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Preoperative Skin Cultures Predict Periprosthetic Infections in Revised Shoulder Arthroplasties

A Preliminary Report

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Background: Current approaches do not provide a practical method for the accurate prediction of a Cutibacterium periprosthetic joint infection (PJI) in failed arthroplasties. Thus, surgeons revising failed arthroplasties must decide whether to exchange the implants and to institute antibiotic treatment without knowing the results of cultures of deep specimens obtained at the revision procedure. This study tests the hypothesis that the results of preoperative culture specimens of the skin surface obtained in the clinic can predict the presence of culture-positive Cutibacterium PJIs.

Methods: Revision shoulder arthroplasties performed between October 3, 2017, and February 4, 2020, that had both preoperative clinic culture specimens and surgical culture specimens were included in this analysis. Culture results were assigned a value from 0 to 4. The percentage of the total skin bacterial load contributed by Cutibacterium (Cutibacterium percentage) was determined. To reduce concern about contamination, a robust criterion for culture-positive Cutibacterium PJI was applied: ≥2 surgical specimens with a Cutibacterium value of ≥1. The predictive values for a culture-positive Cutibacterium PJI were determined for a clinic skin culture Cutibacterium value of >1 and a clinic skin percentage of Cutibacterium of ≥75%.

Results: Eighteen cases met the inclusion criteria; of these, 7 (6 male patients) met our criterion for a culture-positive Cutibacterium PJI. For all patients, a preoperative clinic skin Cutibacterium value of >1 predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 89%, and a clinic skin Cutibacterium percentage of ≥75% predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 94%. For male patients, a preoperative clinic skin Cutibacterium value of >1 predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 91%, and a clinic skin Cutibacterium percentage of ≥75% predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 100%.

Conclusions: A simple culture specimen of the unprepared skin surface obtained in a clinic prior to revision shoulder arthroplasty may provide valuable assistance to surgeons planning a revision arthroplasty.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

One of the most important decisions that a surgeon must make when revising a failed shoulder arthroplasty is whether to treat the shoulder as if it is infected, recognizing that the culture results of intraoperative specimens will not be available until weeks after the revision procedure. Because the optimal treatment of a shoulder periprosthetic joint infection (PJI) is prosthesis exchange[1] and postoperative antibiotics[2], the decision to treat for infection must be made at the time of the surgical procedure.

This decision is complicated by the fact that no preoperative tests or intraoperative findings have been established to reliably distinguish a benign shoulder from one with a culture-positive PJI from the most common causative organism, Cutibacterium[3]. Although blood tests, fluid aspirates, intraoperative Gram stains, and histology may be useful for detecting other organisms, these tests lack the sensitivity and specificity necessary to accurately predict the presence of Cutibacterium in a failed shoulder arthroplasty; in part, this is because the

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human host usually does not mount a typical inflammatory response against this commensal organism[4-17].

The results of cultures for Cutibacterium and other bacteria can be expressed in a semiquantitative way, reflecting the load of the bacteria in the specimen, rather than simply as the presence or absence of the bacteria[18]. Using this approach, it has been shown that the load of Cutibacterium on the skin of the shoulder is strongly influenced by the patient's age, sex, and health[19]. The semiquantitative results of culture specimens for Cutibacterium taken of the unprepared skin surface in the operating room immediately prior to a primary shoulder arthroplasty have been correlated with the load of this organism in the dermis freshly incised at the surgical procedure[18,20]. Other studies have shown that the semiquantitative Cutibacterium culture results of skin surface specimens obtained in the operating room prior to a revision shoulder arthroplasty correlated with the load of Cutibacterium in deep tissue and prosthesis explant specimens harvested at the time of the revision arthroplasty[21,22]. However, to our knowledge, there have been no published studies examining the utility of preoperative skin culture specimens obtained in the clinic prior to revision shoulder arthroplasty in predicting the presence of a culture-positive Cutibacterium PJI. Furthermore, although research has shown that the microbiome of the skin over the normal shoulder is diverse[19], it is not known whether this diversity is disrupted in patients with periprosthetic Cutibacterium infection.

This study tested the hypothesis that the semiquantitative results of skin surface culture specimens obtained in the clinic prior to revision shoulder arthroplasty can accurately predict the presence or absence of a culture-positive periprosthetic Cutibacterium infection. A second hypothesis was that the normal diversity of the shoulder skin's microbiome can be distorted by an overabundance of Cutibacterium and that the degree of this dysbiosis is also predictive of a culture-positive Cutibacterium PJI.

Materials and Methods

From a longitudinally maintained institutional shoulder arthroplasty database, all patients were retrospectively identified who had an open revision shoulder arthroplasty performed by 1 of 2 surgeons at our center between October 3, 2017, and February 4, 2020, and met the inclusion criteria of having a complete set of demographic data, index shoulder diagnosis, index procedure type, and culture specimens of the skin surface obtained in the clinic prior to the revision arthroplasty as well as having the results of intraoperative tissue and explant cultures. Patients who were taking antibiotics within 3 months of the surgical procedure and patients who were not fluent in English were excluded. This study was approved by our Human Subjects Review Committee (STUDY00007300, CR00002924).

For each patient, the results of 3 sets of cutaneous culture specimens were recorded: (1) that of the unprepared skin surface over the area of the skin incision obtained in the outpatient clinic prior to the day of the surgical procedure, (2) that of the unprepared skin surface over the area of the skin incision obtained in the operating room after home showers with chlorhexidine[23] but before skin preparation and administration of intravenous antibiotics, and (3) that of the freshly incised dermis obtained immediately after skin incision (after skin preparation and antibiotic administration). All cutaneous culture specimens were obtained using a swab (ESwab 480C; COPAN Diagnostics) passed twice along the length of the incision[21]. At the surgical revision, a median of 5 samples (mean [and standard deviation], 4.5 ± 1.5 samples [range, 2 to 7 samples]) from deep tissues and prosthetic explants were submitted for culture. Samples typically included the capsule, the collar membrane (the membrane between the modular humeral head and the humeral body), the humeral canal membrane, the explanted humeral head, the explanted body, and the explanted glenoid (if present).

All culture specimens were processed by the same laboratory using broth as well as aerobic and anaerobic media with a 3-week observation period, based on a previously published evidence-based study[24]. Culture results for each specimen were given a value based on the laboratory report: 0 for no growth, 0.1 for growth in broth only or for 1 colony only on a plate, 1 for 1+ growth, 2 for 2+ growth, 3 for 3+ growth, and 4 for 4+ growth on a plate, where the values from 1 to 4 indicate the number of quadrants on the streaked plate showing growth[18]. Specimen values were assigned separately for Cutibacterium, for coagulase-negative Staphylococcus, and for other bacterial types. A prior study using this same culturing protocol found that none of the 50 control cultures were substantially positive (specimen Cutibacterium values of ≥1)[20].

For each of the specimens, the percentage of the total bacterial load contributed by Cutibacterium was calculated by dividing the Cutibacterium specimen value by the sum of the Cutibacterium specimen value, the coagulase-negative Staphylococcus specimen value, and the other bacteria specimen value ([specimen value for Cutibacterium × 100%]/[specimen value for Cutibacterium + specimen value for coagulase-negative Staphylococcus + specimen value for other bacteria]). For shoulder skin culture specimens obtained prior to primary shoulder arthroplasty, the mean percentage of Cutibacterium has been reported to be <50%[19]; thus, in the current study, a Cutibacterium percentage of ≥75% was used as a threshold indicating a large preponderance of Cutibacterium relative to other bacteria on the skin.

For each revision, the sum of all of the specimen values, a Shoulder Score, was calculated for each organism (Shoulder Score for Cutibacterium, Shoulder Score for coagulase-negative Staphylococcus, and Shoulder Score for other bacteria). To reduce concern about contamination and false-positive results, a robust criterion for culture-positive Cutibacterium PJI was applied: ≥2 surgical specimens with a Cutibacterium value of ≥1, yielding a Shoulder Score for Cutibacterium of ≥2[25]. For each revised shoulder, the mean Shoulder Scores for Cutibacterium, coagulase-negative Staphylococcus, and other bacteria were calculated by dividing the respective Shoulder Scores by the number of specimens submitted.

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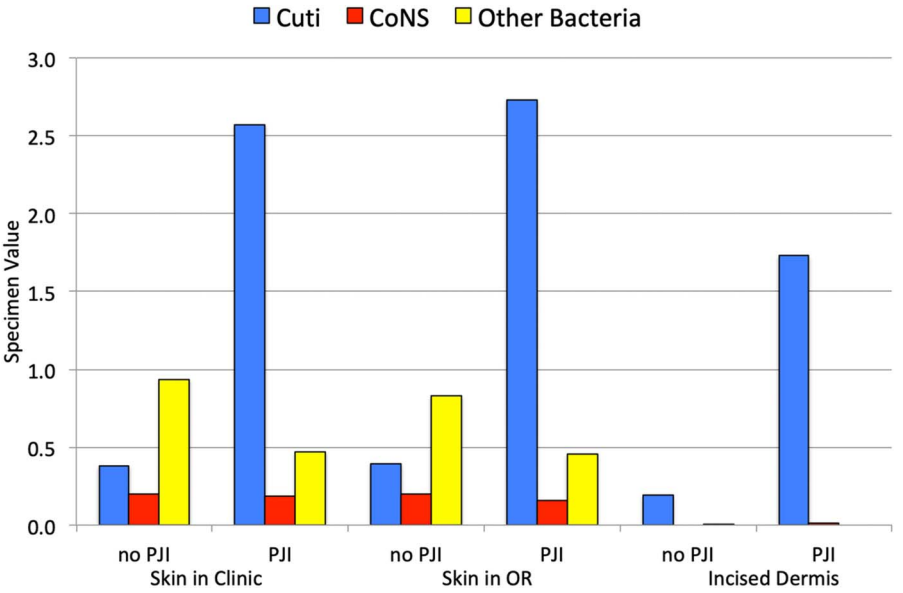

Fig. 1

Culture results are expressed as the specimen values: 0 for no growth, 0.1 for growth in broth only or for 1 colony only on a plate, 1 for 1+ growth, 2 for 2+ growth, 3 for 3+ growth, and 4 for 4+ growth on a plate, where the values from 1 to 4 indicate the number of quadrants on the streaked plate showing growth. Plate streaking was performed in the standardized manner used in most clinical microbiology laboratories. A heat-sterilized loop is used to take a sample of the inoculum from the culture tube and spread it over the first quadrant of the plate using closely parallel back-and-forth streaks. The loop is flame-sterilized and is allowed to cool. A sample from the streaked edge of the first quadrant is streaked into the second quadrant. The loop is flame-sterilized and is allowed to cool. A sample from the streaked edge of the second quadrant is streaked into the third quadrant. The loop is flame-sterilized and is allowed to cool. A sample from the streaked edge of the third quadrant is streaked into the fourth quadrant. In this figure, the specimen values are shown for Cutibacterium (Cuti), coagulase-negative Staphylococcus (CoNS), and other bacteria, comparing shoulders without (no PJI) and those with (PJI) a Cutibacterium PJI. Specimen values are shown for the preoperative cultures in the clinic, for the preoperative cultures in the operating room (OR), and for the dermis freshly incised at the revision surgical procedure.

The possibility of culture-negative infections was not considered in this study.

The characteristics of the patients who underwent a revised shoulder arthroplasty and who did or did not have a culture-positive Cutibacterium PJI were compared, including patient sex and age at the time of the index arthroplasty; race; marital status; diabetes; type of insurance; body mass index (BMI); American Society of Anesthesiologists (ASA) class; use of tobacco, narcotics, or alcohol; diagnosis; surgical procedure on the shoulder prior to the index arthroplasty; type of index arthroplasty; time from the index arthroplasty to open revision; and the results of preoperative and perioperative cultures.

For these comparisons, an unpaired t test (Microsoft Excel) was used for continuous variables and the Mann-Whitney U test[26], for semiquantitative culture results.

To test the first hypothesis, we assessed the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of a clinic skin Cutibacterium value of >1 for a culture-positive Cutibacterium PJI[27]. To test the second hypothesis, we assessed the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of a percentage of the total clinic skin culture specimen bacterial load contributed by Cutibacterium (Cutibacterium percentage) of ≥75% for a culture-positive Cutibacterium PJI.

We performed this analysis for all patients and for male patients only.

Results

Eighteen cases met the inclusion criteria; of these, 7 (6 male patients) met the criterion for a culture-positive Cutibacterium PJI. Of the 11 male patients who underwent revision arthroplasty, 6 met the criterion for a Cutibacterium PJI (Shoulder Scores for Cutibacterium of 10.1, 6.3, 4.1, 4.1, 2.4, and 2.1). Of the 7 female patients, only 1 met the criterion (Shoulder Score for Cutibacterium of 2). The first hypothesis was that the results of skin surface culture specimens obtained in the clinic prior to a revision shoulder arthroplasty are a valuable predictor of the presence or absence of a culture-positive Cutibacterium PJI; this hypothesis was supported by this study. The clinic skin Cutibacterium value was >6 times greater for the Cutibacterium PJI group (2.6 ± 1.7) than for the no-PJI group (0.4 ± 0.5) ($p = 0.002$) (Fig. 1, Table I). For all patients, a preoperative clinic skin Cutibacterium value of >1 predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 89%; for male patients only, the accuracy was 91% (Table II).

The second hypothesis was that a greater preponderance of Cutibacterium is predictive of the presence of a culture-

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TABLE I Characteristics of Patients without and with a Culture-Positive Cutibacterium PJI

	No PJI (N = 11)	Cutibacterium PJI (N = 7)	P Value
No. of male patients	5	6	0.151
Age*† *(yr)*	51 ± 15 (23 to 73)	48 ± 15 (27 to 63)	0.638
BMI*† *(kg/m²)*	33 ± 7 (23 to 42)	26 ± 4 (22 to 31)	0.009
ASA class*†	2.5 ± 0.7 (1 to 3)	1.7 ± 0.5 (1 to 2)	0.017
Time from index to revision*† *(yr)*	1.9 ± 1.7 (0.2 to 5.5)	1.7 ± 0.6 (0.9 to 2.3)	0.697
Time from clinic culture to revision*† *(days)*	19 ± 19 (1 to 62)	33 ± 42 (1 to 97)	0.420
Diagnosis for index procedure			<0.001
Primary osteoarthritis	10%	72%	
Cuff tear arthropathy	18%		
Secondary arthritis	18%		
Capsulorrhaphy arthropathy	27%	14%	
Osteonecrosis	9%		
Other	18%	14%	
Index procedure			0.308
Total shoulder arthroplasty	9%	14%	
Ream-and-run arthroplasty	27%	72%	
Hemiarthroplasty	37%	14%	
Reverse arthroplasty	27%		
Clinic skin surface culture*†			
Specimen Cutibacterium value	0.4 ± 0.5 (0.0 to 1.0)	2.6 ± 1.7 (1.0 to 6.0)	0.002
Specimen coagulase-negative Staphylococcus value	0.2 ± 0.4 (0.0 to 1.0)	0.2 ± 0.4 (0.0 to 1.0)	0.617
Specimen other bacteria value	0.9 ± 0.5 (0.0 to 2.0)	0.5 ± 0.8 (0.0 to 2.0)	0.124
Operating room skin surface culture*†			
Specimen Cutibacterium value	0.4 ± 0.7 (0.0 to 2.0)	2.7 ± 2.2 (0.1 to 7.0)	0.004
Specimen coagulase-negative Staphylococcus value	0.2 ± 0.4 (0.0 to 1.0)	0.2 ± 0.4 (0.0 to 1.0)	0.818
Specimen other bacteria value	0.8 ± 1.5 (0.0 to 5.0)	0.5 ± 0.5 (0.0 to 1.0)	0.928
Operating room skin dermal culture			
Specimen Cutibacterium value	0.2 ± 0.6 (0.0 to 2.0)	1.7 ± 1.7 (0.0 to 5.0)	0.038
Specimen coagulase-negative Staphylococcus value	0.0 ± 0.0 (0.0 to 0.0)	0.0 ± 0.0 (0.0 to 0.1)	0.653
Specimen other bacteria value	0.0 ± 0.0 (0.0 to 0.1)	0.0 ± 0.0 (0.0 to 0.0)	0.787
Type of revision†			0.007
Complete prosthesis exchange	37%	86%	
Head exchange only	18%	14%	
Revision reverse arthroplasty	18%		
Hemiarthroplasty to total shoulder arthroplasty	9%		
Spacer	9%		
Explantation	9%		
Sum of values of deep cultures from surgery*†			
Shoulder Score for Cutibacterium *(points)*	0.1 ± 0.4 (0.0 to 1.2)	4.4 ± 2.9 (2.0 to 10.1)	0.001
Average Shoulder Score for Cutibacterium§ *(points)*	0.0 ± 0.1 (0.0 to 0.2)	0.8 ± 0.4 (0.3 to 1.7)	0.001
Shoulder Score for coagulase-negative Staphylococcus *(points)*	0.2 ± 0.6 (0.2 to 2.0)	0.0 ± 0.0 (0.0 to 0.1)	0.818
Average Shoulder Score for coagulase-negative Staphylococcus§ *(points)*	0.1 ± 0.2 (0.0 to 0.7)	0.0 ± 0.0 (0.0 to 0.0)	0.787
Shoulder Score for other bacteria *(points)*	0.5 ± 0.7 (0.0 to 2.0)	0.3 ± 0.5 (0.0 to 1.0)	0.889
Average Shoulder Score for other bacteria§ *(points)*	0.1 ± 0.2 (0.0 to 0.7)	0.1 ± 0.1 (0.0 to 0.3)	0.719

*The values are given as the mean and the standard deviation, with the range in parentheses. †Student t test. ‡Mann-Whitney U test. §The score was divided by the number of samples submitted for culture.

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TABLE II Prediction of a Culture-Positive Cutibacterium PJI*

	Clinic Skin Cutibacterium Value >1	Cutibacterium Percentage ≥75%
For all patients		
Sensitivity	71% (29% to 96%)	86% (42% to 100%)
Specificity	100% (72% to 100%)	100% (72% to 100%)
Positive predictive value	100%	100%
Negative predictive value	85% (63% to 95%)	92% (64% to 99%)
Accuracy	89% (65% to 99%)	94% (73% to 100%)
For male patients only		
Sensitivity	83% (36% to 100%)	100% (54% to 100%)
Specificity	100% (48% to 100%)	100% (48% to 100%)
Positive predictive value	100%	100%
Negative predictive value	83% (46% to 97%)	100%
Accuracy	91% (59% to 100%)	100% (72% to 100%)

*The values are given as the percentage, with or without the 95% confidence interval in parentheses.

positive Cutibacterium PJI; this hypothesis was also supported. The mean clinic skin percentage of Cutibacterium for the Cutibacterium PJI group was 81% ± 16% (range, 50% to 97%), 5 times higher than the percentage of Cutibacterium for the no-PJI group, 16% ± 20% (range, 0% to 50%) ($p < 0.001$). Six (86%) of the 7 cases of Cutibacterium PJI had a Cutibacterium percentage of ≥75%, and none (0%) of the 11 no-PJI cases had a Cutibacterium percentage of ≥75% (Fisher exact text; $p < 0.001$). For all patients, a Cutibacterium percentage of ≥75% predicted the presence of a culture-positive Cutibacterium PJI with an accuracy of 94%; for male patients only, the accuracy was 100% (Table II).

In this series of revised shoulders, there were no culture-positive PJIs by organisms other than Cutibacterium; in other words, no patient had ≥2 culture specimens from the revision surgical procedure with a specimen non-Cutibacterium bacterium value of ≥1.

The Shoulder Score for Cutibacterium was >40 times greater for the Cutibacterium PJI group (4.4 ± 2.9) than for the no-PJI group (0.1 ± 0.4) ($p = 0.001$) (Fig. 2, Table I). The mean

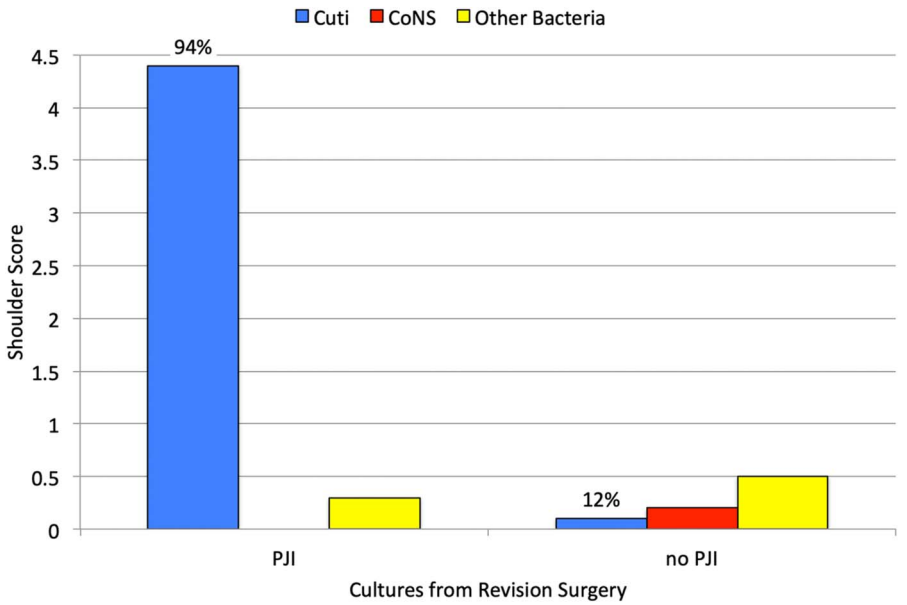

Fig. 2

The results of intraoperative cultures are shown as the Shoulder Scores for Cutibacterium, coagulase-negative Staphylococcus (CoNS), and other bacteria, comparing shoulders with (PJI) and without (no PJI) a Cutibacterium PJI. The percentage of the total bacterial load contributed by Cutibacterium is shown by the numbers above the Cutibacterium columns. These percentages demonstrate the dysbiosis of the deep tissues in shoulders with Cutibacterium PJI.

TABLE III Characteristics of Male and Female Patients

	Men (N = 11)	Women (N = 7)	P Value
Age* *(yr)*	48 ± 13 (27 to 69)	52 ± 16 (23 to 73)	0.670
BMI* *(kg/m²)*	30 ± 6 (22 to 42)	32 ± 7 (23 to 42)	0.567
ASA class*	1.8 ± 0.6 (1 to 3)	2.7 ± 0.5 (2 to 3)	0.004
Time from index arthroplasty to revision* *(yr)*	1.8 ± 1.1 (0.6 to 4.2)	1.9 ± 1.8 (0.2 to 5.5)	0.911
Clinic cultures*			
Specimen Cutibacterium value	1.8 ± 1.7 (0 to 6)	0.3 ± 0.5 (0 to 1)	0.016
Specimen coagulase-negative Staphylococcus value	0.3 ± 0.5 (0 to 1)	0 ± 0 (0 to 0.1)	0.075
Specimen other bacteria value	0.7 ± 0.8 (0.0 to 2.0)	0.9 ± 0.3 (0.1 to 1.1)	0.447
Surgical cultures*			
Shoulder Cutibacterium score *(points)*	2.8 ± 3.2 (0.0 to 10.1)	0.3 ± 0.7 (0.0 to 2.0)	0.033
Shoulder coagulase-negative Staphylococcus score *(points)*	0.2 ± 0.6 (0.0 to 2.0)	0.0 ± 0.0 (0.0 to 0.0)	0.271
Shoulder other bacteria score *(points)*	0.6 ± 0.7 (0.0 to 2.0)	0.2 ± 0.4 (0.0 to 1.0)	0.131
No. meeting the definition of Cutibacterium PJI	6	1	
Clinic specimen Cutibacterium value			
Patients with Cutibacterium PJI*	2.8 ± 1.7	1.0	
Patients with no PJI*	0.6 ± 0.52	0.2 ± 0.4	
P value for Cutibacterium PJI vs. no PJI†	0.018	Not determinable	

*The values are given as the mean and the standard deviation, with the range in parentheses. †Mann-Whitney U test.

Shoulder Score for Cutibacterium was significantly greater (p = 0.001) for the Cutibacterium PJI group (0.8 ± 0.4) than for the no-PJI group (0.0 ± 0.1). The Shoulder Scores for coagulase-negative Staphylococcus and other bacteria were similar between the Cutibacterium PJI and no-PJI groups.

The Cutibacterium PJI group had a higher percentage of male patients, lower BMI, lower ASA score, higher rate of primary arthritis as the indication for the index arthroplasty, and higher rate of the ream-and-run procedure in contrast to other types of primary arthroplasty (Table I). These findings are consistent with a recent report demonstrating that an increased dermal load of Cutibacterium was significantly associated with male sex, younger patient age, and ASA class of 1[19]. Male patients were healthier (significantly lower ASA class), had higher clinic specimen Cutibacterium values, and had higher Shoulder Scores for Cutibacterium for specimens harvested at revision surgical procedures (Table III).

Other variables such as age; race; marital status; diabetes; type of insurance; use of tobacco, narcotics, or alcohol; and non-arthroplasty surgical procedure on the shoulder prior to the index arthroplasty were not significantly different between the Cutibacterium PJI group and the no-PJI group.

Discussion

To our knowledge, this study is the first to demonstrate the value of semiquantitative preoperative skin culture specimens obtained in the clinic in predicting the presence of a culture-positive periprosthetic Cutibacterium infection. A high load of Cutibacterium (specimen Cutibacterium value) and a high percentage of Cutibacterium in the skin culture sample were predictive of a culture-positive Cutibacterium PJI. Obtaining a skin culture is a noninvasive and relatively inexpensive test that can be conveniently done in the clinic before the surgical procedure so that the results will be known before the date of revision arthroplasty. These results can be used in combination with other patient characteristics to plan the revision procedure, including the need for prosthesis exchange and postoperative antibiotics.

Figures 3-A and 3-B show a case demonstrating the utility of preoperative skin culture specimens obtained in the clinic in predicting the presence of a culture-positive Cutibacterium PJI at the surgical revision of a shoulder without other clinical manifestations of infection.

In Table IV, the results for male and female patients are compared with those in a prior study of patients having skin swabs submitted for culture prior to elective primary shoulder arthroplasty[19]. It is of interest that, for both male and female patients undergoing primary arthroplasty, the mean values for the skin specimen Cutibacterium value and the Cutibacterium percentage lie between the corresponding values for the patients with Cutibacterium PJI and those with no PJI in the current study.

As recently emphasized by Ricchetti et al.[28], periprosthetic shoulder infections differ from those of the knee and hip because of the indolent nature of the common infecting organism, Cutibacterium. As a result, the guidelines for the diagnosis and treatment of these PJIs are different from those for the joints of the lower extremity. Traditionally used preoperative diagnostic laboratory values, such as erythrocyte sedimentation rate,

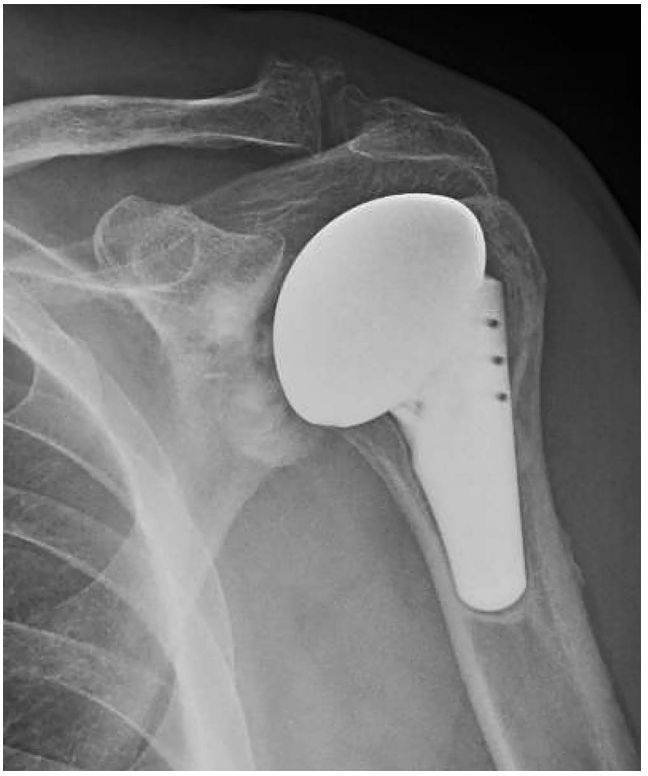

Fig. 3-A

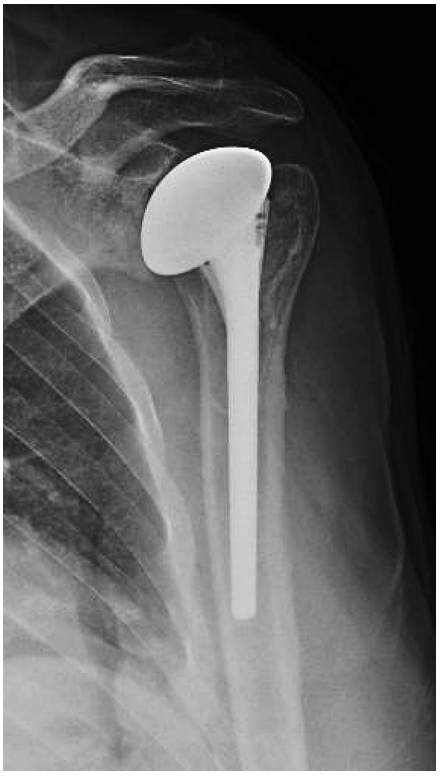

Fig. 3-B

Figs. 3-A and 3-B A case showing the utility of preoperative clinic culture specimens. A 60-year-old man presented with increasing shoulder pain and stiffness of insidious onset at 2 years after a short-stemmed total shoulder arthroplasty performed at an outside hospital. He was a nonsmoker in good health with a BMI of 28 kg/m^2 and ASA class of 2. He had no systemic signs or laboratory evidence of infection. **Fig. 3-A** His pre-revision radiograph suggested humeral component loosening. A preoperative clinic swab of his unprepared skin over the shoulder incision area grew 3+ Cutibacterium, 1+ coagulase-negative Staphylococcus, and no other organisms, for a Cutibacterium percentage of 75%. At the time of the surgical procedure, there was no synovitis, no free joint fluid, and a loose humeral component. Frozen sections of the periprosthetic tissue showed no neutrophils and no organisms. **Fig. 3-B** In view of the results of his clinic cultures, but in the absence of clinical signs of infection, he had a single-stage revision of the total shoulder arthroplasty to a ream-and-run arthroplasty with impaction allografting of a standard smooth stem inserted after thorough debridement and irrigation. Immediately after the surgical procedure, he was administered intravenous ceftriaxone through a peripherally inserted central catheter. When his intraoperative cultures were finalized at 3 weeks after the surgical procedure, they showed 3+ growth from the explanted stem, 2+ growth from the humeral-head component, 1+ growth from the glenoid component, and 0.1+ growth from each of the humeral periosteum, the collar membrane, and the humeral membrane, for a Shoulder Score for Cutibacterium of 6.3 points and a mean Shoulder Score for Cutibacterium of 1.1 points. No other types of bacteria were recovered from his surgical specimens. At the last follow-up, the patient had discontinued antibiotics and was continuing to regain comfort and function after the revision.

TABLE IV Comparison of the Results of This Study and Those of a Prior Study of Patients Undergoing Primary Arthroplasty[19]

	Men*		Women*	
	Skin Specimen Cutibacterium Value	Cutibacterium Percentage	Skin Specimen Cutibacterium Value	Cutibacterium Percentage
Prior study	1.6 ± 0.7	64% ± 35%	0.3 ± 0.6	31% ± 39%
Current study				
Cutibacterium PJI	2.8 ± 1.7	86% ± 10%	1	50%
No PJI	0.6 ± 0.5	25% ± 20%	0.2 ± 0.4	10% ± 19%

*The values are given as the mean and the standard deviation.

C-reactive protein level, and serum interleukin-6, may not be elevated in cases of Cutibacterium PJI. Consequently, the diagnosis and the surgical and antibiotic treatments have been based largely on clinical suspicion, patient characteristics, and intraoperative findings. Although newer testing procedures, such as synovial fluid analysis, lowered thresholds for frozen-section analysis, culturing of bacterial variants, polymerase chain reaction (PCR) analysis, and use of implant sonication may hold the potential for increasing accuracy and sensitivity in the diagnosis of indolent infections, the predictive value of these tools has yet to be demonstrated for the detection of Cutibacterium PJI. Recent publications have pointed to the use of serum interleukin-6[7], synovial fluid alpha-defensin[29], synovial fluid interleukin-6[30], combined synovial fluid cytokine analysis[6], and the synovial alpha-defensin lateral flow test[31] in the diagnosis of PJIs; however, these studies have not specifically evaluated the value of these tests in predicting culture-positive Cutibacterium PJI. The culturing of arthroscopically obtained tissue samples has been shown to have predictive value for Cutibacterium PJI[14,32-34], but this test is substantially more invasive and expensive than a skin specimen for culture obtained in the clinic. Further studies are needed to evaluate the relative value of different modalities in predicting the presence of a culture-positive Cutibacterium PJI.

The results of our study need to be viewed in light of certain limitations. First, in this preliminary report, the sample size was small. As such, there were differences between the cohorts that might have been significant with a larger sample size. Second, patients with and without culture-positive Cutibacterium PJIs differ in characteristics other than the results of clinic skin cultures; these characteristics may also be of use in predicting the presence of a culture-positive Cutibacterium PJI. Third, we did not compare the value of preoperative clinic cultures with other preoperative and intraoperative methods for predicting the presence of a Cutibacterium PJI. Fourth, although our protocol is to obtain preoperative clinic culture specimens on all revision arthroplasties, this was not always possible during the time of this preliminary study. Fifth, the cases represented the practice at 1 center; therefore, the selection of patients for revision arthroplasty and the culturing protocols may not have been representative of those used in other practices. Sixth, it was possible that culture-negative infections were missed in our study. As emphasized by Palan et al.[11], fungi and mycobacteria may be responsible for 7% to 15% of culture-negative shoulder PJIs. The criteria for establishing this diagnosis remains undefined. Seventh, in their 2019 report on the Proceedings from the 2018 International Consensus Meeting on Orthopedic Infections: Evaluation of Periprosthetic Shoulder Infection, Garrigues et al.[35] pointed to "the current lack of a uniform definition of PJI specific to shoulder arthroplasty" and particularly the difficulty in defining a Cutibacterium PJI. This report pointed out that, although Cutibacterium may be less virulent than some other organisms, it is widely recognized as a definite pathogen. A robust criterion for culture-positive Cutibacterium PJI was applied: ≥2 surgical specimens with a Cutibacterium value of ≥1. This criterion may be stricter than that used in other centers.

In conclusion, in spite of its small sample size, this study demonstrates that the results of cultures of preoperative skin swabs obtained in the clinic are highly correlated with the presence or absence of a culture-positive Cutibacterium PJI in revised shoulder arthroplasties. Both the absolute value of the Cutibacterium load and the percentage of the total bacterial load contributed by Cutibacterium were highly predictive of the presence of a culture-positive Cutibacterium PJI. We conclude that a simple culture specimen of the unprepared skin surface obtained in the clinic prior to a revision shoulder arthroplasty may provide valuable assistance to surgeons planning a revision arthroplasty with respect to the need for prosthesis exchange and postoperative antibiotics. ■

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References

1. Hsu JE, Gorbaty JD, Whitney IJ, Matsen FA 3rd. Single-stage revision is effective for failed shoulder arthroplasty with positive cultures for Propionibacterium. J Bone Joint Surg Am. 2016 Dec 21;98(24):2047-51.

2. Yao JJ, Jurgensmeier K, Woodhead BM, Whitson AJ, Pottinger PS, Matsen FA 3rd, Hsu JE. The use and adverse effects of oral and intravenous antibiotic administration for suspected infection after revision shoulder arthroplasty. J Bone Joint Surg Am. 2020 Jun 3;102(11):961-70.

3. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, Warme WJ, Matsen FA 3rd. Prognostic factors for bacterial cultures positive for Propionibacterium acnes and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. J Bone Joint Surg Am. 2012 Nov 21;94(22):2075-83.

4. Deirmengian C, Feeley S, Kazarian GS, Kardos K. Synovial fluid aspirates diluted with saline or blood reduce the sensitivity of traditional and contemporary synovial fluid biomarkers. Clin Orthop Relat Res. 2020 Aug;478(8):1805-13. Epub ahead of print.

5. Falstie-Jensen T, Daugaard H, Søballe K, Ovesen J, Arveschoug AK, Lange J; ROSA study group. Labeled white blood cell/bone marrow single-photon emission computed tomography with computed tomography fails in diagnosing chronic periprosthetic shoulder joint infection. J Shoulder Elbow Surg. 2019 Jun;28(6):1040-8. Epub 2019 Jan 31.

6. Frangiamore SJ, Saleh A, Grosso MJ, Farias Kovac M, Zhang X, Daly TM, Bauer TW, Derwin KA, Iannotti JP, Ricchetti ET. Neer Award 2015: analysis of cytokine profiles in the diagnosis of periprosthetic joint infections of the shoulder. J Shoulder Elbow Surg. 2017 Feb;26(2):186-96. Epub 2016 Oct 5.

7. Grosso MJ, Frangiamore SJ, Saleh A, Kovac MF, Hayashi R, Ricchetti ET, Bauer TW, Iannotti JP. Poor utility of serum interleukin-6 levels to predict indolent periprosthetic shoulder infections. J Shoulder Elbow Surg. 2014 Sep;23(9):1277-81. Epub 2014 Apr 13.

8. Hecker A, Jungwirth-Weinberger A, Bauer MR, Tondelli T, Uçkay I, Wieser K. The accuracy of joint aspiration for the diagnosis of shoulder infections. J Shoulder Elbow Surg. 2020 Mar;29(3):516-20. Epub 2019 Sep 25.

9. Mook WR, Garrigues GE. Diagnosis and management of periprosthetic shoulder infections. J Bone Joint Surg Am. 2014 Jun 4;96(11):956-65. Epub 2014 Jun 4.

10. Nelson GN, Paxton ES, Narzikul A, Williams G, Lazarus MD, Abboud JA. Leukocyte esterase in the diagnosis of shoulder periprosthetic joint infection. J Shoulder Elbow Surg. 2015 Sep;24(9):1421-6.

11. Palan J, Nolan C, Sarantos K, Westerman R, King R, Foguet P. Culture-negative periprosthetic joint infections. EFORT Open Rev. 2019 Oct 7;4(10):585-94.

12. Paxton ES, Green A, Krueger VS. Periprosthetic infections of the shoulder: diagnosis and management. J Am Acad Orthop Surg. 2019 Nov 1;27(21):e935-44.

13. Plate A, Anagnostopoulos A, Glanzmann J, Stadler L, Weigelt L, Sutter R, Kästli M, Zinkernagel AS, Zingg PO, Achermann Y. Synovial C-reactive protein features high negative predictive value but is not useful as a single diagnostic parameter in suspected periprosthetic joint infection (PJI). J Infect. 2019 Jun;78(6):439-44. Epub 2019 Apr 6.

14. Ricchetti ET. Editorial commentary: in search of the optimal diagnostic tool for periprosthetic joint infections of the shoulder. Arthroscopy. 2019 Sep;35(9):2578-80.

15. Shields MV, Abdullah L, Namdari S. The challenge of Propionibacterium acnes and revision shoulder arthroplasty: a review of current diagnostic options. J Shoulder Elbow Surg. 2016 Jun;25(6):1034-40. Epub 2016 Mar 30.

16. Unter Ecker N, Koniker A, Gehrke T, Salber J, Zahar A, Hentschke M, Citak M. What is the diagnostic accuracy of alpha-defensin and leukocyte esterase test in periprosthetic shoulder infection? Clin Orthop Relat Res. 2019 Jul;477(7):1712-8.

17. Villacis D, Merriman JA, Yalamanchili R, Omid R, Itamura J, Rick Hatch GF 3rd. Serum interleukin-6 as a marker of periprosthetic shoulder infection. J Bone Joint Surg Am. 2014 Jan 1;96(1):41-5.

18. Ahsan ZS, Somerson JS, Matsen FA 3rd. Characterizing the Propionibacterium load in revision shoulder arthroplasty: a study of 137 culture-positive cases. J Bone Joint Surg Am. 2017 Jan 18;99(2):150-4.

19. Matsen FA 3rd, Whitson AJ, Pottinger PS, Neradilek MB, Hsu JE. Cutaneous microbiology of patients having primary shoulder arthroplasty. J Shoulder Elbow Surg. 2020 Aug;29(8):1671-80. Epub 2020 Apr 1.

20. MacNiven I, Hsu JE, Neradilek MB, Matsen FA 3rd. Preoperative skin-surface cultures can help to predict the presence of Propionibacterium in shoulder arthroplasty wounds. JB JS Open Access. 2018 Feb 16;3(1):e0052.

21. Hsu JE, Neradilek MB, Russ SM, Matsen FA 3rd. Preoperative skin cultures are predictive of Propionibacterium load in deep cultures obtained at revision shoulder arthroplasty. J Shoulder Elbow Surg. 2018 May;27(5):765-70. Epub 2018 Mar 12.

22. Matsen FA 3rd, Whitson A, Neradilek MB, Pottinger PS, Bertelsen A, Hsu JE. Factors predictive of Cutibacterium periprosthetic shoulder infections: a retrospective study of 342 prosthetic revisions. J Shoulder Elbow Surg. 2020 Jun;29(6):1177-87. Epub 2019 Oct 24.

23. Matsen FA 3rd, Whitson AJ, Hsu JE. While home chlorhexidine washes prior to shoulder surgery lower skin loads of most bacteria, they are not effective against Cutibacterium (Propionibacterium). Int Orthop. 2020 Mar;44(3):531-4. Epub 2020 Jan 14.

24. Matsen FA 3rd, Butler-Wu S, Carofino BC, Jette JL, Bertelsen A, Bumgarner R. Origin of Propionibacterium in surgical wounds and evidence-based approach for culturing Propionibacterium from surgical sites. J Bone Joint Surg Am. 2013 Dec 4;95(23):e1811-7.

25. Hsu JE, Somerson JS, Vo KV, Matsen FA 3rd. What is a "periprosthetic shoulder infection"? A systematic review of two decades of publications. Int Orthop. 2017 Apr;41(4):813-22. Epub 2017 Feb 21.

26. Social Science Statistics. Mann-Whitney U test calculator. Accessed 2020 Apr 10. https://www.socscistatistics.com/tests/mannwhitney/default2.aspx

27. MedCalc Software Ltd. Free statistical calculators. Diagnostic test evaluation calculator. Accessed 2020 Apr 10. https://www.medcalc.org/calc/diagnostic_test.php

28. Ricchetti ET, Frangiamore SJ, Grosso MJ, Alolabi B, Saleh A, Bauer TW, Iannotti JP. Diagnosis of periprosthetic infection after shoulder arthroplasty: a critical analysis review. JBJS Rev. 2013 Nov 19;1(1):01874474-201311000-00005.

29. Frangiamore SJ, Saleh A, Grosso MJ, Kovac MF, Higuera CA, Iannotti JP, Ricchetti ET. α-defensin as a predictor of periprosthetic shoulder infection. J Shoulder Elbow Surg. 2015 Jul;24(7):1021-7. Epub 2015 Feb 8.

30. Frangiamore SJ, Saleh A, Kovac MF, Grosso MJ, Zhang X, Bauer TW, Daly TM, Ricchetti ET, Iannotti JP. Synovial fluid interleukin-6 as a predictor of periprosthetic shoulder infection. J Bone Joint Surg Am. 2015 Jan 7;97(1):63-70.

31. Weigelt L, Plate A, Stadler L, Sutter R, Frustaci D, Zbinden R, Zingg PO, Gerber C, Achermann Y. Alpha-defensin lateral flow test does not appear to be useful in predicting shoulder periprosthetic joint infections. Int Orthop. 2020 Jun;44(6):1023-9. Epub 2020 Mar 14.

32. Akgün D, Maziak N, Plachel F, Minkus M, Scheibel M, Perka C, Moroder P. Diagnostic arthroscopy for detection of periprosthetic infection in painful shoulder arthroplasty. Arthroscopy. 2019 Sep;35(9):2571-7. Epub 2019 Jul 24.

33. Dilisio MF, Miller LR, Warner JJ, Higgins LD. Arthroscopic tissue culture for the evaluation of periprosthetic shoulder infection. J Bone Joint Surg Am. 2014 Dec 3;96(23):1952-8.

34. Sanchez-Sotelo J. Periprosthetic shoulder infections are less elusive to diagnostic arthroscopy: commentary on an article by Matthew F. Dilisio, MD, et al.: "Arthroscopic tissue culture for the evaluation of periprosthetic shoulder infection". J Bone Joint Surg Am. 2014 Dec 3;96(23):e197.

35. Garrigues GE, Zmistowski B, Cooper AM, Green A; ICM Shoulder Group. Proceedings from the 2018 International Consensus Meeting on Orthopedic Infections: evaluation of periprosthetic shoulder infection. J Shoulder Elbow Surg. 2019 Jun;28(6S):S32-66.