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General Assembly, Prevention, Wound Management: Proceedings of International Consensus on Orthopedic Infections

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Question 1: Does the type of wound closure (technique and material) affect the incidence of subsequent SSI/PJI?

Recommendation:

There is a lack of strong evidence clearly demonstrating the superiority of any wound closure method after total joint arthroplasty (TJA). The majority of the high-quality studies demonstrate no difference between the various types of wound closure.

Level of Evidence: Moderate

Delegate Vote: Agree: 90%, Disagree: 8%, Abstain: 2% (Super Majority, Strong Consensus)

Rationale:

Currently there are several techniques available for wound closure after total joint arthroplasty which include staples, sutures, adhesives, and transdermal systems [1]. Although several randomized clinical trials (RCTs) are available, surgeons primarily select wound closure systems based on personal preference. The ultimate goal is to use a wound closure system that balances cosmetic appearance, clinical outcomes, and cost-effectiveness. Based on the currently available literature, no closure system has been shown to consistently reduce the risk of surgical site infection/periprosthetic joint infection. Despite several level I evidence studies investigating the complications of wound closure systems, they are dramatically underpowered. A summary of the available literature on each method of wound closure is discussed in the following sections.

Conventional Suture and Staples

Historically, total joint arthroplasty wound incisions have been closed using nylon sutures or metal staples. Both options have demonstrated low wound complication rates, easily reproducible

application, and cost-effectiveness but require a clinic visit within 2 weeks of surgery for removal [2]. Many studies have comparatively evaluated outcomes after closure with conventional sutures and staples with inconsistent results. Several RCTs and a retrospective study have reported no significant difference in wound complication rates between sutures and staples [2–7]. Some studies have reported superior outcomes for staple closures, whereas others have reported an increased incidence of infection with staple closures [8–13].

Barbed Sutures

Barbed sutures have been popularized by eliminating the need for knots while demonstrating superior water-tight closures in cadaveric models [14]. Similar to conventional closure techniques, barbed suture has been evaluated in numerous retrospective studies and RCTs with inconsistent results when compared with conventional closures [15–26]. Likewise, the published meta-analyses on barbed suture closure have provided inconsistent results. The meta-analysis by Zhang et al reported significantly fewer complications and superficial infections when the arthrotomy, subcutaneous, and subcuticular tissues are closed using barbed sutures [27]. A meta-analysis by Meena et al has indicated a higher rate of infection for barbed suture albeit not statistically significant [28]. However, another meta-analysis by Borzio et al confirmed the cost savings associated with barbed sutures but demonstrated no significant difference in complication rates between conventional and barbed sutures [29].

Noninvasive Skin Closure Using Adhesives and Transdermal Systems

Currently there are two categories of noninvasive skin closure that include adhesives and transdermal systems. The majority of RCTs have demonstrated no difference in cosmetic and clinical outcomes between sutures, staples, and adhesive closures [4,6,30]. In the Cochrane review by Dumville et al, the effects of various tissue adhesives were compared with sutures, staples, and other methods of skin closure techniques using wound infection and dehiscence as the two outcome measures [31]. The results demonstrated no difference in the risk of wound infection between the closure methods; however, there was wide variability in the definition of wound infection between studies. Regarding wound dehiscence, conventional sutures were significantly better than tissue adhesives, but the analysis relied heavily on studies with lower quality evidence.

Only limited evidence exists on the performance of transdermal closure systems. Ko et al compared outcomes between staples and a transdermal closure in a small cohort of TKA patients, which reported no complications, improved cosmesis, and reduced pain scores at the time of removal [32]. Similarly, Carli et al assessed a prospective series of TKA patients and found that the transdermal closure cohort avoided home care and had fewer complications than the staple cohort [33].

Question 2: What is the role for vacuum-assisted incisional dressings in orthopedic patients?

Recommendation:

Prophylactic vacuum-assisted incisional dressings (iVAC) appear to be a reasonable option for improved wound healing and decreasing the infection rate in orthopedic patients at risk for such complications. Prophylactic iVACs used routinely in uncomplicated cases do not appear to provide benefit and lead to increased costs. Finally, evidence suggests that iVACs may also play a role in resolving some cases of early, benign postoperative drainage.

Level of Evidence: Moderate

Delegate Vote: Agree: 85%, Disagree: 11%, Abstain: 4% (Super Majority, Strong Consensus)

Rationale:

Wound management through the application of negative pressure has been used for decades in multiple surgical disciplines, including plastic surgery, general surgery, trauma surgery, cardiothoracic surgery, and orthopedic surgery. It is thought to act through several mechanisms that result in wound contraction, stimulation of epithelial growth, and prevention of fluid collection and wound drainage [34].

Within orthopedic surgery, the use of vacuum-assisted incisional dressings (iVAC) has been investigated in studies spanning multiple subdisciplinary areas, with moderate-strength evidence suggesting that iVACs may benefit wounds in at-risk patients. In retrospective studies, iVAC were associated with fewer wound complications, deep infections, and reoperation than standard surgical dressings after treatment of periprosthetic hip and knee fractures [35]. Similarly, incisional negative-pressure wound therapy (iNPWT) dressings were associated with improved wound healing and fewer surgical site infections after revision total hip or knee arthroplasty, but there was no difference in wound dehiscence, deep infection, or reoperation [36,37]. Similar results were observed when iNPWT was used after total ankle arthroplasty [38], long-segment thoracolumbar fusions [39], and high-risk musculoskeletal oncologic wounds [40]. Two prospective randomized controlled trials have also explored the use of iNPWT in high-risk orthopedic trauma wounds. In industry-funded research, Stannard et al demonstrated a significant reduction in total infections when iNPWT was used after severe open tibia fractures [41] and high-risk lower extremity fractures (calcaneus, pilon, and tibial plateau fractures) [42].

In addition, evidence suggests that iNPWT decreases postoperative hematoma and seroma size and the time to a dry wound. Multiple prospective randomized controlled trials have further shown that iNPWT decreases hematoma/seroma size and the time to a closed dry wound after high-energy trauma [43], hemiarthroplasty [44], total hip arthroplasty [45], and spine fracture care [46]. Although there is strong evidence that iNPWT has a causal effect on known risk factors for infection (e.g. persistent hematoma or seroma, continued wound drainage), none of these trials were adequately powered to assess for differential infection rate in wounds treated with iNPWT vs standard surgical dressings.

iVACs, however, do not appear to provide a clinical benefit in routine cases. A retrospective study by Redfern et al demonstrated no difference in superficial or deep infection rates with the use of iVACs in primary total hip or knee arthroplasty [47]. Three prospective randomized controlled trials have studied the use of iNPWT to prevent infection after standard closure in trauma or arthroplasty. Crist et al found no difference in the rate of deep infection when iNPWT was used after open reduction and internal fixation of uncomplicated acetabular fractures [48]. Similarly, there was no difference in wound healing or wound complications between iNPWT in standard surgical dressings after routine total hip arthroplasty and after total knee arthroplasty [49,50]. In addition, in routine cases, iVACs incur unnecessary additional cost and may cause iatrogenic problems such as skin blistering [51,52].

Finally, evidence suggests that iVACs may also play a role in resolving some cases of early, benign postoperative drainage. In a retrospective study of the use of iVACs for 109 patients with benign early postoperative drainage after hip arthroplasty, Hansen et al found that the intervention halted wound drainage without further surgery in most cases and did not find increased complications specific to the device [53].

In conclusion, the use of iVAC dressings is a reasonable option in orthopedic patients at risk for wound-healing complications and may decrease such complications in such patients. The use of iVACs in all cases is likely unnecessary. In addition, iVACS may also play a role in resolving some cases of early, benign postoperative drainage [44].

Question 3: Do antibacterial-coated sutures reduce the risk of subsequent SSI/PJI?

Recommendation:

The use of antibacterial-coated sutures reduces the risk of SSI after colorectal surgery. There is no conclusive evidence that its use reduces the risk of subsequent SSI/PJI in orthopedic patient populations.

Level of Evidence: Limited

Delegate Vote: Agree: 92%, Disagree: 3%, Abstain: 5% (Super Majority, Strong Consensus)

Rationale:

The risk factors for surgical site infection (SSI) are multifactorial [54]. The presence of suture material, considered a prosthetic implant, logarithmically reduces the number of organisms needed for SSI from 10^5 to 10^2 colony-forming units and therefore increases the rate of an SSI [55]. Triclosan, a broad-spectrum antibacterial agent against gram-positive and gram-negative bacteria, has been effectively used in suture material since 2003 to reduce SSI [56,57]. Triclosan-coated sutures (TCS) can create an "active zone" around the suture, inhibiting *Staphylococcus aureus*, *Staphylococcus epidermidis*, and methicillin-resistant strains of Staphylococci (methicillin-resistant *Staphylococcus aureus* and methicillin-resistant *Staphylococcus epidermidis*), *Escherichia coli*, and *Klebsiella pneumoniae* from colonizing on the suture for a minimum of 48 hours in in vitro studies [58,59].

TCS have been reported to reduce SSI in many surgical disciplines. In a randomized controlled trial of colorectal surgery, the use of TCS had a significantly lower incidence of wound infection than the use of nonantimicrobial sutures (4.3% vs 9.3%) [60]. In a meta-analysis with level I evidence, no publication bias and a robust sensitivity analysis, the use of TCS provided a reduction of approximately 30% in a population of 5000 patients after various clean, clean-contaminated, and contaminated surgeries [61]. A recent systematic review and meta-analysis included 21 randomized controlled trials (6462 patients) with various surgery types (colorectal, head and neck, abdominal, cardiac and vascular, and general surgery) and showed that SSIs were reduced significantly by the use of TCS compared with uncoated sutures (relative risk, 0.72; 95% confidence interval, 0.60 to 0.86; $P < .001$) [62].

Current clinical guidelines have contradictory suggestions for TCS. The World Health Organization [63] and the National Institute for Health and Care Excellence [64] support the use of TCS for the risk reduction of SSI. The Infectious Diseases Society of America [65] and the Society for Healthcare Epidemiology of America [66] are against its routine use. The recent Centers for Disease Control and Prevention guideline supports consideration of TCS use for the prevention of SSI, balancing clinical benefit and harm [67].

There is little evidence assessing the efficacy of TCS on SSI after total joint arthroplasty. To our knowledge, there has been one prospective study involving 2546 patients undergoing elective total joint arthroplasty at three hospitals [68]. A total of 1323 patients were randomized to a standard suture group and 1223 to the TCS group with SSI at 30 days postoperatively as a primary endpoint. Sprowson et al reported that the rate of superficial SSI was 0.8% in the control group and 0.7% in the TCS group ($P = .651$). The rate of deep SSIs was 1.6% in the control group and 1.1% in the TCS group ($P = .300$). The rate of deep and superficial SSIs was 2.5% in the control group and 1.8% in the TCS group ($P = .266$).

Based on the aforementioned level I studies on various types of surgeries and surgical wounds, the use of TCS seems to reduce the rate of SSI.

Question 4: Does the use of topical incisional sealants (i.e., Integuseal, Dermabond, and so forth) reduce the incidence of subsequent PJI/SSI in patients undergoing orthopedic procedures?

Recommendation:

Although we recognize that the use of topical incisional sealants has the potential to reduce wound drainage, there is no evidence that the use of such products has any impact on the incidence of SSI/PJI.

Strength of the Recommendation: Limited

Delegate Vote: Agree: 93%, Disagree: 2%, Abstain: 5% (Super Majority, Strong Consensus)

Rationale:

Commercially available topical incisional sealants (Integuseal, Dermabond, Liquiband, and others) aim to add strength and integrity to wound closure, and by sealing the wound, they may reduce the incidence of wound drainage. With the creation of an impervious mechanical barrier at the incision, these products are believed to reduce the entry of infecting organisms into the deeper tissues and the potential for subsequent surgical site infection (SSI)/periprosthetic joint infection (PJI). These products can be convenient to use as they may reduce the need for placement and removal of sutures and staples. These products remain popular in a variety of surgical specialties.

Some of the products have also demonstrated bactericidal activities against gram-positive bacteria in vitro [69]. However, effectiveness in preventing SSI remains in question. To date, randomized studies across surgical subspecialties have not shown significant reductions in infection rate with the use of these products. Two recent systematic reviews were conducted evaluating the effectiveness of adhesive sealants across multiple surgical specialties, primarily outside of orthopedics.

In 2010, fourteen randomized clinical trials (1152 patients) were included to determine the relative effects of various tissue adhesives and conventional skin closure techniques on the healing of surgical wounds. Only one of these studies was in the field of orthopedics. This study demonstrated that sutures were significantly better than tissue adhesives for minimizing dehiscence (10 trials). There was no difference between low-viscosity and high-viscosity adhesives in respect to dehiscence. Surgical procedures that were described by the studies were diverse and included hand surgeries, blepharoplasty, circumcision, and excision of benign skin lesions. None of these trials evaluated incisions around areas of high tension such as the knee.

There was no significant difference in the rate of infection comparing sutures and tissue adhesives. However, no study reported an a priori calculation for the sample size, and this may be relevant [70].

In 2014, another update of the previous study identified 19 additional eligible randomized clinical trials resulting in a total of 33 studies (2793 patients). There was low-quality evidence that sutures were significantly better than tissue adhesives for reducing the risk of wound breakdown (dehiscence; relative risk, 3.35; 95% confidence interval, 1.53 to 7.33; 10 trials, 736 participants that contributed data to the meta-analysis). For other outcomes—infection rate, patient and operator satisfaction, and cost—there was no evidence of a significant difference for either sutures or tissue adhesives. Eighteen trials that compared the use of tissue adhesives with sutures reported wound infection data; however, as eight of these 18 trials had no cases of infection, only data from the remaining ten studies contributed to the meta-analysis. The studies included for this review did not demonstrate any significant difference in the proportion of infections in incisions closed with tissue adhesives compared with other conventional techniques. No study reported an a priori calculation for the sample

size, and this may be relevant. Even the largest of the studies would have been unlikely to be adequately powered to show any significant difference given the relatively low incidence of wound infections after many types of surgery [31].

Recent SSI-prevention guidelines from the World Health Organization state that "antimicrobial sealants should not be used after surgical site skin preparation for the purpose of reducing SSIs." [71] A Cochrane review also found that "sutures were significantly better than tissue adhesives for minimizing wound dehiscence," and there was no difference in the SSI when skin adhesives were used [31,70].

The effect of 2-octyl cyanoacrylate (Integuseal) on SSI was evaluated in randomized trials in sternotomy [72,73], colorectal [74], and trauma surgery wounds [75]. A prospective study found that 2-octyl cyanoacrylate reduced the rate of SSI compared with the use of staples for skin closure in spinal surgery [76]. The use of Integuseal was also shown to decrease the incidence of SSI in cardiac surgery in another prospective study [77]. Nonrandomized data in orthopedics examine its use in arthroplasty [78] and scoliosis [79] surgery. The arthroplasty study was a single-arm, single-surgeon series of 360 patients with a 0.8% rate of superficial SSI, no PJI, and a single case of contact dermatitis.

Data on patients undergoing orthopedic procedures on the use of Dermabond have not revealed differences in SSI/PJI rates. One randomized trial found no difference in scar cosmesis or infection rate [30], and another two studies found decreased wound drainage with the use of Dermabond, but no difference in SSI/PJI rate [4,80]. No trial was adequately powered to detect a difference. In a large historical control study of hip and knee arthroplasty patients, no differences in infection rate were noted at 6-week follow-up [81]. A randomized controlled trial for skin closure after scheduled cesarean delivery demonstrated similar results using Dermabond or a monofilament synthetic suture [82].

Hypersensitivity reactions to these organic sealants are rare but can be serious [83–87]. A recent report of 3 patients with blistering periincisional contact dermatitis was found [86,87].

Given the presence of extensive data in other surgical subspecialties suggesting that topical adhesives do not lower surgical infection rates, the lack of data suggesting efficacy in orthopedics, and the rare, but serious, hypersensitivity reactions to these agents, we cannot recommend the routine use of incisional sealants for the purpose of prevention of SSI/PJI in patients undergoing orthopedic procedures.

Question 5: Does the use of surgical suction drains increase the risk of subsequent SSI/PJI?

Recommendation:

There is no direct evidence to suggest that the use of surgical drains (for <48 hours) leads to an increase in the rate of subsequent SSI/PJI. The use of surgical drains leads to a higher volume of blood loss and an increased need for allogeneic blood transfusion, which may indirectly increase the rate of SSI/PJI.

Level of Evidence: Limited

Delegate Vote: Agree: 90%, Disagree: 7%, Abstain: 3% (Super Majority, Strong Consensus)

Rationale:

In orthopedic surgery, the use of surgical drains has been most extensively evaluated in the subspecialty of hip and knee arthroplasty. Most of the studies regarding the use of surgical drains in hip and knee arthroplasty have focused on its effect on blood loss, on the need for transfusions, and on their effectiveness in preventing subsequent wound-healing complications including periprosthetic joint infections (PJIs) and surgical site infections (SSIs). The purpose of surgical drains is to optimize wound healing by reducing fluid (blood) accumulation in the surgical site. This may be related to several advantages including decreased tissue swelling and skin tension, which improves skin perfusion and decreases wound complications [88–92], reduced postoperative pain, enhanced recovery [89,92–94], and potentially lower risk for infection as the hematoma is believed to interfere with the body's defense mechanisms [94,95].

In a systematic review of the Cochrane database, Parker et al investigated the use of closed suction drainage after orthopedic surgery [96]. The investigation involved 36 studies involving 5697 surgical wounds and did not find benefit to the use of drains. Some of the outcomes specifically investigated were infection, wound complications, hematoma formation, and reoperation. The authors found no difference in the majority of the outcomes between cases with surgical drains and those without surgical drains. The only difference was found in the blood transfusion requirement with drains leading to a greater rate of transfusion. The use of drain reduced the rate of ecchymosis around the incision, the only benefit attributed to the use of surgical drain.

Additional studies illuminated on the incidence of superficial wound infections (Table 1). Only one study by Zeng et al [94] found a significantly lower rate of wound infection in patients undergoing primary total hip arthroplasty, in whom a surgical drain was used, versus those without a surgical drain. However, a pooled analysis found an elevated superficial infection rate in the nondrainage group ($P = .045$; relative risk, 0.76; 95% confidence interval, 0.574 to 1.017). No significant differences in the prevalence of superficial wound infections were noted when studies for total hip and total knee arthroplasties were examined separately (Tables 2 and 3). The duration of drainage was not found to be related to the rate of superficial wound infection, which was 3.3% for the entire cohort and for both arthroplasties types ($P = 1$) (relative risk, 1; 95% confidence interval, 0.823 to 1.220). Yet, when reviewing the influence of drainage duration on total knee arthroplasties by itself, a longer drainage period was found to be related to increased superficial wound infection rates (2.1% vs. 0%). No similar effect was found for total hip replacements (Table 4).

Regarding deep wound infections, the literature shows that the use of surgical drain in general was not related to increased rates of deep infection. None of the thirteen included studies have reported a significant difference in the incidence of deep wound infections (Table 5). Likewise, the pooled results have also failed to demonstrate a significant difference between groups and for total hip and knee arthroplasties separately. The rate of deep infection was 1.5% in total, 0.8% for wounds treated with drains, and 1.6% for wounds left without drains ($P. = 0.185$) (relative risk, 0.7; 95% confidence interval, 0.405 to 1.210) (Table 1). Deep infection rates were 1% (0.9% and 1.1% for the drainage and nondrainage groups, respectively) and 1.4% (0.7% and 2.4% for the drainage and nondrainage groups, respectively) after total hip and total knee arthroplasties, respectively (Tables 2 and 3).

A subanalysis was performed on the influence of drainage duration on infection rates and found that a longer drainage duration was significantly related to increased deep infection rates. This correlates with results of others who showed increased positive cultures from drainages that were left inside the wound for

Table 1
Results for Total Hip and Total Knee Arthroplasties.

Outcome Measure	Studies Included		Cohort	N (%)	*P* Value
Blood transfusion (patients)	7	Drainage	679	190 (28.0)	.013
		No drainage	585	127 (21.7)	
Superficial wound infection	13	Drainage	987	28 (2.8)	.045
		No drainage	883	39 (4.7)	
Deep wound infection	13	Drainage	987	8 (0.8)	.185
		No drainage	883	13 (1.6)	
Length of stay	6	Drainage	613	6.9 ± 3.3	.871
		No drainage	575	6.6 ± 3.3	

Table 2
Results for Total Knee Arthroplasty.

Outcome Measure	Studies Included		Cohort	N (%)	*P* Value
Blood transfusion (patients)	3	Drainage	211	67 (31.8)	.794
		No drainage	100	30 (30)	
Superficial wound infection	13	Drainage	410	4 (1.0)	.727
		No drainage	296	4 (1.4)	
Deep wound infection	13	Drainage	410	3 (0.7)	.104
		No drainage	296	7 (2.4)	

longer periods [91,97]. The duration of time for which the drainage was left in the wound was stated in 10 studies [90,92,94,98–104] and was either 24 or 48 hours (in one study [98], the average duration was 20 hours, range of 15-26 hours, and was added to the 24-hour group for analysis). A longer duration of wound drainage was found to be significantly associated with an increased rate of deep wound infection, as the prevalence of deep wound infection was 2.7% in the 48-hour group and only 0.3% in the 24-hour drainage group ($P = 0.006$) (relative risk, 0.363; 95% confidence interval, 0.1123 to 1.1702). This was also true for a pooled analysis for the total knee arthroplasty group (6 studies included, $P = 0.016$), but not for the total hip arthroplasty group (4 studies included, $P = 0.162$) (Table 4). It can be summarized that both deep and superficial infection rates were insignificant when drainage duration was limited to shortened periods of time and with prompt removal.

In general, it was found that surgical drains led to an increased need for blood transfusion. This is important regarding SSI/PJI because blood transfusions are believed to be associated with immunosuppression, and postoperative infections rates are reported to be higher after blood transfusion [105,106]. Seven studies provided the number of patients treated with blood transfusions after surgery [94,99,102–104,107,108]. Three studies [99,103,108] found the drainage group to require significantly higher transfusion rates. Likewise, the pooled analysis also found this group to necessitate more blood units, as 28% of the patients in the drainage group were given blood compared with 21.7% in the nondrainage group ($P = 0.013$) (relative risk, 1.16; 95% confidence interval, 1.001 to 1.238) (Table 1). Separate analysis for total hip arthroplasties, including 4 studies, also found the number of patients requiring blood transfusions to be higher in the drainage group, 26.3% vs. 20% the other group ($P = 0.026$; relative risk, 1.19; 95% confidence interval, 1.032 to 1.367). No similar effect was found for total knee arthroplasties (Tables 2 and 3).

Many of the aforementioned randomized controlled studies have investigated the use of surgical drains in the setting of hip and knee arthroplasties. It has been established that for most measures, there are no differences when comparing drains to no drains, except increased blood loss and transfusion requirements. Many of these studies have investigated whether drains decrease wound complications and SSI/PJI, and they have universally shown no difference, in turn showing that surgical drains do not appear to increase the risk of subsequent SSI/PJI when used for a shortened duration of time.

Table 3
Results for Total Hip Arthroplasty.

Outcome Measure	Studies Included		Cohort	N (%)	*P* Value
Blood transfusion (patients)	4	Drainage	468	123 (26.3)	.026
		No drainage	485	97 (20)	
Superficial wound infection	13	Drainage	577	24 (4.2)	.110
		No drainage	537	35 (6.5)	
Deep wound infection	13	Drainage	577	5 (0.9)	.767
		No drainage	537	6 (1.1)	

Table 4
Results for Duration of Drainage, Total Hip Arthroplasty, and Total Knee Arthroplasty.

Outcome Measure	Studies Included			Cohort	N (%)	*P* Value
Blood transfusion (patients)		5	24 h	476	104 (21.8)	<.001
			48 h	98	53 (54.1)	
Superficial wound infection	All	10	24 h	679	22 (3.3)	1
			48 h	187	6 (3.3)	
	Knee	6	24 h	268	0 (0)	.004
			48 h	92	4 (2.1)	
	Hip	4	24 h	411	22 (5.4)	.282
			48 h	95	2 (2.1)	
Deep wound infection	All	10	24 h	679	2 (0.3)	.006
			48 h	187	5 (2.7)	
	Knee	6	24 h	268	0 (0)	.016
			48 h	92	3 (3.3)	
	Hip	4	24 h	411	2 (0.5)	.162
			48 h	95	2 (2.1)	

Question 6: Which surgical dressing (i.e., occlusive, silver impregnated, dry gauze) is associated with a lower risk of SSI/PJI in patients undergoing orthopedic procedures?

Recommendation:

Occlusive and/or silver-impregnated dressings have been proven to reduce the rate of wound complications, surgical site infection (SSI), and periprosthetic joint infection (PJI) compared with standard gauze dressings and should be considered for routine use. The majority of the literature at present focuses on total joint arthroplasty. However, further research is required to see if the added antimicrobials (such as silver), the occlusive, active nature of the dressing, or their combination is responsible for the demonstrated reduction in SSI/PJI.

Level of Evidence: Moderate

Delegate Vote: Agree: 81%, Disagree: 12%, Abstain: 7% (Super Majority, Strong Consensus)

Rationale:

To successfully prevent the surgical site infection (SSI) and periprosthetic joint infection (PJI), the patient must be optimized before, during, and after orthopedic surgery. One method of infection prevention gaining recent attention is the type of postsurgical dressing. Wound complications are common after orthopedic procedures. These are particularly important in total joint arthroplasty (TJA) as patients are encouraged to mobilize early and often and wounds are over mobile areas such as the knee joint. Appropriate prevention and management is crucial because wound issues can lead to PJI if left untreated [54]. Although traditional gauze and tape dressings have been used after surgical procedures for decades, new commercial dressings have questioned this practice [109–111].

Dressings have been classified as passive (gauze, absorbent pads, adhesive tapes, island dressings), active (films, hydrocolloid, hydrofiber, alginate, foam), and interactive (antimicrobial, biomaterial, larva therapy, vacuum dressings) [112]. Passive dressings only serve a protective function, whereas active dressings promote healing through the creation of a moist environment. Interactive dressings interact with the wound bed to further enhance healing and include, for example, antimicrobial agents (such as silver). An increasing body of literature supports the use of a dressing that provides an impermeable barrier to pathogens and preserves a moist environment. Good fluid management capacities are important to prevent excess exudation, which causes maceration, and to reduce the frequency of dressing changes, thereby reducing the risk of exposure to outside pathogens [112]. Although many studies have compared various dressings and the rate of wound complications (defined as blisters, erythema, maceration, leakage) or fluid-handling capacity (wear time, mean dressing changes)

Table 5
Characteristics of the Studies.

First Author	Publication Year	Procedure	No. of Wounds With Drainage	No. of Wounds Without Drainage	Mean Age	Male Patients (%)	Length of Follow-Up (mo)
Abolghasemian [90]	2016	Revision TKA	42	41	NA	38 (47)	3
Fichman [103]	2016	Revision THA	44	44	68	40 (45)	1.5
Suarez [107]	2016	Primary THA	59	61	63	60 (52)	1.5
Koyano [89]	2015	Bilateral TKA	51	51	NA	NA	1[a]
Zhang [101]	2015	Primary UKA	48	48	67	28 (30)	18.3
Zeng [94]	2014	Primary THA	83	85	60	81 (48)	3
Li [108]	2011	Primary TKA	50	50	63	26 (34)	12
Omonbude [98]	2010	Primary TKA	40	38	NA	NA	1.5
Seo [102]	2010	Primary TKA	111	0	73	6 (5)	12
Strahovnik [92]	2010	Primary THA	97	42	66	46 (33)	3
Walmsley [99]	2005	Primary THA	282	295	68	213 (39)	36
Esler [104]	2003	Primary TKA	50	50	73	45 (45)	NA
Kim [100]	1998	Bilateral TKA	69	69	64	10	12

THA, total hip arthroplasty; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty; NA, not available.
For all the 13 studies, only patients in the nonproteinase inhibitor groups were included.
[a] No specific follow-up duration was mentioned, yet a complication after one month was noted.

[112], few have been adequately powered to investigate rates of SSI and PJI [113–119]. Sharma et al [112] recently performed a systemic review and meta-analysis on twelve randomized controlled trials [113–124] comparing alternative dressing materials for postoperative management of wounds after TJA. Eight of these studies reported SSI data, but no dressing type was superior over another in SSI reduction. However, occlusive film dressings (odds ratio [OR], 0.35; 95% confidence interval [CI], 0.21–0.57) or occlusive dressings with hydrofiber (OR, 0.28; 95% CI, 0.20–0.40) were significantly less likely to have wound complications than those managed with passive (standard) dressings [112]. The authors concluded that there was insufficient evidence available to determine whether the use of these advanced dressings reduced PJI.

Recently, two interactive dressings are gaining popularity. One is the Aquacel Ag surgical dressing (ConvaTec) that both maintains a moist environment through the use of a weaved cellulose center (hydrofiber) that allows it to contour to the skin and prevents the growth of microorganisms by releasing antimicrobial ionic silver when in contact with fluid [125,126]. Another is the Silverlon Surgical Dressing (Argentum Medical) with a woven nylon dressing that is silver plated and embedded in a waterproof foam adhesive [127]. Three large-cohort, case-controlled studies have retrospectively investigated the utlility of these dressings for PJI reduction after TJA. All three studies used the Musculoskeletal Infection Society criteria for PJI [125–127]. Cai et al compared 903 patients receiving an Aquacel Ag dressing (removed at 5 days) to 875 receiving a standard xeroform and gauze dressing removed at 2 days after TJA [126]. They reported an acute PJI rate (within 3 months of surgery) of 0.44% in the Aquacel Ag dressing group compared with 1.7% in the standard gauze dressing group ($P = .005$). A multivariate analysis revealed that the use of Aquacel dressing was an independent risk factor for reduction of PJI (OR, 0.165; 95% CI, 0.051–0.533; $P = .003$) [126]. These results were corroborated by Grosso et al who compared 605 patients with Aquacel Ag dressing (removed at 7 days) to 568 patients with xeroform and gauze dressings (removed at 2 days and changed every other day) after TJA [125]. The incidence of acute PJI for patients managed with a sterile xeroform dressing was 1.58% (9/568). The incidence of PJI for patients managed with the use of Aquacel dressing was 0.33% (2/605, $P = .03$). Similar to Cai et al, a multiple logistic regression demonstrated the use of an Aquacel dressing as a protective factor for PJI (OR, 0.092; 95% CI, 0.017-0.490; $P = .005$) [125]. Tisosky et al evaluated 309 patients with the Silverlon dressing (removed at 7 days) compared with 525 patients with xeroform and gauze (removed at 2 days) after TJA [127]. They found an overall infection rate of 8.4% in the control group versus 3.90% in the Silverlon group (OR, 0.38; 95% CI, 0.25-0.58; $P = .012$). There was no PJI in the Silverlon group vs 12 (2.3%) in the control group ($P = .007$). In addition, the superficial infection rate was 6.1% in control vs 3.9% in Silverlon (OR, 0.54; 95% CI, 0.34-0.87; $P = .011$). In a multivariate logistic regression analysis, the Silverlon dressing was independently associated with decreased infection (OR, 0.39; 95% CI, 0.27-0.57; $P < .0001$) [127]. Finally, Kuo et al performed a prospective, randomized control trial comparing the Aquacel Ag to a standard dressing in 240 TKA patients [128]. They found that the Aquacel Ag dressing was independently associated with a reduction in SSI (as defined by the Center for Disease Control [129]) when controlling for confounding variables (OR, 0.07; 95% CI, 0.01–0.58; $P = .01$) [128].

In conclusion, active and interactive dressings have been shown to reduce the rates of SSI and PJI after joint arthroplasty compared with passive dressings. The benefit of adding antimicrobial/antiseptic agents such as silver or 0.2% polyhexamethylene biguanide [130] in postoperative dressings is still controversial as few studies have compared active dressings to interactive dressings [131]. In addition, studies investigating the use of active or interactive dressings in foot and ankle surgery [132], hip fracture surgery [133], and spinal fusion [134] are limited and have not demonstrated a reduction in SSI. Finally, formal cost-effectiveness studies will be needed to see if the increased price of the occlusive, silver-impregnated dressings (USD $30-40) [126,127] compared with that of standard dressings (USD $2-5) is justified for routine vs selective use by the reduction in cost with decreased SSI/PJI.

Question 7: When should sterile surgical dressings be removed and how frequently should subsequent dressings be changed after orthopedic procedures?

Recommendation:

The dressing placed over the surgical wound under sterile conditions in the operating room should be changed based on saturation of the dressing. Early removal and frequent changes of the surgical dressing are not needed if there is no significant bleeding or drainage on the original dressing. If the dressing remains dry, wound coverage for a minimum of 48 hours has been recommended.

Level of Evidence: Limited

Delegate Vote: Agree: 97%, Disagree: 3%, Abstain: 0% (Unanimous, Strongest Consensus)

Rationale:

Sterile dressings are applied to the skin after primary closure in most orthopedic surgery. Dressing acts as a physical barrier, which protects the wound from contamination until the continuity of the skin is restored [114]. The first phase of the wound-healing cycle is the hemostasis phase, during which the continuity of the skin is restored. In the clean wound, with regular edges after incisions, the wound is usually closed within 48 hours [135]. The general practice is to cover surgical incisions after procedure to control postoperative bleeding, to absorb exudates, and to provide protection [109]. The ideal dressings produce a moist, warm, and clean environment that promotes wound healing [136,137]. However, the moist environment created by a dressing left on the wound for a longer period could increase the risk of maceration, leading to weakening of the tissue and wound [138].

Concerning the prevention of surgical site infections (SSIs), the ideal timing of dressing removal is an unresolved issue. Some professionals prefer to leave wounds uncovered from the moment of closure, others uncover them after a certain time, and still others keep them covered until suture removal [109]. Clinical guidelines from the US Centers for Disease Control and Prevention (Mangram et al 1999) and the British National Collaborating Center for Women's and Children's Health, the latter commissioned by the National Institute for Health and Clinical Excellence (2008), mainly recommend covering surgical incisions with a dressing for a period of at least 48 hours postoperatively. Uncovered or early exposed wounds seem to be associated with an increased risk of contamination and SSIs, but some studies suggest that longer dressing periods have no benefits [109]. Although an abundance of studies comparing different dressings are available, no meta-analyses or systematic reviews of randomized clinical trials (RCTs) of early vs late removal of sterile dressings in orthopedic surgery exist. One RCT comparing removal of a bulky dressing after 2 weeks to removal after 48-72 hours after carpal tunnel decompression found no significant difference in wound complication, but the study consisted of a rather small cohort of 94 patients, none of whom developed an SSI [139].

One systematic review on early vs late dressing removal including all surgical specialties was identified, in which 3 RCTs were included with a total of 280 patients [140]. Participants in the three studies were randomized to early dressing removal (<48 hours after surgery) or delayed dressing removal (continued dressing for >48 hours after surgery). The primary outcome was SSI as defined by Horan et al [141]. There was no significant difference in the proportion of people who developed superficial SSI between the early and delayed dressing removal groups. No deep SSI or deep dehiscence was reported in the early or in the delayed dressing removal groups [140].

In addition to the systematic review, two randomized controlled trials were identified, which investigated the effect of early removal of wound dressing on the risk of infection. The primary outcome for both the studies was SSI. Heal et al compared removing the dressing within the first 12 hours with leaving the dressing on for the first 48 hours and found no statistically significant difference in the incidence of SSI [142]. In a similar study, Chrintz et al compared removal of dressing after 24 hours with keeping the wound dressed until removal of the sutures and found no statistically significant difference in the incidence of SSI [143].

If the dressing is disturbed less often, the risk of infection is reduced, and this aids the healing process [144]. Every time a dressing is changed, there is a potential risk for introducing pathogens into the wound, which can subsequently lead to SSI or periprosthetic joint infection. Wound dressings keep the wound near core body temperature, which increases the rate of mitotic cell division and leukocyte activity that are necessary for wound healing. When a dressing is changed, it takes 3-4 hours for the cellular activity of the wound to resume. Hence, episodic cooling associated with dressing changes should be avoided as much as possible. Also, fewer dressing changes protect the wound from repeated exposure to pathogens in the surrounding air [145].

The costs associated with a wound dressing depend on two factors: (1) the unit cost of the dressing and (2) the number of dressing changes required [146], which means fewer dressing changes can decrease the costs.

Dressing changes can also be affected by dressing type. Modern dressings need less frequent changes and can decrease the rate of acute SSI/periprosthetic joint infection [126]. Abuzakuk et al demonstrated that there were less dressing changes for hydrofiber dressings within the first five postoperative days compared with the use of a central pad group. They theorized that leaving the hydrofiber dressing undisturbed for a longer period of time could help prevent wound infections [118]. Hopper et al showed that wear time for the traditional dressing (2 days) was significantly shorter than that for the modern dressing (7 days; $P < .001$) and required more changes. They also found that the modern dressing can create less needs for dressing changes, thus decreasing burden on health-care personnel, diminishing superficial wound problems, and avoiding delays in hospital discharge due to wound-healing issues [147].

Question 8: Do patients need to refrain from getting the surgical incision wet or submerged in water to prevent SSI/PJI? If so, for how long postoperatively?

Recommendation:

Patients need to refrain from getting the surgical incision wet for the first 48 hours after surgery.

Level of Evidence: Limited

Delegate Vote: Agree: 86%, Disagree: 11%, Abstain: 3% (Super Majority, Strong Consensus)

Rationale:

Adequate postoperative wound hygiene is of major importance for prevention of surgical site infection (SSI). However, limited literature about postoperative washing is available. Wound reepithelialization of the incision occurs within 48 hours, although this process can vary among patients [148]. Owing to lack of evidence regarding the best manner of managing surgical wounds in the postoperative period, surgeons' instructions to patients for treating surgical wounds vary. Time period of 2 weeks is widely proposed to prevent contamination of sutures themselves [149] because this is the time frame for staple or suture removal [12].

The 2008 National Institute for Health and Care Excellence guidelines [150] suggest keeping surgical wounds covered and dry for at least 48 hours after surgery. During this time, wounds may be washed with sterile saline solution. Only one randomized controlled trial with a relatively low number of patients (32) has evaluated if showering can affect bacterial load after primary total knee arthroplasty [151]. Yu et al evaluated wound colonization by bacteria at various points up to 2 weeks in two groups consisting of 16 patients each. One group was allowed to shower at 2 days postoperatively, and the other group was instructed to wait until 2 weeks. They reported no statistically significant differences in terms of microorganism prevalence, with no infections noted during the study. Greater patient satisfaction was noted in the early shower group; however, a significant limitation of the study was its small sample size [151]. Hsieh et al in another clinical trial compared wound-related outcomes after general surgical procedures in two equal groups comprising of 222 patients [152]. One group was allowed to get the surgical wound wet at 48 hours after surgery and the other delayed washing until stitch removal. They demonstrated that clean and clean-contaminated wounds can be safely showered 48 hours after surgery. Postoperative showering did not increase the risk of surgical site complications. Increased

patient satisfaction and lower cost of wound care are two benefits reported for early wound washing. Heal et al conducted a large prospective randomized controlled trial for minor skin excisions within general practice [142]. They concluded that wounds can be allowed to get wet in the first 48 hours after minor skin excision without increasing the incidence of infection.

In a systematic review, Dayton et al found 9 randomized clinical trials which showed that there was no reason to avoid showering or bathing the surgical wound as part of routine hygiene during the healing period [153]. In addition, there was no increased risk of surgical wound infection after wound washing at 12 hours after surgery. In two Cochrane database reviews, Toon et al [154] and Chang [155] reported that no conclusive evidence is currently available regarding the benefits or harms of early vs delayed postoperative showering or bathing for the prevention of wound complications. They recommended further randomized controlled trials to compare early vs delayed postoperative showering or bathing.

Several other studies, not directly related to arthroplasty, including general surgical incisions [156], sutured wounds [157], spinal surgical sites [158], and foot and ankle surgeries [159] have failed to demonstrate increased infection rates when early showering was allowed. Nevertheless, published data also demonstrate similar rates of SSI in surgical wounds that remained covered or uncovered and washed with tap water in the first 48 hours after surgery [160,161]. In addition, cleaning with tap water vs sterile saline was found to have no effect on the incidence of infection [162].

The role of wound submersion in terms of SSI is further complicated by the availability of occlusive dressings, which have gained wide acceptance recently [163]. Dressings that are impermeable to water have been reported to reduce incidence of infection after joint arthroplasty [113,126,128].

Showering after surgery remains a controversial issue in orthopedic surgery. A potential harm would be wound-related complications. On the contrary, benefits of early showering would be an improvement in quality of life and better rehabilitation outcomes [164].

Question 9: What is the definition of persistent wound drainage?

Recommendation:

There is no validated definition of "persistent wound drainage". In the absence of such data, we define persistent wound drainage as any continued fluid extrusion from the operative site occurring beyond 72 hours from index surgery.

Level of Evidence: Consensus

Delegate Vote: Agree: 78%, Disagree: 17%, Abstain: 5% (Super Majority, Strong Consensus)

Rationale:

Early wound drainage is not uncommon in patients undergoing total joint arthroplasty and can be observed in up to 10% of patients [165–167]. Serous or serosanguinous drainage shortly after the procedure is benign and can be explained by the surgical disruption of superficial capillaries. On the contrary, many publications have noted the severity of persistent drainage, which may potentially be a sign of an evolving infectious process [166,168–172]. The previous 2013 international consensus meeting on periprosthetic joint infection reached a strong consensus that continued drainage at 72 hours postoperatively should be closely monitored and that a wound persistently draining for more than 5 or 7 days after diagnosis should be reoperated on without delay [169]. It is also advisable to refrain from collecting culture samples of the drainage early on because these will often yield normal skin flora [168].

In a study conducted by Patel et al composed of 2437 total hip arthroplasty and total knee arthroplasty (TKA) patients, they concluded that every additional day of wound drainage increased the probability of developing a wound complication after total hip arthroplasty and TKA by 42% and 29%, respectively [173]. In addition, Galat et al performed a study of 17,784 patients who underwent primary TKA and discovered that patients who require earlier surgical intervention for wound-healing complications are at a significantly increased risk for additional interventions, such as deep infection surgery, resection arthroplasty, muscle flap coverage, or amputation [167].

The difficulty lies in accepting a definition for "persistent drainage" to allow for timely intervention because literature is not consistent. For instance, in a recent study involving 127 orthopedic surgeons who replied to wound drainage questionnaires, the highest portion of respondents (36.7%) defined persistent wound

Table 6
Literature with Definitions of Persistent Wound Drainage.

Author	Year	Number of Procedures	Definition	Additional Notes/Conclusions
Weiss and Krackow [165]	1993	597	1. Drainage for 4 consecutive days after POD 5 2. Drainage that significantly soaks a 2" × 2" gauze dressing 3. Drainage that emanated from the same specific site(s) along the wound.	Primary and revision TKA; 1.3% developed persistent drainage.
Saleh K et al [170]	2002	2305	2 d postoperatively for noninfected cases; 5.5 d postoperatively for infected cases.	There is a 12.7 times greater risk of SSSI for wounds draining more than 5 d.
Jaberi et al [166]	2008	11,785	Drainage for more than 48 h postoperatively that soaks through postoperative dressings.	Primary and revision TJA; 2.9% developed persistent drainage.
Butt et al [175]	2011	77	Continued drainage beyond POD 4.	Primary TKA; periarticular local anesthesia, subvastus approach, and tourniquet time led to less wound drainage.
Hansen et al [53]	2013	109	Continued drainage beyond POD 3 or 4.	Primary and revision THA.
Parvizi et al [169] (2013 ICM on PJI)	2013	n/a	Continued drainage from operative site for more than 72 h postoperatively.	Strong consensus among delegates. Persistent drainage for more than 5 or 7 d after diagnosis should be reoperated on without delay.

ICM, international consensus meeting; TKA, total knee arthroplasty; TJA, total joint arthroplasty; THA, total hip arthroplasty; POD, postoperative day; PJI, periprosthetic joint infection; SSSI, superficial surgical site infection.

drainage as one occurring for more than 5 days postoperatively, whereas other respondents defined the duration as anywhere from more than 1 day to greater than 14 days postoperatively [174]. Weiss and Krackow were among the first to attempt defining persistent drainage [165]. Several other authors afterward defined persistent wound drainage by time, type of exudate (serous, sanguineous, purulent, and so forth), site (wound or from suction drains), and presence of microorganisms from culture. Table 6 shows a list of predominant definitions that have been developed.

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