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Microbial colonization of subscapularis tagging sutures in shoulder arthroplasty: a prospective, controlled study

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Background: Reducing intraoperative wound contamination is a critical preventive strategy for reducing the risk of prosthetic joint infection in shoulder arthroplasty. The aim of this study was to investigate the potential microbial colonization of subscapularis tagging sutures during shoulder arthroplasty.

Methods: In this prospective study, 50 consecutive patients undergoing primary shoulder arthroplasty (anatomic or reverse) were enrolled. Patients with revision shoulder arthroplasty and proximal humeral fractures were excluded. Nonabsorbable, braided tagging sutures were placed through the subscapularis tendon prior to tenotomy. A similar nonabsorbable, braided suture (control) was placed in a sterile container on the back table, open to the operating room environment. Subscapularis tagging sutures (experimental specimens) and control sutures were collected prior to subscapularis tenotomy repair and submitted for aerobic and anaerobic cultures. Cultures were held for 21 days to account for extended growth of slow-growing bacteria.

Results: A total of 12 of 50 experimental and 16 of 50 control sutures had positive cultures. *Staphylococcus epidermidis* and *Cutibacterium acnes* were the 2 most commonly isolated organisms. Active tobacco use ($P = .038$) and procedure length ($P = .03$) were significantly associated with positive cultures. No significant association between positive subscapularis tagging suture cultures and positive control cultures was found ($P = .551$). Patient age, sex, body mass index, and significant medical comorbidities were not significantly associated with positive cultures.

Discussion: Subscapularis tagging sutures are a potential source of microbial contaminant in shoulder arthroplasty, and we recommend exchanging the tagging suture with a suture opened immediately prior to subscapularis repair.

Level of evidence: Basic Science Study; Microbiology

Keywords: Total shoulder arthroplasty; reverse shoulder arthroplasty; subscapularis tenotomy; periprosthetic joint infection; sutures; subscapularis repair

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Prosthetic joint infection (PJI) is a devastating complication after shoulder arthroplasty. With the annual number of shoulder replacements expected to rise to 75,000 by 2020, minimizing PJI is of paramount importance.[2] Previously published series estimated the rate of infection after shoulder surgery to range from 0.43% to 4.6%.[5,8] A large retrospective study found a 0.98% infection rate in 82,498 primary total shoulder arthroplasties (TSAs).[16] In another retrospective review looking specifically at primary TSA, a 1.2% infection rate was observed in 2588 cases.[24] Common bacterial pathogens isolated from PJI cases include *Cutibacterium acnes* (formerly called *Propionibacterium acnes*), *Staphylococcus* species, and *Streptococcus* species.[21] *C acnes* is an anaerobic, gram-positive, pleomorphic rod, ubiquitous to the skin.[6] *C acnes* more frequently colonizes the skin surrounding the shoulder compared with the hip or knee and is one of the most common organisms isolated in periprosthetic shoulder infections.[5,17,22,29] In revision shoulder arthroplasty, *C acnes* is present in up to 70% of intraoperative specimens.[1,12,20,23,24]

Risk factors for PJI after TSA have been established. Singh et al[24] looked at 2207 patients who underwent 2588 primary TSAs. They reported 32 deep infections. Male sex and younger age were found to be significant risk factors. Wagner et al[26] showed that the body mass index (BMI) was associated with worse outcomes, most specifically increased rates of superficial infection. Pottinger et al[20] reviewed risk factors for *C acnes* infection in 193 revision shoulder arthroplasties. Male sex, humeral osteolysis, and cloudy fluid were each associated with significant increases of at least 600% in the likelihood of obtaining positive *C acnes* cultures. In addition, humeral loosening, glenoid wear, and membrane formation were associated with significant increases in the likelihood of obtaining positive *C acnes* cultures.

Whereas host risk factors such as the aforementioned factors are well known, intraoperative risk factors are less established. Modern surgical preparation solutions, laminar airflow, and limiting operating room traffic have significantly reduced intraoperative contamination; however, other modifiable factors still exist.[9,13,19] The risk of axillary hair exposure during shoulder surgery has been proposed as a risk factor for surgical-site infection (SSI). A recent study by Marecek et al[15] looked at the effect of axillary hair on surgical-site antisepsis. They determined that axillary hair clipping has no effect on *C acnes* axillary burden after standard surgical-site preparation. We believe another potential source of contamination during open shoulder surgery is subscapularis tagging sutures. Throughout the case, these sutures are continuously exposed to the axilla and the operating room environment. The aim of this study was to investigate the potential microbial colonization of subscapularis tagging sutures during shoulder arthroplasty. Our hypothesis was that the subscapularis tagging sutures would become colonized throughout the duration of the surgical procedure and thus would be a potential source of contamination.

Methods

All patients provided informed consent. Patients undergoing primary TSA or primary reverse TSA were invited to participate and enroll in this prospective study. Patients undergoing revision shoulder arthroplasty or arthroplasty for proximal humeral fractures and those who declined to participate were excluded.

Fifty consecutive patients who met the inclusion and exclusion criteria were included in the study. Two surgeons (J.D.Z. and M.V.) performed all shoulder arthroplasties. Patients were positioned in the beach-chair position and were prepared and draped according to our institution's standard protocol. The preparation solution consisted of chlorhexidine gluconate (CHG), 2%, and isopropyl alcohol, 70% (Chloraprep; CareFusion, San Diego, CA, USA). The axilla was draped with an adhesive drape (Ioban Antimicrobial Incise Drapes; 3M, St. Paul, MN, USA). Subscapularis tenotomy was performed in all cases, and tagging with nonabsorbable, braided sutures (1 to 4 sutures) was performed during this procedure. Prior to tenotomy, a separate, nonabsorbable, braided suture was placed in a sterile container by the surgical technician with clean, sterile gloves. This served as our control suture. The suture was not handled during the procedure but was left open to the operating room environment. At the conclusion of the case, prior to subscapularis tendon repair, the experimental sutures were exchanged with new sutures. Both the experimental and control sutures were placed in separate, sterile specimen collection jars (BBL Port-A-Cul; BD Biosciences, San Jose, CA, USA) and appropriately labeled. New sterile gloves were placed prior to collection. The collection jars were sent to our institution's clinical microbiology laboratory for aerobic and anaerobic cultures.

Microbiology procedure

Each suture was removed from the BBL Port-A-Cul jar under a biosafety level 2 cabinet using sterile forceps and carefully transferred to a wide-mouth 50-mL sterile conical tube to which 32 mL of thioglycolate broth enriched with vitamin K and hemin (BBL 221787; BD Biosciences) was added. The sample was then vortexed for 15 seconds and incubated at 37°C in ambient air for 21 days. The tubes were examined daily for visible evidence of growth. Visually positive samples were subcultured immediately, whereas samples with no visible growth were subcultured weekly until termination. All specimens were subcultured aerobically (trypticase soy agar with 5% sheep blood, Columbia nalidixic acid agar, and chocolate and MacConkey agar) and anaerobically (Brucella agar with vitamin K and hemin and Centers for Disease Control and Prevention and phenylethyl alcohol agar). Aerobic plates were held for 4 days, whereas anaerobic plates were held for 7 to 10 days. All organisms were identified to the genus and/or species level using matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry with the Vitek 2 system (bioMérieux, Marcy-l'Étoile, France) or conventional methods. Basic demographic information was collected from patients' charts and included age, sex, BMI, history of diabetes, and smoking history.

Statistical analysis

Data were analyzed with SPSS statistical software (version 24; IBM, Armonk, NY, USA). Means and standard deviations or proportions and percentages were calculated for all baseline characteristics and microbial culture results. Continuous variables were assessed using paired-sample t tests and Student t tests. Categorical variables were assessed using χ^2 tests. Significance was set at $P < .05$ for all analyses.

Results

A total of 50 patients (34 female patients, 68%) with a mean age (± standard deviation) of 70.0 ± 7.9 years were included in the final statistical analysis. Patient demographic characteristics and surgical data are summarized in Table I.

A total of 12 experimental sutures and 16 control sutures showed positive bacterial cultures. The most frequently identified organism was *Staphylococcus epidermidis* in both cohorts (subscapularis tag, n = 6; control, n = 4) (Table II). No significant association was found between a positive experimental suture culture and positive control culture ($P = .551$).

Cases with positive experimental suture cultures had a significantly longer procedure time than cases with negative cultures (199 minutes vs. 131 minutes, $P = .030$). Procedure times were not significantly different between positive and negative control cultures (124 minutes vs. 119 minutes, $P = .308$). Current smokers had a significantly higher risk of a positive subscapularis tagging suture culture than nonsmokers and former smokers (odds ratio, 12.3; 95% confidence interval, 1.14-132.9; $P = .038$). Patient age, sex, BMI, and comorbidity were not significantly associated with positive subscapularis tagging suture cultures (Table III). At a minimum of 60 days' follow-up, no clinical infections were reported in any of the patients.

Table I Patient and surgical characteristics

Characteristic	Data
Age, mean ± SD, yr	70.0 ± 7.9
Female sex, n (%)	34 (68)
BMI, mean ± SD	30.6 ± 6.3
Smoking status, n (%)	
Nonsmoker or former smoker	46 (92)
Smoker	4 (8)
Comorbidity, n (%)	
Hypertension	37 (74)
Hyperlipidemia	24 (48)
Diabetes mellitus	14 (28)
Procedure, n (%)	
Anatomic TSA	22 (44)
Reverse TSA	28 (56)
Procedure time, mean ± SD, min	122.2 ± 16.1

SD, standard deviation; *BMI*, body mass index; *TSA*, total shoulder arthroplasty.

Discussion

Minimizing infections after total joint replacement is critical. Besides the obvious benefit to the patient, reductions in PJI can decrease the overall cost to the health care system. Although preoperative and postoperative risk factors have been well established in the total shoulder literature, less is known about the intraoperative factors that contribute to PJI. The goal of this study was to investigate the subscapularis tagging suture as a potential source of intraoperative contamination. Our hypothesis that the subscapularis tagging suture could become colonized throughout open shoulder replacement was supported.

A total of 28 of 100 specimens resulted in positive cultures, 12 of 50 (24%) in the experimental cohort and 16 of 50 (32%) in the control cohort. To better understand the origin of the contamination, we looked at patients who had both positive experimental and control sutures. In 3 patients, both the experimental and control specimens had positive cultures, and the speciation of the cultured bacteria differed in each patient. This finding suggests a different origin of contamination. No association was found between a positive control specimen and a positive experimental specimen. Active smoking and procedure time were significantly associated with a positive culture found on the experimental subscapularis suture. No association was found between patient age, sex, BMI, and comorbidity.

Intraoperative contamination results from endogenous or exogenous sources. Exogenous sources include circulated air; staff; and inanimate objects such as surgical gloves, suction devices, electrocautery tips, and irrigation basins. Airborne contamination is the most likely source of exogenous contamination. Laminar airflow, air filtration, and positive pressure have been developed to decrease rates of contamination. Recent evidence has called into question the beneficial effects of laminar airflow.[4,11] Bischoff et al[4] performed a systematic review and meta-analysis that demonstrated no benefit of laminar airflow in reducing SSIs. Operating room traffic has also been correlated with contamination. Andersson et al[3] investigated the effects of operating room traffic and the number of patients in the operating room on air contamination in orthopedic trauma surgery. They found that both the overall traffic and number of patients were positively correlated with colony forming units after controlling for duration of surgery.

The major source of endogenous contamination is the patient's skin. Skin preparation has evolved to effectively limit this source. The World Health Organization

Table II Microbial culture results

	n (%)
Subscapularis tagging suture	
Bacillus species	1 (2)
Cutibacterium (*Propionibacterium*) species	
C acnes	2 (4)
P avidum	1 (2)
Staphylococcus species	
S epidermidis	6 (12)
S haemolyticus	1 (2)
S hominis	1 (2)
Control*	
Bacillus species	1 (2)
Micrococcus species	1 (2)
C acnes	3 (6)
Staphylococcus species	
S cohnii	1 (2)
S epidermidis	4 (8)
S haemolyticus	3 (6)
S hominis	3 (6)
S lugdunensis	1 (2)

* One culture was positive for both *S haemolyticus* and *C acnes*.

recommends surgical-site preparation with alcohol-based antiseptic solutions containing CHG.[27] Saltzman et al[22] summarized the effects of skin preparation in shoulder surgery. They reported that CHG skin preparation was superior to povidone-iodine solutions in reducing the density of skin flora. A study by Falconer et al[10] cultured various sources of contamination during shoulder arthroplasty, specifically looking at *C acnes* culture positivity. They reported that the subdermal layer is likely the source of contamination and transfers bacteria to anything in contact with it throughout the procedure. Other studies have echoed these findings, suggesting that bacteria are contained in the subdermal layer and pilosebaceous glands within the axilla and may render prophylactic antibiotics and preincision skin preparation ineffective.[14,18] Wong et al found a high rate of positive cultures in primary total arthroplasty surgery despite perioperative antibiotics, with *C acnes* being the most commonly isolated organism.[27-29] Furthermore, Marecek et al[15] looked at the effect of axillary hair removal on microbial burden and found no difference as long as standard skin sterilization solution was used; in fact, prior to sterilization with preparation solution, shaved axillae had a higher microbial burden.

Operative time has also been correlated with an increased risk of SSI. In a recent systematic review of 81 studies, Cheng et al[7] showed that a prolonged operative time can increase the risk of SSI. Their analysis included 5 orthopedic studies with defined time points that demonstrated that an increase in mean operative time by 20% or greater (ie, $\geq$3 hours) was associated with adjusted odds ratios ranging from 3.63 to 7.40. This finding is in accordance with our findings.

On the basis of the results of our study, we recommend changing the subscapularis tagging suture prior to repair. The suture should be opened immediately prior to use, as exposure to the operating room environment yields a risk of contamination as well. The rate of contamination of 32% in our control specimens elucidates this fact. We are unable to state whether a positive culture will result in a clinical infection. In fact, we have encountered no clinical infections in our study group. However, this study provides evidence of a potential source of bacterial contamination with a simple and relatively inexpensive intervention of exchanging the subscapularis suture with a suture opened immediately prior to repair.

There are several limitations to our study. First, although we attempted to standardize the protocol through a number of means, including limiting the number of surgeons, using a standardized preparation and draping protocol, and changing gloves before handling the experimental and control sutures, there were still a number of factors that could not be controlled. One notable example is that the

Table III Comparisons between positive and negative cultures of subscapularis tagging sutures

	Positive culture (n = 12)	Negative culture (n = 38)	*P* value
Age, mean ± SD, yr	71.0 ± 7.1	69.7 ± 8.2	.633
Female sex, n (%)	6 (18)	28 (82)	.125
BMI, mean ± SD	30.2 ± 4.5	30.7 ± 6.8	.807
Smoking status, n (%)			.038
Nonsmoker or former smoker	9 (20)	37 (80)	
Smoker	3 (75)	1 (25)	
Comorbidity, n (%)			
Hypertension	9 (24)	28 (76)	.624
Hyperlipidemia	7 (29)	17 (71)	.411
Diabetes mellitus	2 (14)	12 (86)	.270
Procedure time, mean ± SD, min	131.0 ± 15.0	119.5 ± 15.7	.030

SD, standard deviation; *BMI*, body mass index.

number of surgical technicians and the number of persons entering the room during each procedure were neither controlled nor recorded. Laboratory processing is another variable that is difficult to control. Although this best replicates clinical environments, it also happens to be a source of false-positive findings. In unpublished data (March 2019) procured from multiple internal reviews of the institution's microbial laboratory, false-positive rates ranged from 0% to 9%. Even if a 9% false-positive rate is assumed, our results demonstrate an additional source of suture contamination. It is also possible that there was indirect contamination as a result of the opening process of the package for the specimen container. Trier et al[25] investigated the relationship of the package size and risk of contamination during opening and presentation of devices in the sterile field. They demonstrated that the risk of contamination increased with the package size. Packages less than 7.62 × 20.32 cm—which is much larger than the size of suture packages used in our study—had a probability of contamination of 0.05%. This finding suggests that the risk of contamination during opening and package handling is very low. In addition, our sample size of 50 patients is relatively low; however, given the relatively high rate of contamination detected, we believed that this was adequate. Finally, a high rate of positive cultures was found in the control group. When designing the study, we designated a control as a suture exposed to the operating room environment throughout the duration of the procedure. We did so to help account for potential airborne contamination, making any positive cultures in the experimental group more specific to the axilla and our stated hypothesis.

As discussed earlier, only 3 patients had both positive experimental and control specimens. The bacterial profiles of the control and experimental specimens from each of these patients were different, suggesting different sources of contamination. On the basis of the results, we cannot definitively state that exposure to the axilla is a risk factor for contamination, although our results support this hypothesis. We can, however, conclude that exposure to the operating room environment, including the patient's axilla, is a significant risk factor for suture colonization and contamination.

Conclusion

Sutures used to tag the subscapularis tendon during primary shoulder arthroplasty are colonized at a rate of 24%. *S epidermidis* and *C acnes* were isolated in 3% of the experimental group cultures. In addition, sutures exposed to the operating room environment for the duration of the procedure were contaminated at a high rate. On the basis of these results, we recommend exchanging the subscapularis tagging suture with a suture opened just prior to the start of the subscapularis tenotomy repair.

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