyhexanide instillation. Pulsatile lavage is recommended over continuous flow.**
Infected wounds
• NPWT-i with or without 0.5% silver nitrate is more effective at reducing healing time than NS wet-to-moist treatment
• NPWT-i with 0.1% polyhexanide, 0.25% acetic acid, or 10% PVI may be more effective than NPWT-i with NS at reducing healing time and infection rate
• **Evidence-based guideline: Infected wounds should receive continuous NPWT-i with 0.5% silver nitrate, 0.1% polyhexanide, 0.25% acetic acid, or 10% povidone-iodine. However, the data are heterogeneous.**
Burn wounds
• Gravity flow irrigation with tap water is more effective than NS-soaked gauze at reducing healing time
• 2% hydrogen peroxide-soaked gauze is more effective than NS-soaked gauze at promoting graft take
Breast implant wounds
• Gravity lavage with 10% PVI is more effective than NS at reducing the risk of capsular contracture
• Gravity lavage with a mixture of 25 ml of 10% PVI, 15 ml of NS, 750 mg of cefuroxime, and 80 mg of gentamicin is more effective than no irrigation at reducing the risk of capsular contracture
• Triple antibiotic irrigation may be more effective than NS at reducing the risk of capsular contracture; however, large studies have reported antimicrobial irrigation to increase the risk of capsular contracture
• Gravity lavage with antibiotics is more effective than NS at reducing infection rate and may improve risk of capsular contracture
• NS lavage delivered by means of bulb syringe does not improve outcomes compared with no lavage
• **Evidence-based guideline: Gravity lavage with 10% PVI or antibiotics may reduce the risk of capsular contracture and infection, respectively. However, data heterogeneity limits our ability to establish evidence-based guidelines.**
Tenosynovitis
• Continuous intraoperative and (24–48 hr) postoperative catheter irrigation with NS does not improve healing time or reduce complication rates compared with intraoperative irrigation alone
Surgical-site infections
• Intraoperative gravity lavage with 10% PVI is more effective than NS at reducing the rate of SSI

NS, normal (0.9%) saline; HPPWJ, high-pressure pulsatile water jet; PVI, povidone-iodine; NPWT-i, negative pressure wound therapy with instillation; NPWT, negative pressure wound therapy; SSI, surgical-site infection.
*Open fracture, pressure ulcer, diabetic foot ulcer, and nonhealing postoperative dehiscence wounds.

Summary of Results

Eight studies provided appropriate data for analysis. Two thousand nine hundred eighty patients with complex wounds underwent irrigation with normal saline, 0.45% with castile soap, 3.5% with povidone-iodine, and 0.1% with polyhexanide solutions delivered by high- and low-pressure pulsatile lavage, gravity flow, and negative-pressure wound therapy with and without instillation. Our review demonstrated the following:

- Irrigation with castile soap increases reoperation rates versus saline.
- Gravity flow with povidone-iodine reduces infection rates versus no irrigation.
- Negative-pressure wound therapy with instillation with polyhexanide reduces healing time versus negative-pressure wound therapy with instillation with saline.
- There is difference in reoperation rate between gravity flow and continuous high-pressure lavage.
- Pulsatile lavage reduces healing time compared to gravity flow.
- Negative-pressure wound therapy with instillation may be more effective at promoting tissue production than negative-pressure wound therapy alone.
- **Evidence-based guideline: Complex wounds should receive continuous negative-pressure wound therapy with instillation with polyhexanide. Pulsatile lavage is recommended over continuous flow**.

Infected Wounds

Silver Nitrate Negative-Pressure Wound Therapy with Instillation versus Normal Saline Wet-to-Moist

In 2008, Gabriel et al. reviewed 30 patients receiving treatment for infected wounds with a 0.5% solution of silver nitrate and surgical débridement. Group A patients received traditional wet-to-moist treatment with normal saline. Group B received negative-pressure wound therapy with instillation with 50 to 75 ml of 0.5% silver nitrate over 30 to 45 seconds followed by 2 hours of continuous negative-pressure wound therapy, repeated 12 times daily. The authors reported that patients treated with negative-pressure wound therapy with instillation cleared clinical infection earlier (6.0 versus 25.9; $p < 0.001$) and required fewer in-hospital stay days (14.7 days versus 39.2 days; $p < 0.001$), fewer days of treatment (9.9 days versus 36.5 days; $p < 0.001$), and fewer days to wound closure (13.2 days versus 29.6 days; $p < 0.001$) compared with the wet-to-moist group.[19]

Negative-Pressure Wound Therapy with Instillation versus Negative-Pressure Wound Therapy Alone

In 2014, Kim et al. performed a retrospective cohort study of 142 patients that received negative-pressure wound therapy and surgical débridement for treatment of infected wounds. Among the 142 patients, 74 received negative-pressure wound therapy alone and 68 received negative-pressure wound therapy with instillation with 0.1% polyhexanide eight to 12 times daily. The authors reported significantly fewer operative visits (2.5 versus 3.0; $p < 0.05$) and days spent in the hospital (11.4 days versus 14.9 days; $p = 0.034$), and a significantly higher percentage of wounds closed before discharge (94 percent versus 62 percent; $p < 0.001$) and culture improvement for Gram-positive bacteria (90 percent versus 63 percent; $p < 0.001$) in patients treated with negative-pressure wound therapy with instillation compared with negative-pressure wound therapy without instillation.[20]

Based on independent randomized controlled trials with a combined 240 patients, Davis et al. and Lavery et al. independently concluded that negative-pressure wound therapy with instillation did not significantly improve wound outcomes, versus negative-pressure wound therapy alone, in patients undergoing surgical débridement for moderate to severe foot infections.[21,22] However, in a systematic review comparing negative-pressure wound therapy with instillation with normal saline versus 0.1% polyhexanide, 0.25% acetic acid, and 10% povidone-iodine, Back et al. recommended the prophylactic use of negative-pressure wound therapy with instillation with polyhexanide, acetic acid, or povidone-iodine after surgical débridement in both infected and noninfected wounds that cannot be closed primarily by surgical means.[23]

Summary of Results

Five studies provided appropriate data for analysis. Three hundred ninety-seven patients with infected wounds underwent irrigation with normal saline, 0.5% silver nitrate, 0.25% acetic acid, 10% povidone-iodine, or 0.1% polyhexanide solutions delivered by wet-to-moist treatment, negative-pressure wound therapy, or negative-pressure wound therapy with instillation. Our review demonstrated the following:

- Negative-pressure wound therapy with instillation with or without silver nitrate is more effective at reducing healing time than saline wet-to-moist treatment.
- Negative-pressure wound therapy with instillation with polyhexanide, acetic acid, or povidone-iodine may reduce healing time and rate of infection compared with negative-pressure wound therapy with instillation with saline.
- **Evidence-based guideline: Infected wounds should receive continuous negative-pressure wound therapy with instillation with silver nitrate, polyhexanide, acetic acid, or povidone-iodine. However, the data remain heterogeneous.**

Burn Wounds

Continuous Tap Water versus Soaked Gauze

Tan and Wong reviewed 99 patients undergoing treatment of chemical burn wounds. The authors reported that continuous tap water irrigation after immediate surgical débridement significantly reduced time to recovery and length of hospital stay compared with wet packs alone (10.8 days versus 20.5 days; $p = 0.021$).[24]

2% Hydrogen Peroxide

Mohammadi et al. performed a randomized controlled trial with 49 patients undergoing split-thickness skin graft for treatment of chronically colonized bilateral burn wounds. Each patient in this study served as their own control. After excision and débridement of granulation tissue, patients' right limb wounds were soaked for 5 minutes with a 2% solution of hydrogen peroxide before normal saline gravity flow irrigation and split-thickness skin graft. Patients' left limb wounds received only gravity flow irrigation with normal saline and split-thickness skin graft. The authors reported an 82.9 percent graft take rate in right limbs and a 65.6 percent graft take rate in left limbs ($p < 0.05$), showing that irrigation of burn wounds with 2% hydrogen peroxide improves graft take compared with normal saline.[25]

Summary of Results

Two studies provided appropriate data for analysis. One hundred forty-eight patients with burn wounds underwent irrigation with tap water, normal saline, and 2% hydrogen peroxide delivered by continuous gravity flow or soaked gauze. Our review demonstrated the following:

- Continuous gravity flow with tap water reduces time to recovery compared with saline-soaked gauze.
- Graft take is improved in burn wounds soaked with hydrogen peroxide versus saline.

Breast Implant Wounds

Normal Saline Bulb Syringe Lavage

Platt et al. performed a randomized controlled trial with 30 patients undergoing bilateral breast reduction surgery. Group A patients received 300 ml of normal saline lavage delivered by means of a bulb syringe. Group B did not receive any irrigation. The authors reported that normal saline lavage by means of bulb syringe had no significant effect on surgical outcomes when compared with no lavage.[26]

10% Povidone-Iodine and Antibiotics

Several studies, including a meta-analysis of 5153 patients and a systematic review of 11,772 patients, concluded that gravity lavage with a 10% solution of povidone-iodine reduces the incidence of capsular contracture when compared with normal saline (2.7 percent versus 8.9 percent; $p < 0.001$) in patients undergoing breast augmentation surgery.[27,28]

Giordano et al. reviewed 330 patients undergoing implant-based breast augmentation. Among the 330 patients, 165 patients had each implant and breast pocket irrigated with 25 ml of a 10% povidone-iodine solution mixed with 750 mg of cefuroxime and 80 mg of gentamicin diluted in 15 ml of normal saline. The authors concluded that 10% povidone-iodine with antibiotic irrigation yielded lower capsular contracture rates compared with no irrigation (0.6 percent versus 6 percent; $p = 0.006$).[29]

Pfeiffer et al. reviewed 436 patients undergoing breast augmentation. In group A, 218 received 1000 mg of cephalothin, a first-generation cephalosporin, added to the normal saline/epinephrine solution used to irrigate the implant pocket. In group B, 218 patients were irrigated in the same manner using the normal saline/epinephrine solution only without cephalothin. The authors reported significantly reduced rates of infection (6.7 percent versus 12.8 percent; $p = 0.044$) and seroma formation (2.9 percent versus 7.6 percent; $p = 0.036$) but not capsular contracture (5.9 percent versus 8.1 percent; $p = 0.393$) in patients irrigated with cephalothin.[30] Similarly, a study by Blount et al. with 856 patients reported significant reduction in capsular contracture rates when a triple antibiotic solution containing bacitracin, cefazolin, and gentamicin was compared with normal saline alone (0.4 percent versus 3.9 percent; $p = 0.04$).[31]

In 2018, Lynch et al. performed a meta-analysis of 4725 patients receiving irrigation during breast augmentation. Antibiotic irrigation significantly reduced the rates of clinical infection (relative risk, 0.52; 95 percent CI, 0.33 to 0.81) and capsular contracture (relative risk, 0.36; 95 percent CI, 0.16 to 0.83) when compared with normal saline irrigation alone.[32] In contrast, a meta-analysis of 10,923 patients concluded that antimicrobial irrigation was associated with an increased risk of capsular contracture (OR, 2.60; 95 percent CI, 2.3 to 2.94; $p < 0.001$).[33]

Although numerous studies have generated strong evidence to support breast pocket irrigation with 10% povidone-iodine and/or antibiotics, the overall consensus remains heterogeneous. In 2018, two systematic reviews with a combined 16,942 patients concluded that infection and capsular contracture rates were not significantly reduced in patients that received 10% povidone-iodine and/or antibiotics versus only normal saline irrigation.[34–36]

Summary of Results

Eleven studies provided appropriate data for analysis. Fifty-one thousand two hundred twenty-two patients undergoing breast surgery received lavage with normal saline, 10% povidone-iodine, or antibiotic agents including cefuroxime, bacitracin, cefazolin, gentamicin, or cephalothin, delivered by gravity or bulb syringe lavage. Our review demonstrated the following:

- Povidone-iodine lavage with or without antibiotics is more effective at reducing the risk of capsular contracture than no lavage or saline alone.
- Triple antibiotic (bacitracin, cefazolin, gentamicin) lavage may reduce the risk of capsular contracture versus saline alone.

- Gravity lavage with cephalothin (1000 mg) reduces rates of infection and seroma formation, but not risk of capsular contracture.
- Saline lavage delivered by means of bulb syringe does not improve outcomes compared with no lavage.
- **Evidence-based guideline: Gravity lavage with povidone-iodine or antibiotics may reduce the risk of capsular contracture and infection. However, data remain heterogeneous.**

Tenosynovitis

Lille et al. reviewed 75 patients undergoing treatment for pyogenic flexor tenosynovitis. Among the 75 patients, 55 patients received both intraoperative and continuous postoperative catheter irrigation with normal saline for 24 to 48 hours. Twenty patients received normal saline irrigation only intraoperatively. The authors found no significant differences in wound healing outcomes with 24 to 48 hours of continuous postoperative irrigation with normal saline.[37]

Surgical-Site Infections

Fournel et al. performed a meta-analysis of 24 randomized controlled trials totaling 5004 patients who underwent abdominal or soft-tissue surgery, with surgical-site infection as the primary outcome. The authors concluded that intraoperative 10% povidone-iodine irrigation by means of gravity lavage significantly reduced the rate of surgical-site infections compared with gravity lavage using normal saline alone (relative risk, 0.58; 95 percent CI, 0.40 to 0.83; $p = 0.003$).[38]

DISCUSSION

Optimal wound care requires a multimodal approach centered around débridement and irrigation.[39] Irrigation practices are highly variable and not always evidence-based.[40–42] This is the first review of wound irrigation that systematically summarizes the literature using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and distills the evidence into a practical format. This work not only represents a valuable addition to the literature as a "one-stop-shop" for information, but also helps mitigate against methods that may do harm.

Amid the coronavirus disease of 2019 pandemic, strategies that minimize physical contact and aerosolization of particulate matter should be considered to reduce the risk of hospital-acquired infections.[43] Closed irrigation systems such as negative-pressure wound therapy with instillation significantly reduce aerosolization compared with lavage.[44]

Our study is limited by the heterogeneity of the included studies, many of which presented small sample sizes or specific patient subpopulations. Furthermore, the included studies lacked consistency in study design, outcome and comorbidity reporting, surgical approach, and perioperative management, potentially limiting generalizability. Despite having Level I and II data, the limited number of high-level studies in several wound categories makes it challenging to draw definitive conclusions, and these results must be interpreted with caution.

CONCLUSIONS

Wound care has come a long way since 1650 BC. Based on current evidence provided by this review, we recommend the following:

1. Acute soft-tissue wounds should receive continuous gravity flow irrigation with polyhexanide.
2. Complex wounds should receive continuous negative-pressure wound therapy with instillation with polyhexanide. Pulsatile lavage is recommended over continuous flow.
3. Infected wounds should receive continuous negative-pressure wound therapy with instillation with silver nitrate, polyhexanide, acetic acid, or povidone-iodine. However, the data are heterogeneous.
4. Breast implant wounds should receive gravity lavage with povidone-iodine or antibiotics to reduce the risk of capsular contracture and infection.
5. Surgical-site infections are significantly reduced with intraoperative povidone-iodine irrigation versus saline.

Additional high-quality studies are warranted to further establish evidence-based irrigation guidelines.

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