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Proceedings from the 2018 International Consensus Meeting on Orthopedic Infections: prevention of periprosthetic shoulder infection

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The Second International Consensus Meeting on Orthopedic Infections was held in Philadelphia, Pennsylvania, in July 2018. Over 800 international experts from all 9 subspecialties of orthopedic surgery and allied fields of infectious disease, microbiology, and epidemiology were assembled to form a consensus workgroup. The following proceedings on the prevention of periprosthetic shoulder infection come from 16 questions evaluated by delegates from the shoulder section.

Keywords: Prevention; shoulder arthroplasty; periprosthetic shoulder infection; antibiotic-impregnated cement; chlorhexidine gluconate (CHG); MRSA; *Cutibacterium acnes*; antibiotic prophylaxis

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[1] Question 15
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Antibiotics

Question 1: What are the optimal perioperative antibiotics for primary shoulder arthroplasty?

Recommendation

Patients undergoing primary shoulder arthroplasty should receive intravenous antibiotics that cover gram-positive and gram-negative organisms specific to the regionally (geographic) encountered organisms. The peer-reviewed literature supports that cefazolin be dosed based on body weight. Patients with methicillin-resistant *Staphylococcus aureus* (MRSA) colonization should receive weight-based glycopeptide, preferably in combination with cefazolin. Patients with an intolerance to β-lactam antibiotics should be further evaluated to determine if they can receive cefazolin. Patients with a true hypersensitivity reaction or adverse reaction that precludes the use of cefazolin should receive vancomycin or clindamycin.

Level of Evidence: Consensus

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

A thorough search of the PubMed database for all available literature on the topic of optimal perioperative antibiotics for primary shoulder arthroplasty was undertaken. There are no prospective controlled studies comparing surgical antibiotic prophylaxis strategies for shoulder arthroplasty that adequately assess clinical outcomes. Studies measuring microbial burden (primarily *Cutibacterium acnes*) at the time of incision after antimicrobial prophylaxis in the setting of shoulder surgery have been disappointing. One small randomized controlled study comparing preoperative doxycycline administration vs. placebo did not demonstrate a reduction in *C acnes* colonization.[85] The relevance of these findings with respect to surgical prophylaxis in the shoulder is not known. Surgical prophylaxis in total joint arthroplasty does reduce the burden of other cutaneous microorganisms and is recommended for all orthopedic implant surgery.[2,6,11]

Prophylaxis should target organisms most likely to cause prosthetic shoulder infection. The most common organisms causing shoulder surgical-site infection (SSI) and periprosthetic joint infection (PJI) are coagulase-negative *Staphylococcus* species, *C acnes*, and *Staphylococcus aureus*.[42,63,75,104,117] In addition to the antimicrobial spectrum, agents selected for prophylaxis should achieve bactericidal tissue concentrations at the time of incision. In the absence of shoulder-specific literature and recognizing the microbiology and other factors, we believe it is reasonable to extrapolate from the non–shoulder arthroplasty literature. The agent most likely to provide optimal tissue concentrations for prophylaxis against these organisms is cefazolin, dosed based on patient body weight (Table I).[9] Vancomycin should be used when patients have a history of MRSA colonization or infection. Paying close attention to dosing based on body weight and the earlier timing of prophylaxis when vancomycin is used is paramount.[11,59] Ideally, vancomycin should not be given alone, as studies have identified an increased risk of PJI and SSI potentially owing to the narrower spectrum of vancomycin compared with cefazolin.[7,44] Combination therapy with vancomycin and cefazolin has not been prospectively demonstrated to reduce SSI risk in arthroplasty patients over cefazolin alone, although 2 studies have suggested a trend toward reduced infection.[10,100] Combination therapy may be associated with higher rates of nephrotoxicity than vancomycin alone[10]; however, the value of preventing PJIs may still justify its use. Additional study to clarify the risks and benefits of these strategies is warranted.

One of the most common reasons for use of an alternative perioperative antibiotic is β-lactam allergy or intolerance. Most of these patients are not actually allergic and will be able to safely receive cefazolin after evaluation by

Table I Recommended antimicrobial prophylaxis for patients undergoing primary shoulder arthroplasty

Clinical situation	Antimicrobial recommended
No β-lactam allergy	Cefazolin, 2 g IV (3 g if patient weighs > 120 kg), should be administered starting within 30-60 min prior to incision; re-dosing is performed every 4 h; postoperative doses are not required and should not be given beyond 24 h.
Personal history of MRSA infection or colonization	Vancomycin, 15 mg/kg (maximum dose, 2 g), should be administered starting within 2 h prior to incision; postoperative doses are not required and should not be given beyond 24 h. We favor the addition of cefazolin to vancomycin.
Proven serious β-lactam allergy	Vancomycin, 15 mg/kg (maximum dose, 2 g), should be administered starting within 2 h prior to incision; postoperative doses are not required and should not be given beyond 24 h.

IV, intravenously; *MRSA*, methicillin-resistant *Staphylococcus aureus*.

an allergist.[92] Patients with a true hypersensitivity reaction or adverse reaction that prohibits cefazolin should receive vancomycin or clindamycin, in agreement with the Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery.[11]

Question 2: What are the optimal perioperative antibiotics for patients undergoing revision shoulder arthroplasty?

Recommendation

Patients undergoing revision shoulder arthroplasty should receive prophylactic antibiotics as discussed in Question 1. As addressed in Question 5, if there is suspicion of pre-existing infection during surgery, oral amoxicillin or first-generation cephalosporin (or oral doxycycline if the patient is allergic to β-lactam) should be considered until cultures are finalized.

Level of Evidence: Consensus

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

A thorough search of the PubMed database for studies evaluating the optimal perioperative antibiotic for patients undergoing revision shoulder arthroplasty did not identify any prospective controlled studies comparing surgical antibiotic prophylaxis strategies for revision shoulder arthroplasty that adequately assess clinical outcomes.

Prophylaxis should target organisms most likely to cause prosthetic shoulder infection (Table I). The most common organisms to cause shoulder SSI and PJI are coagulase-negative *Staphylococcus* species, *C acnes* (formerly known as *Propionibacterium acnes*), and *S aureus*.[42,104,117] In revision surgery, absent an obvious reason for joint failure such as trauma, there may be a question of whether pain and/or stiffness is the result of occult PJI. *C acnes*, in particular, has emerged as a pathogen often isolated from deep operative specimens in patients undergoing revision shoulder arthroplasty for pain and/or stiffness.[49]

Unfortunately, inflammatory markers are often normal in these patients, and intraoperative evaluation is often benign appearing, making it difficult to predict which cases will have positive culture findings. Thus, surgeons may consider postoperative oral antibiotics to cover the most likely pathogen that may be detected after discharge—*C acnes*—until final culture results are obtained.[9] This is distinctly different from the prophylactic antibiotic strategy for primary shoulder arthroplasty cases, which is typically limited to the first 24 hours after surgery.[59] Continuing prophylactic antibiotics carries a risk of adverse events such as diarrhea, *Clostridium difficile* infection, toxicities, development of antibiotic resistance, and drug interactions.

The rationale for selection of prophylactic antibiotics for revision shoulder arthroplasty cases is the same as that for primary cases (as described in the "Rationale" section for Question 1). Of note, timely administration of intravenous

Table I Recommended antimicrobial prophylaxis for patients undergoing revision shoulder arthroplasty

Clinical situation	Antimicrobial recommended at surgery*	Postoperative antimicrobials to consider if high intraoperative suspicion of infection
No β-lactam allergy	Cefazolin, 2 g IV (3 g if patient weighs > 120 kg), starting within 30 min prior to incision; re-dosing every 4 h; postoperative doses not required and should not be given beyond 24 h	Amoxicillin, 500 mg orally every 8 h, or cefadroxil, 500 mg orally twice daily × 14 d, until operative culture findings are negative (adjust for renal insufficiency)
Personal history of MRSA infection or colonization	In addition to cefazolin above, add vancomycin, 15 mg/kg (maximum dose, 2 g), starting within 1 h prior to incision; postoperative doses not required and should not be given beyond 24 h	Same as above unless positive intraoperative gram stain or culture finding positive for MRSA (in which case, convert to treatment program with ID consultation)
Proven serious β-lactam allergy	Vancomycin, 15 mg/kg (maximum dose, 2 g), starting within 1 h prior to incision; postoperative doses not required and should not be given beyond 24 h	Doxycycline, 100 mg orally every 12 h × 14 d, until operative culture findings are negative

IV, intravenously; *MRSA*, methicillin-resistant *Staphylococcus aureus*.

* Administration should be performed on time as usual, even if concern for occult infection exists.

prophylactic antibiotics immediately before incision is unlikely to negatively impact the yield of deep cultures, if obtained.[98]

Question 3: Are there perioperative antibiotics that should be used for patients who have specific preoperative risk factors (eg, patient sex and comorbidities) for shoulder PJI?

Recommendation

Although the risk of infection may be affected by demographic factors and comorbidities, outside of known MRSA colonization or true allergy, there are no patient-specific factors that justify a change in antimicrobial prophylaxis recommendations. Patients with MRSA colonization should receive a glycopeptide in addition to standard prophylaxis.

Level of Evidence: Consensus

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

The most common organisms to cause shoulder PJI are coagulase-negative *Staphylococcus* species, *C acnes*, and *S aureus*.[20,31,42,81,104,108,113] Although the risk of shoulder PJI is impacted by comorbidities and the prevalence of *C acnes* colonization is higher in men, there are no available data to support targeted modification of antimicrobial prophylaxis outside the setting of known MRSA colonization. In the hip and knee arthroplasty setting, 1 study did not find that differential antimicrobial prophylaxis impacted SSI risk when comorbidities were considered.[44] Studies have identified an increased risk of hip and knee PJI and SSI when prophylaxis with an agent other than cefazolin is used.[59,124]

Question 4: What is the optimal duration of perioperative antibiotics following primary or revision shoulder arthroplasty?

Recommendation

In primary cases, prophylactic intravenous antibiotics should be given within 1 hour prior to incision to decrease the risk of infection. Intravenous antibiotics may be continued for 24 hours postoperatively. In revision cases, intravenous antibiotics should be given within 1 hour prior to incision. Although controversial, the current evidence suggests that prophylactic antibiotics should not routinely be held until tissue specimens for culture are obtained. Intravenous antibiotics should only be continued for 24 hours postoperatively, unless there is a concern for periprosthetic infection. Antibiotics can be continued up until final culture results are obtained in revision cases if there is some suspicion of infection while awaiting the final culture results.

Level of Evidence: Moderate

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

Primary shoulder arthroplasty

Prophylactic intravenous antibiotics should be started within 1 hour prior to incision to decrease the risk of infection.[12,22,36,96,121,122,128] Intravenous antibiotics may be continued for 24 hours postoperatively.[121,122,128]

However, recent recommendations from the Centers for Disease Control and Prevention (CDC) suggest that prophylactic antibiotics be administered such that a bactericidal concentration is present in the serum and tissues prior to incision and suggest that additional prophylactic antibiotic treatment not be administered after the surgical incision is closed for clean and clean-contaminated procedures even in the presence of a drain.[6] Similar recommendations have recently been proposed by the World Health Organization suggesting preoperative antibiotic prophylaxis without postoperative dosing.[2]

Revision shoulder arthroplasty

Intravenous antibiotics should be started within 1 hour prior to incision. There remains some controversy regarding whether to administer antibiotics prior to obtaining culture specimens in the revision setting (Table I). On the basis of previous experience with revision shoulder arthroplasty,[101] McGoldrick et al[76] recommended withholding prophylactic antibiotics until after tissue cultures have been obtained especially in cases ''that have no overt preoperative evidence of clinical infection.'' Nevertheless, there is some evidence suggesting that withholding prophylactic intravenous antibiotics prior to revision for obvious or highly suspected infection is not needed, but this is mostly reported from the hip and knee arthroplasty literature (Table I).[98,133] Routine prophylactic intravenous antibiotics should only be continued for 24 hours postoperatively, unless there is a concern for periprosthetic infection, in

Table I Level of evidence of cited literature by procedure

	Shoulder surgery	TKA, THA, or other
Level I	0	1
Level II: prognostic	0	1
Level III: retrospective cohort	4	4
Level IV: case series	3	3
Level V: opinion	2	3
Total	9	12

THA, total hip arthroplasty; *TKA*, total knee arthroplasty.

which case intravenous or oral antibiotics can be continued while awaiting the final culture results.[90,98,115] *C acnes* may require 13 to 17 days to grow, necessitating antibiotics for 2 weeks after revision arthroplasty with a concern for PJI.[74-76,90,114,115]

Re-dosing of prophylactic antibiotics has been recommended for procedures lasting longer than 3 to 4 hours,[111,120] although there are no shoulder arthroplasty studies on re-dosing of antibiotics.

Question 5: Is there a role for postoperative (pending culture results) antibiotics after revision shoulder arthroplasty without suspicion of infection?

Recommendation

In revision shoulder arthroplasty without clinical suspicion of infection, prolonged antibiotics are not routinely required.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

The prevalence of subclinical infections (unexpected positive culture [UPC] findings) is especially common with shoulder arthroplasty. The rate of positive culture findings in primary and revision arthroplasty settings has been reported to be as high as 56%.[13,101,113] However, the significance and optimal treatment for UPCs remain unknown. There are limited data in the shoulder literature to define the role of postoperative prophylactic or suppressive antibiotics after revision shoulder arthroplasty without clinical or radiographic signs of infection ("Search Methodology" in Appendix). Although several studies described the use of prophylactic or suppressive antibiotics after revision shoulder arthroplasty, there was a lack of prospective randomized studies and none of the studies specifically evaluated the efficacy of such antibiotics or included a comparative group.

Published studies of outcomes after revision shoulder arthroplasty with UPC findings are retrospective and have differing and suboptimal methodologies.[33,43,52,58,90] No studies have reported a detrimental effect to not prescribing prolonged antibiotics postoperatively, although 1 study with no comparison group reported a 25% recurrence rate after UPC findings.[58] Studies that treated patients with UPC findings with prolonged antibiotics reported low recurrence rates (0%-3.5%). One systematic review reported a pooled true infection rate after UPC findings of 10.2%, with no difference related to antibiotic use after UPC findings ($P = .498$).[60] In the lower-extremity arthroplasty literature, there was 1 randomized controlled study that found a limited benefit to prolonged oral antibiotic therapy after 2-stage revision with negative culture findings (5% vs. 19%), although culture profiles from the reinfection tended to differ from the original infection organism profile.[33]

Two studies reported a 19% to 42% complication side effect rate from prolonged antibiotic use, which was seen with both oral and intravenous medication use.[43,52] The vast majority (>80%) of UPC findings were *C acnes* or coagulase-negative Staphylococcus organisms, and therefore, meaningful comparisons to other more virulent organisms could not be performed.

Recent recommendations from the World Health Organization and CDC suggest that a single perioperative dose is adequate for clean and clean-contaminated procedures.[2,6] One meta-analysis included 69 randomized controlled trials and did not demonstrate a difference in the odds of SSI with a single intraoperative dose compared with multiple doses of postoperative surgical antimicrobial prophylaxis (odds ratio, 0.89; 95% confidence interval, 0.77-1.03).[2] Encompassing concerns regarding the potential adverse consequences of antimicrobial use, in particular the risk of antimicrobial resistance, the panel made a strong recommendation, based on moderate-quality evidence, that surgical antimicrobial prophylaxis not be extended beyond the completion of the operation.[2] The applicability to UPC findings was not addressed in the studies.

In aggregate, these retrospective studies do not support routine use of prolonged postoperative antibiotics in the setting of UPC findings after revision shoulder arthroplasty. Specifically, there is no identified evidence to demonstrate that earlier pre-emptive treatment of patients with UPC findings will ultimately alter outcomes. Patients without true infection may be unnecessarily exposed to a significant course of prolonged antimicrobials. There are well-reported risks of antibiotic-related side effects and less obvious risks of antibiotic resistance with widespread prescribing.

Intraoperative

Question 6: Should antibiotic-impregnated cement be used during shoulder arthroplasty (primary and revision)?

Recommendation

There is insufficient evidence to determine whether antibiotic-impregnated cement should be used during primary or revision shoulder arthroplasty.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

PJI is relatively rare in shoulder arthroplasty (0.4%-2.9%) but can occur at significantly higher rates in reverse shoulder arthroplasty.[8] PJI can have devastating implications for the patient and lead to significant cost and care-

provision challenges to treating surgical teams. Minimizing the risk of infection is therefore imperative, and the use of antibiotic-impregnated cement has been proposed as one such method.[88] Indeed, its use has long been proposed as an effective means of reducing the risk of lower-limb arthroplasty infection[27] ("Search Methodology" in Appendix).

The choice of cement in primary shoulder arthroplasty may have a role in the prevention of PJI. Nowinski et al[88] reported a retrospective study of 501 implants, divided into 2 groups (plain cement vs. antibiotic-impregnated cement), with 4 surgeons using 3 different antibiotic and cement combinations for differing primary pathologies. Deep infection was noted in 3% of patients in the plain cement group, whereas no deep infections were reported in the antibiotic-impregnated cement group ($P < .001$). There was selection bias relating to these groups of patients because they were treated in different facilities by different surgeons and there was, therefore, a substantial risk of confounding variables. In particular, the group without antibiotic-impregnated cement had over twice as many patients with diagnoses of post-traumatic arthritis (n = 37) as the group in which antibiotics were used (n = 16). There were no cases of humeral loosening or osteolysis in the group with antibiotic-impregnated cement.

In revision shoulder arthroplasty, the revision procedure is often dictated by the cause of failure and the underlying pathology. There is no evidence regarding the use of antibiotic-impregnated cement in managing aseptic loosening with a 1-stage prosthesis exchange. However, in the management of PJI, the role of antibiotic-loaded cement choice may be dependent on the approach to revision: débridement and implant retention, 1-stage revision, 2-stage revision, and resection arthroplasty.

Two publications describing small series reported no recurrence of infection with the use of antibiotic-impregnated cement during single-stage revision of infected shoulder arthroplasty.[53,62] There was no comparative control group receiving plain cement, and because all patients also underwent débridement and postoperative antibiotic therapy, no firm conclusions can be drawn regarding the relevance of the cement owing to the presence of too many confounding variables.

Question 7: What is the role of topical intrawound antiseptics (diluted povidone-iodine solution lavage, acetic acid, or antibiotics added to the irrigation solution) and antibiotic powder (such as vancomycin) during primary or revision shoulder arthroplasty?

Recommendation

Dilute povidone-iodine and/or vancomycin powder may have a role in patients considered at high risk of PJI after primary or revision shoulder arthroplasty based on data extrapolated from other orthopedic specialties.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

There are no data in the shoulder literature specific to the use of specific intrawound antiseptic agents, irrigation solutions, or antibiotic powders ("Search Methodology" in Appendix). Because of this, expert opinion recommendations are inferred from data regarding spine surgery,[39,47] elbow surgery,[134] and lower-extremity arthroplasty.[105] Two randomized single-blinded studies have reported that irrigation with diluted povidone-iodine solution reduces the incidence of infection in spine surgery, demonstrating efficacy and safety.[17,18] On the basis of a review of this literature (Table I), there appear to be advantages to the use of

Table I Literature review of studies on use of intrawound antiseptics and antibiotic powder in shoulder arthroplasty

Study	Methods	Intrawound product	Site	Result
Yan et al[134]	Retrospective	Vancomycin powder	Elbow	Positive result: SSI rate of 6.4% vs. 0%
Riesgo et al[105]	Retrospective	Dilute povidone-iodine lavage plus vancomycin powder	Lower-extremity PJI	Positive result: failure rate of 16.7% vs. 37%
Hey et al[47]	Retrospective cohort comparative	Vancomycin powder	Spine	Positive result: SSI rate of 0.9% vs. 6.3%
Ghobrial et al[39]	Meta-analysis	Vancomycin powder	Spine	Systematic review: safety confirmed
Tomov et al[127]	Retrospective	Vancomycin powder, povidone-iodine solution	Spine	Positive result: SSI rates were reduced by 50%

SSI, surgical-site infection; *PJI*, prosthetic joint infection.

diluted povidone-iodine solution and vancomycin powder in cases of primary surgery for prevention of SSI and in cases of treatment of PJI to prevent recurrence. The data do not consider the risk of development of antimicrobial resistance with use of vancomycin powder. Diluted povidone-iodine solution does have a negative influence on osteoblast proliferation in vitro,[86] so its use in cases of fracture may not be recommended. Although data are lacking specifically for the shoulder, consensus from the hip or knee, trauma, and spine groups may provide the ability to make some general recommendations for primary and revision shoulder surgery.

Of note, the CDC released a recommendation on the use of vancomycin in 1995. Owing to concerns for the development of antimicrobial resistance, routine use of vancomycin in prophylaxis has been discouraged. Instead, use of vancomycin is believed to be acceptable for ''prophylaxis for major surgical procedures involving implantation of prosthetic materials or devices at institutions that have a high rate of infections caused by MRSA or methicillin-resistant *S epidermidis*. A single dose of vancomycin administered immediately before surgery is sufficient unless the procedure lasts greater than 6 hours, in which case the dose should be repeated. Prophylaxis should be discontinued after a maximum of two doses.'' This position statement has not been updated recently or amended to include consideration of vancomycin powder.

Question 8: Do surgical drains influence the risk of infection in patients undergoing primary or revision shoulder arthroplasty?

Recommendation

There is no evidence to support routine use of closed-suction drains in patients undergoing shoulder arthroplasty for the prevention of PJI.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

There is a paucity of literature regarding the use of postoperative closed-suction drains and the relationship to infection and PJI after shoulder arthroplasty (''Search Methodology'' in Appendix). There are no current American Academy of Orthopaedic Surgeons clinical practice guidelines that comment on the use of a postoperative drain after anatomic total shoulder arthroplasty or reverse total shoulder arthroplasty. Although very limited literature is available regarding postoperative drain use in shoulder arthroplasty, there are several studies that have evaluated blood loss, change in hemoglobin (Hb) level, clinical outcomes, and complication rates related to the use of drains after total knee arthroplasty (TKA) and total hip arthroplasty (THA).[28]

A level III case-control study compared 64 patients who underwent anatomic total shoulder arthroplasty without closed-suction drainage and 304 patients with drain placement. Drain use was associated with a lower postoperative Hb level, longer length of stay, and lower postoperative Simple Shoulder Test score.[28] There was no clinically significant difference in transfusion rates, superficial wound infections, or deep infections. There was no mention of hematoma formation or analgesic requirements when comparing patients with and without drain use.[28]

A 2007 Cochrane Database systematic review[93] evaluated 36 studies regarding the use of closed-suction surgical wound drainage after orthopedic surgery and reported only 1 study specific to shoulder surgery, by Gartsman et al.[37] This level II randomized trial included 300 patients (100 undergoing shoulder arthroplasty) and reported no statistically significant differences in length of hospital stay, wound dehiscence, infection, reoperation rate, and hematoma between patients who did have a drain and those who did not.[37] Overall, there are few available studies, and these are not sufficiently powered to detect a difference in infection rate after shoulder arthroplasty.

Question 9: What is the role of tranexamic acid (TXA) during primary or revision shoulder arthroplasty in decreasing the risk of PJI?

Recommendation

There is no evidence to support routine use of TXA in patients undergoing shoulder arthroplasty for the prophylaxis of PJI.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

Patients undergoing shoulder arthroplasty may experience variable degrees of perioperative bleeding and blood loss, which in the most severe cases may result in complications including hematoma formation,[19] acute symptomatic anemia, and the need for blood transfusions.[89,107,119] It has been suggested that there is an association between blood transfusions and wound hematomas with postoperative morbidity, including periprosthetic infection.[19,41] Whereas hematomas requiring surgery are uncommon, with a reported rate of 0.3%,[19] blood transfusions are more common, with a reported rate of 4.3% to 6.7%.[3,56,89,107] Besides the costs, allogeneic blood transfusions are associated with rare but serious complications including allergic and immune-mediated reactions, hemodynamic overload, and risk of blood-borne infections.[87] In addition, allogeneic blood transfusions may have an immunomodulatory effect[102] that may predispose to an increased risk of periprosthetic infection as seen in THA or TKA,[34] as well as shoulder arthroplasty.[41]

TXA is a synthetic antifibrinolytic agent that has been shown to be a successful and cost-effective agent for

Table I Summary of findings

Outcome	No. of participants (studies)	Relative effect (95% CI)	Anticipated absolute effect (95% CI)			Certainty
			Without TXA	With TXA	Difference	
Rate of blood transfusion assessed by No. of patients who received postoperative transfusion of packed red blood cells	375 (4 RCTs)	RR, 0.53 (0.17-1.64)	Study population			⊕⊕◯◯: low*,†
			3.7%	2.0% (0.6%-6.1%)	1.8% fewer (3.1% fewer to 2.4% more)	
			Low-risk transfusion patients‡			
			1.0%	0.5% (0.2%-1.6%)	0.5% fewer (0.8% fewer to 0.6% more)	
			High-risk transfusion patients‡			
			15.0%	8.0% (2.6%-24.6%)	7.0% fewer (12.4% fewer to 9.6% more)	
Thromboembolic complications assessed by No. of patients in whom thromboembolic complication (DVT, PE, stroke) developed during follow-up	375 (4 RCTs)	RR, 0.70 (0.11-4.38)	0.5%	0.4% (0.1%-2.3%)	0.2% fewer (0.5% fewer to 1.8% more)	⊕⊕⊕◯: moderate
Total blood loss assessed by estimation of total blood loss with Good and Nadler formula	264 (3 RCTs)	—	Mean total blood loss, 1344 mL	—	MD, 279.5 mL lower (411.7 mL lower to 147.3 mL lower)	⊕⊕⊕⊕: high
Postoperative blood loss assessed by drain output in milliliters (first 24 h) with mean follow-up of 1 d	267 (3 RCTs)	—	Mean postoperative blood loss, 216 mL	—	MD, 105.4 mL lower (161.4 mL lower to 49.4 mL lower)	⊕⊕⊕⊕: high
Decrease in hemoglobin level (hemoglobin change) assessed by change in preoperative vs. postoperative hemoglobin level (in grams per deciliter)	267 (3 RCTs)	—	Mean decrease in hemoglobin level, 3.32 g/dL	—	MD, 0.7 g/dL lower (1 g/dL lower to 0.39 g/dL lower)	⊕⊕⊕⊕: high

CI, confidence interval; *TXA*, tranexamic acid; *DVT*, deep venous thrombosis; *MD*, mean difference; *PE*, pulmonary embolism; *RCT*, randomized controlled trial; *RR*, relative risk.

Hematoma formation was assessed as an outcome, but it was not included in this table as there was only one trial that reported results.

* The CI crosses the clinical decision threshold between recommending and not recommending TXA (RR = 1, meaning no difference in the rate of transfusion between TXA and placebo).

† The accrued sample size of the meta-analysis is underpowered. The estimated optimal sample size with an α error of 5%, 80% power, and RR of 57.4% with a basal risk of 3.7% was 1555 patients.

‡ These numbers were estimated from the literature, considering the rates of transfusion in patients with low and high risks of transfusion.[48]

reducing blood loss and transfusion requirements for patients undergoing THA and TKA.[79] Two recent meta-analyses of TXA use in patients undergoing primary shoulder arthroplasty found that TXA decreases blood loss as measured by drain output, change in Hb level, and total calculated blood loss.[61,64] Nevertheless, results regarding the effectiveness of TXA in reducing transfusion rates after shoulder arthroplasty have been conflicting. One meta-analysis reported that perioperative TXA reduces blood transfusion rates,[64] whereas another reported no differences in transfusion rates.[61] Possible reasons for the conflicting results are (1) the inclusion of nonrandomized studies with biased methodology, (2) the inclusion of studies with zero events of transfusion that were excluded from the calculation of the pooling effect, and (3) lack of an additional analysis to further determine the conclusiveness of the results given the low rate of events.

To evaluate the effectiveness of TXA in reducing transfusion rates, we performed a systematic review and meta-analysis ("Search Methodology" in Appendix) that included only randomized controlled trials that compared the use of TXA vs. placebo in patients undergoing shoulder arthroplasty. This meta-analysis considered the primary outcomes to be the effect of TXA on transfusion rates, formation of hematomas, and thromboembolic events. Secondary outcomes included blood loss as measured by drain output, change in Hb level, and calculated total blood loss. This meta-analysis confirmed the findings of previous meta-analyses indicating that TXA is associated with a statistically significant reduction in perioperative blood loss compared with placebo and that there is no higher risk of thromboembolic events with TXA (Table I). Nevertheless, there was no significant difference in the risk of blood transfusion after shoulder arthroplasty when TXA was compared with placebo (relative risk, 0.53; 95% confidence interval, 0.17-1.64). Due to the fact that the rate of transfusion after shoulder arthroplasty is low, the current data are too sparse to provide conclusive evidence for the effect of TXA on blood transfusions. In addition, there is insufficient evidence for the effect of TXA on hematoma formation or other clinical outcomes after shoulder arthroplasty, including PJI.

The use of TXA in patients at high risk of transfusion or patients undergoing complex revision arthroplasty has not been adequately studied. Patients at high risk of transfusion include those with low preoperative Hb and hematocrit levels (Hb level $<$ 13 g/dL and hematocrit level $<$ 39.6%),[3,56,72,80,89] operative time longer than 5 hours,[1] surgery with a diagnosis of post-traumatic or rheumatoid arthritis,[89,119] and diabetes or ischemic heart disease.[1,56] The use of TXA in these at-risk populations might be justified given the higher baseline risk of transfusion and the greater impact of blood loss. However, this is a recommendation that is weak and limited by the lack of direct evidence. Further study of TXA in these higher-risk patients is warranted.

Patient characteristics

Question 10: What is the role of medical comorbidities as potential risk factors for PJI following primary or revision total shoulder arthroplasty?

Recommendation

Specific patient medical comorbidities and demographic factors are potential risk factors for shoulder PJI, and appropriate preoperative evaluation and perioperative management should be standard practice.

Level of Evidence: Moderate

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

Periprosthetic joint infection after both primary and revision shoulder arthroplasties remains a challenging and costly problem. It is important to recognize medical comorbidities as well as demographic factors that may be risk factors for shoulder PJI. Although medical comorbidities can negatively impact surgical outcomes and lead to an increased risk of complications, there is limited evidence specifically linking medical comorbidities and shoulder PJI. There are some helpful general measures of health including American Society of Anesthesiologists grading, the Charlson Comorbidity Index, and the Functional Comorbidity Index, among others. These indices are often linked to surgical outcomes and PJI, including shoulder PJI[84] ("Search Methodology" in Appendix). Medical comorbidities that have been shown to be potential risk factors for shoulder PJI include American Society of Anesthesiologists grade III or higher,[1] rheumatoid arthritis,[29] long-term corticosteroid use,[29] current and former smokers,[46] hepatitis C virus,[15] human immunodeficiency virus–positive status,[5] weight loss and/or nutritional deficiency,[91] drug abuse,[91] and iron deficiency.[82]

An increased body mass index, that is, 35 kg/m^2 or greater, has been associated with an increased risk of superficial wound infection but was not shown to be associated with an increased risk of shoulder PJI.[130] Patient demographic factors that have been shown to be risk factors for shoulder PJI include younger age[82,91,104,116,132] and male sex.[91,104,116,130,132]

There is a limited but growing body of literature to support medical comorbidities and demographic factors that are potential risk factors for shoulder PJI. It is important to recognize and treat potentially modifiable medical comorbidities as well as counsel patients regarding additional nonmodifiable comorbidities and demographic factors.

Question 11: Does previous shoulder surgery (arthroscopic or open non-arthroplasty) increase the risk of PJI?

Recommendation

Previous ipsilateral non-arthroplasty shoulder surgery likely increases the risk of shoulder PJI.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

Owing to the inability of standard skin preparation solutions[65,99,109] and antibiotics[75,85,99] to eradicate bacteria (eg, *C acnes*) that exist underneath the skin surface, transection of the dermal structures can result in inoculation of bacteria into the deep tissues.[30] Therefore, in theory, previous non-arthroplasty surgery may introduce bacteria into deeper tissues and potentially increase the risk of PJI.

Two studies have addressed the question of whether previous non-arthroplasty surgery increases the risk of shoulder PJI ("Search Methodology" in Appendix). Werthel et al[132] evaluated non-arthroplasty surgery as a risk factor for shoulder PJI and found that previous non-arthroplasty surgery was a risk factor for deep infection after both a univariate analysis ($P = .0094$) and a multivariate analysis ($P = .0390$). An increased number of previous surgical procedures was associated with an increased risk of deep infection ($P = .0272$). Florschütz et al[31] similarly reported that patients undergoing primary total shoulder procedures with a history of non-arthroplasty surgery had a significantly higher rate of infection ($P = .016$) than patients with no previous surgery on the operative shoulder.

A few other studies not primarily focused on answering this question also support this conclusion. Foruria et al[32] studied 107 patients with UPC findings at revision shoulder arthroplasty and found that the number of previous surgical procedures was higher in cases that they deemed to be "true infections" compared with "contaminants" ($P = .025$) (it is unclear whether the previous surgical procedures were all arthroplasty or non-arthroplasty surgical procedures). Horneff et al[50] found that patients undergoing revision arthroscopic surgery had a significantly higher rate of positive culture growth than those undergoing primary arthroscopic surgery (29.4% vs. 3.2%). Zavala et al[135] reported on their experience with deep infection after reverse shoulder arthroplasty and found an overall infection rate of 6% and an infection rate of 12.9% for patients who had previous failed rotator cuff surgery.

Question 12: Does prior corticosteroid injection increase the risk of PJI after primary or revision shoulder arthroplasty?

Recommendation

An increased number of corticosteroid injections and a shorter interval between corticosteroid injection and shoulder arthroplasty may increase the risk of SSI or shoulder PJI.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

It is well documented that standard skin preparation solutions do not adequately penetrate below the skin surface to eliminate bacteria such as *C acnes*.[65,109] Therefore, any instrument transecting the skin surface and sebaceous glands can theoretically inoculate the deep tissues.[30]

Four studies have directly investigated the effect of previous corticosteroid injections on the shoulder ("Search Methodology" in Appendix): 1 database study, 1 clinical study, and 2 studies investigating deep cultures. Werner et al[131] performed a Medicare database study that compared 3 groups: arthroplasty within 3 months after injection, arthroplasty between 3 and 12 months after injection, and a control group. Infection was defined by *International Classification of Diseases, Ninth Revision* and Current Procedural Terminology codes for both superficial and deep infections. The odds ratio for infection after arthroplasty was 2.0 at both 3 months ($P = .007$) and 6 months ($P = .001$) in patients who underwent injection within 3 months of arthroplasty and controls. No statistical difference was seen when those patients who underwent injection 3 to 12 months prior to arthroplasty were compared with the control group. This study suggests that patients undergoing arthroplasty within 3 months after injection have a higher risk of infection.

Rashid et al[103] performed a retrospective matched-cohort study of 23 patients undergoing shoulder arthroplasty with a history of preoperative intra-articular corticosteroid injections and 60 patients without prior injections. None of the patients in either group had a superficial SSI, and only 1 patient had a deep SSI (defined as obvious purulence).

Two other studies investigated the rate of positive deep culture findings at the time of primary open shoulder surgery in patients with and without a history of corticosteroid injections. Mook et al[81] prospectively collected data on 104 patients undergoing open shoulder surgery, at which time control and pericapsular tissue samples were cultured. Patients with a history of 2 or more corticosteroid injections had a higher likelihood of bacterial growth than those with 1 or no injections ($P = .047$). Koh et al[63] retrospectively analyzed 30 patients undergoing primary shoulder arthroplasty, at which time superficial and deep wound swabs were taken. Prior to the procedure, patients' shoulders were examined for the presence of hair around the axilla, shoulder, upper back, chest, or neck on the operative side. After this, the condition of the skin in the same regions was examined for the presence or absence of skin lesions including pimples, comedones, or acne. Steroid injection was not significantly associated with positive deep culture findings ($P = .14$). Patients who had a history

of steroid injections with hair present around the operative site were more likely to have positive *C acnes* deep culture findings, but this finding was not statistically significant ($P = .09$).

Although the evidence in the hip arthroplasty literature is somewhat conflicting,[77,78,97] multiple recent studies from the knee arthroplasty literature support the conclusion that corticosteroid injections before arthroplasty increase the risk of PJI.[5,16]

Skin preparation

Question 13: Is there a role for preoperative skin scrubbing (home scrubs and washes) prior to primary or revision shoulder arthroplasty?

Recommendation

Chlorhexidine gluconate (CHG) showers or cleansing wipes with at least 2 applications decrease the incidence of positive skin culture findings prior to shoulder surgery. Pending further research, this protocol may provide a benefit.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

A systematic review of the published literature was performed in the Scopus, PubMed, and Cochrane databases that included any primary or secondary aims regarding preoperative skin preparation for shoulder arthroplasty. A comprehensive review and list were accumulated, and review was performed to include all relevant studies that met these specific criteria.

SSIs account for 14% to 16% of all nosocomial infections.[118] In an effort to reduce SSIs, protocols have incorporated whole-body showering or bathing with CHG and other antiseptics. The aim is to cleanse the skin and reduce the cutaneous bacterial load prior to surgery. Previous studies have found reduced bacterial counts after use of chlorhexidine baths or washes with an increased effect after multiple applications.[55]

However, there has been much debate on this issue, with various organizations expressing different views on the matter. The CDC has indicated that either soap or other antiseptic agents are equally as efficacious as CHG, whereas the Hospital Infection Control Practice Advisory Committee of the CDC has recommended that patients shower at least 1 time with any kind of antiseptic. Finally, the Institute for Healthcare Improvements-Project Joining Organizations In Tackling SSIs (JOINTS) recommends that patients should bathe or shower with CHG soap for at least 3 days prior to surgery.[106]

Multiple interventional studies have investigated the use of preadmission CHG showers. Eiselt[26] focused on the use of preoperative CHG cloths twice prior to total joint procedures and found that the rate of SSIs was significantly reduced from 3.19% to 2% compared with a no-wash group. Johnson et al[54] studied the at-home use of chlorhexidine-impregnated skin preparation cloths in decreasing the incidence of deep periprosthetic hip arthroplasty infections. Of the 1134 patients studied, 157 complied with the preoperative chlorhexidine preparation protocol. There was no significant difference in the infection rates between the noncompliant and compliant groups (1.6% and 0%, respectively; $P = .231$). Kapadia et al[57] evaluated 557 patients who used preoperative chlorhexidine cloths and 1901 patients who did not. There was a statistically significantly lower infection rate in patients who used the cloths (0.5%) compared with patients who did not (1.7%).

Murray et al[83] studied the use of 2% chlorhexidine no-rinse cloths applied twice before any type of shoulder surgery in a prospective randomized trial of 100 patients, with a control group that used only soap. Cutaneous cultures were taken before surgery, and patients were monitored for postoperative infections. There were no infections in either group. The positive culture rate was 66% in the treatment group and 94% in the control group ($P = .0008$), and the rate of cultures positive for coagulase-negative *Staphylococcus* was 30% and 70%, respectively ($P = .0001$).

In general, most studies have focused on hip and knee replacement surgery rather than shoulder surgery. However, the aforementioned studies have demonstrated the efficacy of CHG-containing products when applied at least twice. Despite weak recommendations by the CDC, clinical evidence supports a minimum of 2 preadmission 4% CHG showers or no-rinse 2% CHG cloth applications as a critical component of a broader interventional strategy for reducing the risk of SSIs in shoulder surgery.[25,106]

Question 14: What is the optimal perioperative surgical skin preparation for primary or revision shoulder arthroplasty?

Recommendation

The best available evidence supports 2% CHG and 70% isopropyl alcohol for surgical skin preparation for shoulder arthroplasty.

Level of Evidence: Moderate

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

A comprehensive search of several databases was undertaken (Figs. 1 and 2). The rationale for the use of chlorhexidine surgical preparation prior to shoulder arthroplasty is based on 1 level I randomized controlled trial by Saltzman et al.[109] In this trial, patients were randomized to compare ChloraPrep (CHG, 2% wt/vol, in isopropyl alcohol, 70% vol/vol; Becton Dickinson, Franklin

#	Searches	Results
1	Arthroplasty, Replacement/	6266
2	exp joint prosthesis/	96013
3	exp shoulder/	44325
4	exp Shoulder Joint/	50050
5	(1 or 2) and (3 or 4)	3220
6	exp shoulder arthroplasty/	2921
7	exp shoulder prosthesis/	997
8	exp Arthroplasty, Replacement, Shoulder/	1056
9	exp shoulder/su	3240
10	exp Shoulder Joint/su	7682
11	(("glenohumeral joint" or "glenoid labrum" or "humeroscapular joint" or "scapulo humeral joint" or "scapulohumeral joint" or shoulder) adj4 (prosthe* or implant* or reconstruc* or replacement* or arthroplast* or "artificial joint*" or surg* or operation* or reconstruct* or procedure*)).ti,ab,hw,kw.	21875
12	5 or 6 or 7 or 8 or 9 or 10 or 11	27190
13	exp Preoperative Care/	99126
14	exp SKIN/	487534
15	13 and 14	692
16	((("Anti-infective*" or Antiinfective* or antiseptic* or "anti-septic*" or antimicrobial* or "anti-microbial*" or antisepsis or "anti-sepsis" or disinfect* or steriliz*) adj3 (agent* or prep* or product* or solution* or topical* or skin or cutaneous*)) or ((preop* or "pre-op*" or protocol*) adj5 (skin or cutaneous*)) or ((surgical or operative or skin or cutaneous* or steriliz* or disinfect*) adj3 prep*) or ((wound* or skin or cutaneous*) adj5 (contaminat* or infect* or steriliz* or disinfect*)) or (local* adj3 Infect*) or alcohol or "benzoyl peroxide" or Chlorhexidine or DuraPrep or "hydrogen peroxide" or iodophor* or iodopovidone or "microbial skin burden*" or "povidone-iodine" or "PVP-I" or "site prep*" or "Surgical drape*" or "Surgical-Site Infection*").ti,ab,hw,kw.	1406854
17	15 or 16	1407106
18	12 and 17	581
19	(case adj3 report).mp,pt.	2235257
20	18 not 19	544
21	limit 20 to (letter or conference abstract or editorial or erratum or note or addresses or autobiography or bibliography or biography or blogs or comment or dictionary or directory or interactive tutorial or interview or lectures or legal cases or legislation or news or newspaper article or overall or patient education handout or periodical index or portraits or published erratum or video-audio media or webcasts) [Limit not valid in Embase,CCTR,CDSR,Ovid MEDLINE(R),Ovid MEDLINE(R) Daily Update,Ovid MEDLINE(R) In-Process,Ovid MEDLINE(R) Publisher; records were retained]	38
22	from 21 keep 36	1
23	(20 not 21) or 22	507
24	limit 23 to yr="1980 -Current"	496
25	remove duplicates from 24	348

Figure 1 Search strategy.

Lakes, NJ, USA), DuraPrep (iodine povacrylex [0.7% available iodine] and isopropyl alcohol, 74%; 3M, St Paul, MN, USA), and povidone-iodine (0.75% iodine scrub and 1.0% iodine paint; Tyco Healthcare Group, Mansfield, MA, USA) in those undergoing shoulder surgery. The rate of positive skin culture findings was reduced but not eliminated with ChloraPrep (7%) compared with DuraPrep (18%) or povidone-iodine (31%). Furthermore, there were no infections in any of the patients at a mean of 10 months' follow-up. In this trial, although the chlorhexidine solution was most active against the bacteria on the shoulder in general, there was no significant difference detected among the agents in the ability to eliminate *C acnes* from the shoulder region.[109] As *C acnes* is increasingly recognized as a key player in shoulder PJI, there is concern that the current preparation solutions are inadequate. Despite this, no postoperative infections occurred in any of the groups at a minimum of 10 months' follow-up.

Chlorhexidine waterless wipes have also been advocated to decrease the bacterial burden preoperatively. Murray et al,[83] in a level I study, randomly assigned patients to 1 of 2 groups: Group 1 wiped the shoulder with 2% CHG–impregnated cloths and group 2 showered with soap and water before surgery. None of the patients had a postoperative infection, and the cultured sites on the skin showed a reduction in positive culture findings for coagulase-negative S*taphylococcus* and *C acnes*. Nevertheless, other authors have found the persistence of *Cutibacterium* within the dermis despite standard skin preparation with chlorhexidine.[63,71,74,75,99] This is likely due to the fact that the preparation solutions do not adequately penetrate into the deeper dermal sebaceous glands where *C acnes* resides.[69,75]

Benzoyl peroxide (BPO), which has known bactericidal properties against *C acnes*, has been investigated for use in shoulder surgery.[24,108,110] BPO is a lipophilic compound that is directly toxic to both surface and ductal bacteria via penetration of the pilosebaceous ducts. Once BPO is applied to the skin, its decomposition creates free oxygen radicals, which have potent bactericidal activity directly

1	TOPIC: ((("glenohumeral joint" or "glenoid labrum" or "humeroscapular joint" or "scapulo humeral joint" or "scapulohumeral joint" or shoulder) NEAR/4 (prosthe* or implant* or reconstruc* or replacement* or arthroplast* or "artificial joint*" or surg* or operation* or reconstruct* or procedure*))) AND TOPIC: (((("Anti-infective*" or Antiinfective* or antiseptic* or "anti-septic*" or antimicrobial* or "anti-microbial*" or antisepsis or "anti-sepsis" or disinfect* or steriliz*) NEAR/3 (agent* or prep* or product* or solution* or topical* or skin or cutaneous*)) or ((preop* or "pre-op*" or protocol*) NEAR/5 (skin or cutaneous*)) or ((surgical or operative or skin or cutaneous* or steriliz* or disinfect*) NEAR/3 prep*) or ((wound* or skin or cutaneous*) NEAR/5 (contaminat* or infect* or steriliz* or disinfect*)) or (local* NEAR/3 Infect*) or alcohol or "benzoyl peroxide" or Chlorhexidine or DuraPrep or "hydrogen peroxide" or iodophor* or iodopovidone or "microbial skin burden*" or "povidone-iodine" or "PVP-I" or "site prep*" or "Surgical drape*" or "Surgical-Site Infection*")) AND DOCUMENT TYPES: (Article OR Abstract of Published Item OR Proceedings Paper OR Review) Indexes=SCI-EXPANDED, ESCI Timespan=1980-2018
2	TS=(case NEAR/3 report)
3	1 NOT 2
4	PMID=(0* or 1* or 2* or 3* or 4* or 5* or 6* or 7* or 8* or 9*)
5	3 NOT 4

Figure 2 Web of Science search strategy.

within the sebaceous follicles. In a study by Sabetta et al,[108] patients were randomly assigned to wipe the surgical site with 5% topical BPO 48 hours before arthroscopic surgery. The authors found that 5 applications of BPO were effective in reducing *C acnes* on the skin at the beginning and end of surgical procedures. A more recent randomized, controlled, single-blinded trial performed by Scheer et al[110] compared the effectiveness of BPO applications vs. chlorhexidine wipes and subsequent chlorhexidine surgical scrubbing in reducing bacteria cultured from skin over the standard site of incision for a deltopectoral approach in healthy volunteers who did not undergo surgical intervention. BPO applications were performed 48 hours prior to culture in this study. Samples were then taken before and after standard surgical preparation with chlorhexidine. The authors found that culture findings remained negative for up to 2 hours after application in the BPO group. Given that the study participants were healthy volunteers without a surgical intervention, the clinical effect could not be measured.

A topical preparation of BPO combined with clindamycin applied the evening prior to surgery is an alternative method to decrease bacterial load, particularly of *C acnes*, in the setting of shoulder surgery. In a level II prospective cohort study of patients undergoing shoulder arthroscopy, Dizay et al[24] reported a statistically significant decrease in *C acnes* colonization of the skin at the time of surgery, particularly when more than 1 application was used.

Despite the positive findings of the aforementioned studies of BPO in reducing *C acnes* on the skin, no study has shown a clinical reduction in infections in arthroplasty patients; therefore, a clinical trial in this specific patient population is needed.

To be effective, skin preparations must cover the skin of the surgical site. In 1 level III investigation, Syed et al[123] examined the type of application of the preparation and found that simple gauze pads were more effective at completely covering the skin than preparation sticks alone. In this study, 22 shoulders of volunteer subjects were prepared with either an applicator stick or 2 sterile 4 × 4–cm gauze sponges. UV-A light and advanced image-analysis software were used to determine areas of the skin that remained unprepared. The applicator-stick method resulted in a statistically higher percentage of unprepared skin than the gauze-sponge method, and the axilla was the region most likely to have unprepared areas. Nevertheless, this study did not explore the effect on infection.

Other ancillary methods related to skin preparation such as axillary hair clipping have not been shown to decrease the bacterial burden or clinical infection rate. In fact, Marecek et al[73] found that the clipped shoulder had a significantly greater bacterial burden than the unclipped shoulder before preparation, but this difference was not present after surgical preparation. Importantly, all shoulders showed a significant reduction in total bacterial load including *C acnes* after surgical preparation with 2% CHG and 70% isopropyl alcohol.

There is limited evidence specifically addressing skin preparation prior to revision shoulder arthroplasty. In an attempt to ''seal off'' pores and isolate remaining bacteria on and in the skin from the wound during revision arthroplasty, Lorenzetti et al,[69] in a level III study, examined the use of cyanoacrylate prior to barrier drapes. The skin edges were painted with glue over the area of the planned incision and allowed to dry prior to the placement of barrier drapes. This study reported a nonsignificant difference in the prevalence of positive intraoperative culture findings, with 18% in the group with standard preparation and iodoform barrier drapes and 7% in the group with a cyanoacrylate

barrier. The role of skin preparation techniques during revision shoulder arthroplasty requires further study.

Question 15: Is there a role for topical skin treatments prior to primary or revision shoulder arthroplasty?

Recommendation

At this time, there is no evidence for or against the use of topical skin treatments to reduce the rate of shoulder PJI.

Level of Evidence: Limited

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

The use of CHG topical skin treatment preoperatively has been recommended by the International Consensus on Periprosthetic Joint Infection. However, specific to shoulder arthroplasty, the use of topical skin treatments has not been shown to significantly reduce the superficial bacterial load of *C acnes* (formerly known as *Propionibacterium acnes*) or reduce culture positivity of deep samples retrieved from the surgical site during primary shoulder arthroplasty.[63,75,94,99,101,104]

C acnes has been reported as the most common pathogen in shoulder PJI, and as well as being present on the skin, it is present within the sebum-rich pilosebaceous hair follicles of the deep dermis, making it difficult to eradicate with topical antiseptic techniques. Surgical incisions transecting *C acnes*–filled dermal glands can lead to contamination of deeper tissues.

C acnes has also been implicated in the pathogenesis of acne vulgaris for which the antibacterial agent BPO has been used as topical therapy. BPO releases free-radical oxygen, which oxidizes bacterial proteins in the sebaceous follicles, decreasing the burden of anaerobic bacteria in the deeper tissues and also inflammation due to the reduction of irritating-type free fatty acids. Leyden et al[67] described a 90% reduction in *C acnes* colonization after 48 hours of topical treatment and a 99% reduction after 72 hours of treatment. The addition of topical clindamycin phosphate, 1.2%, has been shown to further decrease bacterial load.[112] Although BPO with clindamycin may therefore be the optimal treatment for use prior to shoulder surgery to decrease *C acnes* contamination, further research is needed to correlate superficial decontamination with decreased infection rates and shoulder PJI.[51]

Specific to primary shoulder arthroplasty, Levy et al[66] reported that 23 of 55 patients had *C acnes* growth in joint synovial fluid collected during surgery. Despite their protocol of washing the shoulder, arm, and axilla with 4% CHG, they reported a high incidence of *C acnes*. Other recent studies have evaluated colonization rates for primary shoulder arthroplasties and found that around 70% of cases had positive culture findings for *C acnes* despite using CHG and that patients of male sex and those with body hair had higher rates of superficial *C acnes*.[63,65,71,75] In a study by Koh et al,[63] 30 patients undergoing primary shoulder arthroplasty had superficial swabs and deep tissue samples sent for culture at various stages of the operation following CHG application. Positive skin swab culture findings were obtained in 40% (12 of 30) after the chlorhexidine skin scrub in the operating room and 27% (8 of 30) after dual application of chlorhexidine to the skin. On entering the glenohumeral joint, 43% had positive deep culture findings, and deep culture findings after implantation of the prosthesis were positive in 37%. After closure, 43% had positive superficial culture findings. In total, 73% of patients had positive culture findings and Koh et al concluded that topical antiseptic measures did not completely eliminate *C acnes*.[71] Despite proven antiseptic effects, dermal application of CHG during shoulder surgery fails to eradicate or reduce *C acnes* in deep cultures. The current literature is limited by the lack of high-quality studies that can provide definitive answers regarding the clinical effectiveness of various CHG preparations preventing prosthetic shoulder joint infections.[38]

Sabetta et al[108] described the preoperative application of topical 5% BPO cream in addition to the standard use of CHG preoperative skin preparation to reduce *C acnes* rates in patients undergoing arthroscopic shoulder procedures. BPO was applied twice daily for a total of 5 applications in the 48 hours prior to the operation in 50 patients undergoing primary arthroscopic shoulder surgery. Of skin swab culture findings prior to preparation with ChloraPrep from the anterior deltoid of the BPO-treated arm, 16% (8 of 50) were positive, compared with 32% (16 of 50) of those from the anterior deltoid of the untreated arm ($P = .001$). The addition of BPO cream to the authors' standard ChloraPrep protocol appeared to provide an improved method of skin cleansing; however, because of the study design (nonrandomized), differences in deep culture rates could not be determined.[108] Dizay et al[24] prospectively studied 65 patients undergoing shoulder arthroscopy treated with preoperative topical benzoyl peroxide, 5%, plus clindamycin phosphate, 1.2% (BPO/C). The preparation was applied for more than 2 days prior to surgery. Skin surface swab cultures were taken preoperatively, as well as in the operating room before the standard chlorhexidine preparation. A third set of cultures was taken by swabbing the shoulder tissue at the operative site under direct arthroscopic visualization through an arthroscopic cannula on completion of the procedure. Topical BPO/C was effective in eliminating 74.2% of *C acnes* skin colonization (23 of 31 patients with positive preoperative culture findings) by the day of surgery. The rate of positive culture findings from the deep shoulder joint was 3.1% (2 of 65 patients) with preoperative BPO/C topical treatment, much lower than in similar studies that described rates of positive deep culture findings of up to 19.6%.[24,51]

In summary, there is evidence that topical skin treatments can reduce bacterial load, such as that of *C acnes*; however, no studies examined the effect of skin preparation on the most clinically relevant endpoint—the rate of shoulder PJI. The use of topical BPO with or without clindamycin, although encouraging and warranting further study, cannot currently

be fully endorsed as standard practice for prevention of shoulder PJI.

Question 16: Should the subcutaneous and dermal tissues be disinfected during shoulder arthroplasty?

Recommendation

There is insufficient evidence for or against disinfection of the subcutaneous and dermal tissues during shoulder arthroplasty.

Level of Evidence: No Evidence

Delegate Vote: Agree, 100%; Disagree, 0%; Abstain, 0% (Unanimous, Strongest Consensus)

Rationale

A review of PubMed using ''(subcutaneous OR irrigation OR disinfection OR topical OR local) AND shoulder AND arthroplasty)'' and Google Scholar using ''shoulder arthroplasty subcutaneous irrigation disinfection topical local'' was performed to identify articles comparing strategies for disinfection of the subcutaneous and dermal tissues during shoulder arthroplasty. No specific references were identified. In the absence of specific evidence, basic science research and research in other surgical fields were reviewed.

Lee et al[65] performed assessment of punch biopsy cultures from the shoulders of volunteers after standard surgical preparation of the skin. Of 10 subjects, 7 showed positive culture findings for *Cutibacterium*. On this basis, the authors concluded that surgical preparation could leave bacteria under the surface of the skin and further disinfection should be performed.

In a retrospective study of hip and knee arthroplasty, Brown et al[14] compared diluted povidone-iodine solution lavage prior to closure of total hip and knee arthroplasty incisions vs. a control group. The deep infection rate was lower in the group undergoing diluted povidone-iodine solution lavage than in the control group. In contrast, a similar study using CHG showed no difference between CHG irrigation and control groups.[35] However, the conclusions may have been confounded by the fact that povidone-iodine was also used in the control group. A broader meta-analysis of randomized controlled trials across various surgical specialties found that lavage with diluted povidone-iodine solution reduced the rate of SSIs in the majority of trials, with no reported complications.[21]

An intra-articular injection of gentamicin[70] and the application of topical vancomycin powder[45] have also both been described as operative measures to reduce PJIs in shoulder arthroplasty. Although there was no clinical evidence for the use of vancomycin powder in the shoulder, recent literature in the field of spinal surgery has shown a significantly decreased risk of SSI with the use of topical vancomycin.[126] In a retrospective review of 507 shoulder arthroplasty procedures comparing 343 patients who received an intra-articular injection of 160 mg of gentamicin at the end of surgery vs. 164 patients who did not, the infection rate in the control cohort was 3% (5 of 164) compared with 0.3% (1 of 343) in the gentamicin cohort.[4] However, the study design allowed for bias with confounding variables, including the use of antibiotic-impregnated cement, which may have influenced the outcomes.

Owing to concerns for the development of antimicrobial resistance, routine use of vancomycin in prophylaxis has been discouraged. Instead, use of vancomycin is believed to be acceptable for ''prophylaxis for major surgical procedures involving implantation of prosthetic materials or devices at institutions that have a high rate of infections caused by MRSA or methicillin-resistant *S epidermidis*.'' This position statement has not been updated recently or amended to include a discussion of vancomycin powder.

Disclaimer

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Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2019.04.017. The following references are cited in the supplementary data:[23,40,68,95,125,127,129].

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