Cutibacterium acnes infections in revision surgery for persistent shoulder complaints: a retrospective cohort study

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Abstract

Introduction Low-grade *Cutibacterium acnes* (*C. acnes*) infections after shoulder surgery usually result in unexplained complaints. The absence of clinical signs of infection makes the incidence unclear and underreported. This study aimed to determine the incidence of *C. acnes* infections in patients with artificial material and unexplained persistent shoulder complaints. We hypothesized that the incidence of *C. acnes* infections would be higher in patients with artificial material. Risk factors and associations between culture time and contaminations/infections were also assessed.

Materials and methods This retrospective cohort study included patients with and without artificial material undergoing revision shoulder surgery for persistent complaints after primary surgery and the suspicion of a low-grade infection. Three–six cultures were taken in all patients. *C. acnes* infection incidence was determined and logistic regression analysis was performed to identify risk factors. The association between time to culture growth and infections/contaminations was evaluated using Kaplan–Meier analysis and log-rank test.

Results 26/61 (42.6%) patients with and 14/33 (42.2%) without material had a *C. acnes* infection. Age (OR 0.959; 95% CI 0.914–1.000) and BMI (OR 0.884; 95% CI 0.787–0.977) were risk factors. Time to *C. acnes* culture positivity was not different between infections and contaminations.

Conclusion The incidence of *C. acnes* infections was 42.6% in patients with artificial material and 42.2% in patients without artificial material. Younger age and lower BMI are risk factors. Low-grade *C. acnes* infections should be considered in patients with unexplained persistent complaints following shoulder surgery.

Keywords *Cutibacterium aces* · Infection · Contamination · Cultivation time · Revision shoulder surgery · Risk factors

Introduction

Cutibacterium acnes (*C. acnes*), formerly known as Propionibacterium acnes, is the most commonly detected pathogen during shoulder surgery [1–5]. It is suggested that *C. acnes*

The study was performed at the Sint Maartenskliniek Nijmegen, except for the medical microbiology part, which was performed at the Canisius-Wilhelmina Hospital Nijmegen.

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can contaminate the surgeon's instruments or gloves when the sebaceous glands are cut [6] and can in that way contaminate the wound. When a low-grade infection is present, it can result in unexplained pain and stiffness, dysfunctional joints, or loosening of shoulder prostheses, which can affect patient outcomes [7–9].

Because of these non-specific symptoms without elevated infection parameters [4, 10], low-grade infections are often not considered. Consequently, the incidence of *C. acnes* infections is probably underestimated. *C. acnes* infections are currently diagnosed during revision surgery, when cultures are taken. To adequately detect *C. acnes*, 8–14 days of culturing are required [11–13]. Shorter cultivation times result in false-negative results, which contributes to the underestimation of *C. acnes* infections during shoulder surgery. Contrarily, longer cultivation times can result in false-positive cultures. Research has demonstrated that positive *C. acnes* cultures after 9 days were

more associated with possible contamination; whereas, *C. acnes* infections showed positive cultures within one week after surgery [13, 14]. It is likely that a higher amount of bacteria are brought into culture in case of infections, and, therefore, show earlier positive cultures compared to contaminations. Therefore, timing of the first positive *C. acnes* cultures might help to distinguish between *C. acnes* infections and contaminations, which could aid in the decision to prescribe postoperative antibiotics.

To our knowledge, no studies have been performed that describe *C. acnes* infections in a comparative group of patients with or without artificial material in the shoulder. This study aimed to gain insight in the incidence of *C. acnes* infections in patients with pain and/or stiffness following shoulder surgery and the suspicion of a low-grade infection. Risk factors and differences in time to positivity between infections and contaminations were also assessed. We hypothesized that the incidence of *C. acnes* infections would be higher in patients with artificial material compared to those without, and that male gender and younger age would be risk factors. Moreover, we expected infections to have a shorter cultivation time than contaminations.

Materials and methods

A retrospective cohort study was performed including patients who underwent revision shoulder surgery because of suspicion of a low-grade infection due to unexplained persistent pain and/or stiffness, according to one surgeon. All patients with and without artificial material placement during primary surgery, and in whom cultures were taken during revision shoulder surgery (further referred to as target surgery) that took place between February 2016 and April 2018 were included. Patients were excluded if they had used antibiotics active against *C. acnes* two weeks prior to target surgery, if fewer than three tissue specimens were collected for culture, or if they showed overt clinical signs of infection (combined elevated infection parameters, wound leakage, fever). Demographic, clinical, microbiological, and therapeutic data were retrieved from patients' medical records.

Prior to surgery, the skin was disinfected with iodine, or chlorhexidine in case of iodine allergy, and sterilely draped according to protocol. Prophylactic antibiotics were withhold until three–six cultures were taken from the subacromial bursal tissue, intra-articular synovial tissue, acromioclavicular joint capsular tissue or distal clavical bone, biceps tendon, the artificial material itself and/or adjacent soft tissue. Thereafter, the tissue specimens were transported to the microbiology laboratory.

Tissue cultures

All perioperative tissue cultures were put in transport containers, containing thioglycolate, and were processed within 6 h. First, specimens were manually homogenized in thioglycollate (Oxoid, Haarlem, The Netherlands). Thereafter, 100 µL of each suspension was plated onto New York City plates (Oxoid), sheep blood agar plates (Oxoid), and BBA anaerobic plates (Media Products, Groningen, the Netherlands), and 2 mL was inoculated into thioglycollate and brain–heart infusion broth. In an atmosphere of 5% CO_2 and a temperature of 35 °C, aerobic cultures were incubated for 5 days. An anaerobic jar with an anaerobic gas mixture containing 80% nitrogen, 10% carbondioxide, and 10% hydrogen, was used to incubate anaerobic cultures. Aerobic plates were examined daily, while anaerobic plates were examined at 3 and 5 days.

After a 10-day incubation period and subculturing on solid media, broths were examined for bacterial growth the following 4 days. Matrix-assisted laser desorption/ionization time-of-flight (MaldiTof) mass spectrometry (Bruker, Bremen, Germany) was used to identify microorganisms. In addition, microorganisms were tested for antimicrobial susceptibility according to the European Committee on Antimicrobial Susceptibility Testing (EUCAST).

Within 14 days after target surgery, final culture results were released. An infection was considered to be present when two or more tissue cultures were positive for the same microorganism. Hence, a *C. acnes* infection was diagnosed when at least two cultures from the surgical wound were positive for *C. acnes*. When only one culture was positive for *C. acnes*, the surgical wound was considered to be contaminated.

Treatment

Treatment of a native shoulder with a clinically high suspicion of a low-grade infection, based on shoulder stiffness during tests under general anesthesia and no other clear reason for the complaints, consisted of postoperative clindamycin until peroperative culture results were known. In case of positive cultures, clindamycin treatment was extended until 6 weeks postoperative when the bacterium showed to be sensitive to this antibiotic (otherwise, other antibiotics were prescribed). When there was a clinically low suspicion of a low-grade infection, based on a full-range of motion during testing under general anesthesia and other reasons for the complaints during shoulder arthroscopy, antibiotics were withhold until culture results were positive.

When a low-grade infection of a shoulder prosthesis was suspected, arthroscopic or mini-open biopsies were

taken. A two-stage revision followed in case cultures showed the presence of a low-grade infection. First, six new cultures were taken, the prosthesis was extracted, and diluted betadine lavage was used to reduce bacterial load. After cultures were taken, cefazolin IV was started until the preliminary culture results were ready (5 days post-operative). In case of no bacteria growth, patients went home with clindamycin (or amoxicillin when resistance or intolerance for clindamycin occurred). Culture results were final after two weeks. If the antibiogram showed sensitivity, patients continued clindamycin treatment until six weeks postoperative, followed by an antibiotic holiday of at least two weeks and reimplantation of the prosthesis. During reimplantation, cultures were taken and antibiotics were given in the same way as described previously. When there was no bacteria growth, antibiotics were stopped. When a low-grade infection was detected, rifampicin was added to clindamycin with a maximum duration of three months. No spacers were used.

Statistical analysis

Demographic data, including gender, age, body mass index (BMI), smoking status, comorbidities, and history of cortisone injections, were summarized using descriptive statistics. In addition, information about the indication of primary surgery, the time between primary and target surgery, culture results, cultivation time, and if available, infection parameters were described. For patients with artificial material in the shoulder, primary surgery was defined as the surgery in which artificial material was placed for the first time; whereas, it was defined as the first surgery patients underwent in their lifetime for those without artificial material.

Furthermore, the percentage of *C. acnes* contaminations and cultures positive for other bacteria was determined. To identify variables associated with *C. acnes* infections in both groups, simple and multiple logistic regression analyses were performed. After simple logistic regression, variables were included in the multiple regression analysis based on clinical relevance and statistical significance ($P < 0.2$) between patients with and without *C. acnes* infections. Variables were checked for collinearity using the variance inflation factor (VIF). Variables were excluded from logistic regression analysis when more than 10% of the data was missing. One possible risk factor was included per ten events. Variables retained in the stepwise backward multiple logistic regression analysis when $P < 0.05$. Odds ratios (ORs), 95% confidence intervals (CI), and Wald Chi-square P values were presented per variable. To obtain better fitted parameter estimates and ORs, bootstrapping was performed for internal validation.

The association between time to *C. acnes* growth and *C. acnes* infections and contaminations was also evaluated.

For infections, the cultivation time was calculated until the date at which the first culture was positive for *C. acnes*. To visualize the time to *C. acnes* culture growth separately for patients with infections and contaminations, a Kaplan–Meier analysis was performed. Kaplan–Meier curves showed the proportion of patients in whom *C. acnes* was detected over time, and these curves were tested for significant differences using the log-rank test.

All statistical analyses were performed using SPSS version 21 with a statistical significance level of $P < 0.05$.

Ethics

This study was approved by the institutional review board of the Sint Maartenskliniek Nijmegen (entry no. 2017-0802).

Results

Between February 2016 and April 2018, 118 surgeries were performed in which perioperative cultures were taken. In total, 24 patients met the exclusion criteria (Fig. 1), resulting in 94 patients eligible for inclusion in this study.

The different indications for artificial material placement during primary surgery are listed in Table 1. Five patients without artificial material who did not have primary surgery underwent target surgery for suspicion of an infection after shoulder injections; all other patients in the control group did have previous shoulder surgery on the affected shoulder. In one patient, the date of primary surgery was unknown. For patients with artificial material, insoluble suture material, wires, anchors, screws, pins, plates, prosthesis, or a combination thereof were placed into the shoulder area during shoulder surgery. Median time from primary to target surgery for all patients was 30.5 (IQR 14.0–87.8) and, respectively, 26.0 (IQR 14.0–87.5) and 41.0 (IQR 15.0–99.0) months for patients with and without artificial material separately.

During target surgery, 40 patients (42.6%) had at least two positive cultures for *C. acnes* (Table 2). *C. acnes* infections occurred in 26 of the 61 (42.6%) patients with and in 14 of the 33 (42.2%) patients without artificial material. The number of *C. acnes* infections after different surgery indications is shown in Table 1. Only four patients (all with artificial material) had at least two positive cultures for other bacteria (7.1%), which were *S. saccharolyticus*, *S. capitis*, *S. epidermis* or *S. lugdunensis*. Three of them also had a *C. acnes* infection.

After target surgery, 16 patients underwent another revision surgery in which cultures were taken. Of these patients, nine had a *C. acnes* infection. Five of these patients also had a *C. acnes* infection detected during previous target
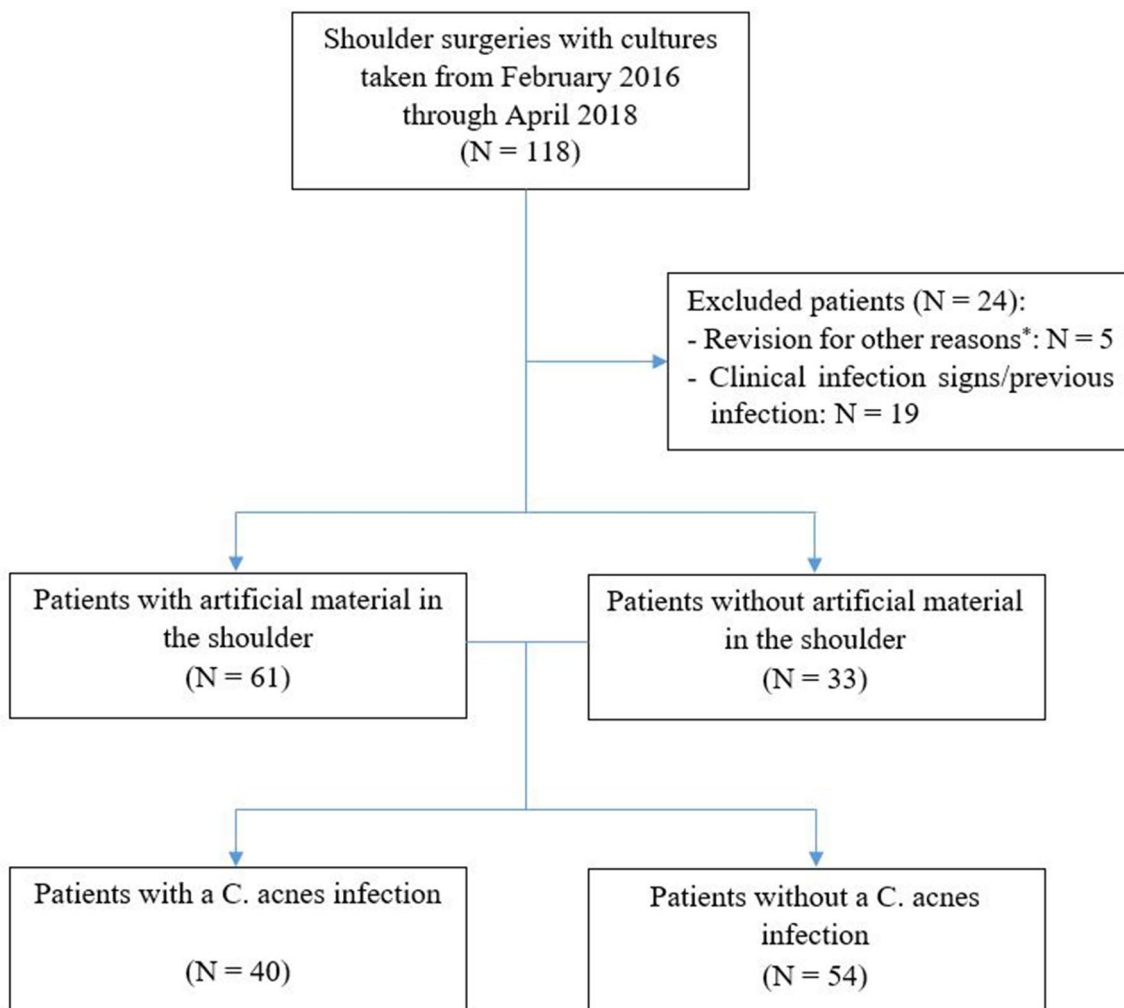
Fig. 1 Flowchart of the study design

surgery, for which four of them were treated with antibiotics (clindamycin).

Characteristics of patients with and without a *C. acnes* infection are shown in Table 3. Noticeably, most patients with a *C. acnes* infection were men, while most patients without were women. Additionally, patients with *C. acnes* infections were on average 6 years younger at the time of primary surgery than patients without infections. Of the 24 patients with prior revision surgeries at the same shoulder, 16 had one revision surgery, five had two revision surgeries, two had three revision surgeries, and one had four revision surgeries before target surgery. More specifically, seven out of the 16 patients with one prior revision surgery and four out of five patients with two prior revision surgeries had a *C. acnes* infection.

Infection parameters were not measured in all patients between the time of primary surgery and revision surgery. ESR, CRP, and leukocyte levels were available in 28, 30, and 29 patients, respectively. Between primary target surgery, 3

patients had only elevated ESR levels (> 20 mm/u), 3 had solely elevated CRP levels (> 10 mg/L), none had solely elevated leukocytes levels (> 11 × 10⁹/L), and 4 had a combination of elevated infection parameters. Of these 10 patients with elevated infection parameters, 3 had a *C. acnes* infection. There were 3 patients with rheumatoid arthritis among the patients with elevated infection parameters, of whom one also had a *C. acnes* infection.

Logistic regression

Simple logistic regression showed that gender, age at primary surgery, BMI, diabetes, history of cortisone injections, and time between primary surgery and complaints were associated ($P < 0.2$) with *C. acnes* infections (Table 4). Based on significance and relevance, gender, age, BMI, and a history of cortisone injections were included in the backward multiple logistic regression

Table 1 Number of *C. acnes* infections per primary surgery indication

Primary surgery indication	No. of patients	No. of infections
Subacromial surgery	19	7
Rotator cuff repair	12	5
Subacromial decompression	5	0
Bursectomy	2	2
Glenohumeral surgery	30	14
Capsular shift	3	1
Bankart repair	5	1
Biceps tenodesis	4	2
Release frozen shoulder	3	2
Latarjet	3	2
Shoulder prosthesis	12	6
Acromioclavicular surgery	12	4
Acromioclavicular reconstruction	2	1
Clavicle resection	10	3
Fracture	18	8
Combined surgeries	10	4

Table 2 Distribution of positive *C. acnes* cultures out of total cultures taken

Culture results (positive cultures/cultures taken)	No. of patients		
	Without material	With material	Total
1/3	1	2	3
2/3	5	2	7
3/3	1	4	5
1/4	0	1	1
2/4	0	1	1
2/5	1	1	2
1/6	0	2	2
2/6	4	2	6
3/6	0	1	1
4/6	1	2	3
5/6	1	5	6
6/6	1	8	9

model (Table 5). There was no collinearity between those variables (VIFs all below 1.1). Age at primary surgery (OR 0.962; 95% CI 0.925–1.000) and BMI (OR 0.891; 95% CI 0.802–0.990) retained in the regression model, indication an association between these variables and the presence of *C. acnes* infections. After internal validation using bootstrapping, ORs for age at primary surgery and BMI decreased to 0.959 (95% CI 0.914–1.000) and 0.884 (95% CI 0.787–0.977), respectively (Table 6).

Cultivation time

In six patients, a *C. acnes* contamination was identified. Median time to detect the 1st positive culture was 6.0 (IQR 5.0–7.0) days in the infection group and 7.0 (IQR 4.8–10.0) days in the contamination group. Kaplan–Meier curves (Fig. 2) showed the probability of a positive *C. acnes* culture over time, separately for contaminations and infections. The log-rank test, comparing these curves, showed that the time to first *C. acnes* culture was not statistically significantly different between the infection and contamination group (P = 0.219).

Discussion

The incidence of low-grade *C. acnes* shoulder infections was identified in patients with unexplained persistent pain and/or stiffness following surgery with or without implantation of different kinds of artificial material. The incidence of low-grade *C. acnes* infections was 42.6% in patients with and 42.2% in patients without artificial material. Other bacterial infections occurred in 4 patients (7.1%). Hence, low-grade *C. acnes* infections remain the most commonly isolated pathogens after shoulder surgery.

Several studies investigated the incidence of positive perioperative cultures during revision surgery in patients without overt clinical signs of infection [1, 4, 5, 7, 9, 11, 15–20]. They found a *C. acnes* incidence ranging from 4.4 to 79.4%. Comparison of the incidence of *C. acnes* infections is difficult, since studies used different methods to calculate the incidence. In one study [20], it was not clear how a wound contamination was distinguished from an infection; while, others [1, 5, 7, 9, 15–18] only looked at the incidence of at least one positive *C. acnes* culture. This might have overestimated their results. Other studies [5, 15, 17] calculated the incidence by dividing the number of surgeries with a positive *C. acnes* culture by the total amount of revision surgeries, which might lead to an underestimation of the results, since cultures were not routinely collected. Three studies calculated the incidence of *C. acnes* infections similar as in our study; by dividing the number of *C. acnes* infections (≥ 2 positive cultures) by the number of surgeries in which cultures were taken [4, 11, 19]. They found a *C. acnes* incidence ranging from 4.4 to 9.5%. These results are lower than our *C. acnes* incidence, which might be explained by the setting. The Sint Maartenskliniek is a tertiary referral center, where a relatively high number of patients are seen for unexplained persistent shoulder complaints after previous surgeries compared to other hospitals. Since patients with *C. acnes* infections frequently do not have typical infection signs, surgeons in other hospitals may not consider a low-grade infection. As a consequence, these patients are

Table 3 Characteristics of patients with and without a *C. acnes* infection

Characteristic	*C. acnes* infection (N=40)	No *C. acnes* infection (N=54)	Total (N=94)
Gender			
Male (%)	22 (55.0)	19 (35.2)	41 (43.6)
Female (%)	18 (45.0)	35 (64.8)	53 (56.4)
Mean age at primary surgery in years (SD)	44.8 (12.8)	50.5 (11.1)	48.2 (12.1)
Mean BMI in kg/m^2 (SD)	27.7 (4.2)	29.6 (5.0)	28.8 (4.7)
Smoking status			
Never (%)	21 (52.5)	30 (55.6)	51 (54.3)
History of smoking (%)	7 (17.5)	3 (5.6)	10 (10.6)
Yes (%)	12 (30.0)	21 (38.9)	33 (35.1)
Diabetes			
No (%)	39 (97.5)	46 (85.2)	85 (90.4)
Type 1 (%)	1 (2.5)	2 (3.7)	3 (3.2)
Type 2 (%)	–	6 (11.1)	6 (6.4)
Rheumatoid arthritis			
No (%)	37 (92.5)	46 (85.2)	83 (88.3)
Yes (%)	3 (7.5)	8 (14.8)	11 (11.7)
History of cortisone injections			
No (%)	13 (32.5)	25 (46.3)	38 (40.4)
Yes (%)	27 (67.5)	29 (53.7)	56 (59.6)
Median time between primary surgery and complaints in months (IQR)	11.0 (0.3–81.5)	4.5 (0.0–19.8)	6.5 (0.0–51.0)
Median time from primary to target surgery (IQR)	42.5 (15.0–118.8)	27.0 (13.3–81.8)	30.5 (14.0–87.8)
Median duration of target surgery in minutes (IQR)	63.0 (36.3–95.3)	60.0 (43.0–110.5)	60.0 (41.8–108.5)
Location of cultures taken during target surgery			
From 1 location (%)	12 (30.0)	21 (38.9)	33 (35.1)
From > 1 location (%)	28 (70.0)	33 (61.1)	61 (64.9)
Revision before target surgery			
No (%)	29 (72.5)	41 (75.9)	70 (74.5)
Yes (%)	11 (27.5)	13 (24.1)	24 (25.5)
Artificial material			
No (%)	14 (35.0)	19 (35.2)	33 (35.1)
Yes (%)	26 (65.0)	35 (64.8)	61 (64.9)

C. acnes Cutibacterium acnes, *BMI* body mass index, *IQR* interquartile range

not treated and no perioperative cultures are taken during revision surgery in other hospitals; while, surgeons in our hospital are more aware of possible low-grade infections and are, thus, motivated to take routine cultures during surgery. In addition, one may imagine that the *C. acnes* incidence is lower in patients who undergo revision surgery for an obvious reason, such as a periprosthetic fracture or rotator cuff failure in case of an anatomical shoulder prosthesis, compared to unexplained persistent pain and/or stiffness.

Gender, age at primary surgery, BMI, diabetes, a history of cortisone injections, and time between primary surgery and complaints were risk factors considered to be in the multiple regression model ($P < 0.2$). Logistic regression analysis showed that age at primary surgery and BMI were associated with the presence of low-grade *C. acnes* infections, with each year increase in age and each kg/m^2 increase in BMI representing a 4.1% and 11.6% lower risk of *C. acnes* infections, respectively. This finding of young age as a risk factor is supported by previous studies [18, 21–24] and may be explained by the fact that younger people have more sebum production, which is favorable for *C. acnes* colonization [25, 26]. Multiple studies [4, 7, 17, 18, 21–24, 27–30] have been performed identifying factors associated with shoulder infections, but most of these studies lacked regression analysis and were, therefore, not able to identify independent risk factors. To our knowledge, five studies performed regression analysis and found the following risk factors: younger age, male gender, obesity, depression,

Table 4 Simple logistic regression analysis

Characteristic	P value	OR	95% CI
Gender (male)	0.057	2.251	[0.975; 5.198]
Age at primary surgery	0.034	0.960	[0.924; 0.997]
Smoking status (smoking)	0.373	0.673	[0.282; 1.607]
BMI	0.052	0.909	[0.825; 1.001]
Diabetes (type 1/2)	0.077	0.147	[0.018; 1.231]
Rheumatoid arthritis	0.284	0.466	[0.115; 1.883]
Cortisone injections	0.180	1.790	[0.765; 4.192]
Time between primary surgery and complaints	0.090	1.005	[0.999; 1.012]
Location of cultures taken during target surgery	0.373	1.485	[0.622; 3.544]
Revision before target surgery	0.707	1.196	[0.470; 3.042]
Number of revisions before target surgery	0.931	0.977	[0.575; 1.661]
Duration of target surgery	0.545	0.998	[0.990; 1.005]
Artificial material	0.985	1.008	[0.428; 2.375]

OR odds ratio, *CI* confidence interval, *BMI* body mass index

Table 5 Multiple logistic regression analysis

Characteristic	Step 1			Step 2			Step 3			
	P value	OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	Estimate
Gender (male)	0.135	2.030	[0.802; 5.139]	0.143	1.991	[0.792; 5.004]				
Age at primary surgery	0.114	0.967	[0.928; 1.008]	0.066	0.963	[0.925; 1.002]	0.051	0.962	[0.925; 1.000]	− 0.039
BMI	0.021	0.876	[0.783; 0.980]	0.028	0.885	[0.793; 0.987]	0.032	0.891	[0.802; 0.990]	− 0.115
Cortisone injections	0.315	1.640	[0.625; 4.302]							

OR odds ratio, *CI* confidence interval, *BMI* body mass index

Table 6 Bootstrapping

Characteristic	Estimate	Shrinkage factor	Adjusted estimate	Adjusted OR	Adjusted 95% CI	P value
Age at primary surgery	− 0.039	− 0.003	− 0.042	0.959	[0.914; 1.000]	0.058
BMI	− 0.115	− 0.008	− 0.123	0.884	[0.787; 0.977]	0.016

Bootstrap results are based on 10,000 bootstrap samples

OR odds ratio, *CI* confidence interval, *BMI* Body mass index

malnutrition, intraoperative steroid injections, chronic anemia, reverse total shoulder prosthesis, and traumatic shoulder arthroplasties [7, 21–24]. Our study did not find obesity to be a risk factor for *C. acnes* infections. On the contrary, a higher BMI was found to decrease the risk. This is biologically speaking not logical because of multiple findings that obesity increases the risk of infections due to an impaired immune response [31, 32]. However, our finding could be explained by the selected study population, since most patients with unexplained complaints are referred to our clinic for a second/third opinion. It is possible that patients with such complaints and a higher BMI have shoulder complaints due to obesity. Consequently, a higher BMI looks like a protective factor of *C. acnes* infections. Hence, the finding of a lower BMI as a risk factor for *C. acnes* infections is not
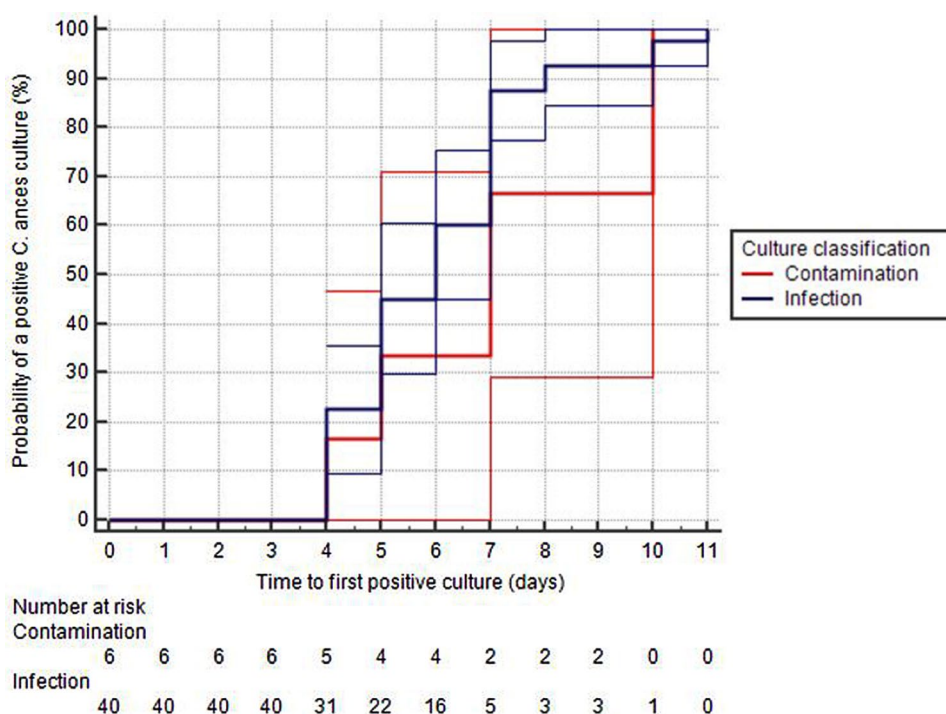
generalizable to other populations. However, our study does support the evidence that younger age is a risk factor for *C. acnes* infections.

Limitations

The main limitation of this study includes the small sample size. Due to this limitation, we were not able to identify all factors associated with the presence of *C. acnes* infections. To prevent overfitting of the model, it is possible that some relevant risk factors were not included in our analysis.

Another limitation is the retrospective design of this study, which did not allow us to take all possible risk factors into account. We may, therefore, have missed some relevant patient-related risk factors. However, based on findings of

Fig. 2 Kaplan–Meier curves showing the probability of a positive *C. acnes* culture over time, separately for contaminations and infections

Number at risk

Contamination

| 6 | 6 | 6 | 6 | 5 | 4 | 4 | 2 | 2 | 2 | 0 | 0 |

Infection

| 40 | 40 | 40 | 40 | 31 | 22 | 16 | 5 | 3 | 3 | 1 | 0 |

other studies, we expect that most important patient-related risk factors, such as age, gender, and BMI, were included in this study. Because of the retrospective design, there may also have been selection bias.

Clinical relevance

Unlike what we expected, the incidence of *C. acnes* infections in the group with artificial material was not different from the group without and therefore, one should take *C. acnes* infections in mind when unexplained persistent shoulder complaints are present. However, we expected a difference in treatment effect between both groups. Some artificial materials, like suture anchors for rotator cuff or labral tear repair, cannot be removed without severe damage to the shoulder anatomy. In case of a chronic low-grade *C. acnes* infection, the question is if open or arthroscopic irrigation followed by antibiotic treatment is an effective infection treatment as long as such suture anchors are still in situ. This question will be the subject of our future research.

Conclusion

The incidence of *C. acnes* infections in patients undergoing revision surgery for unexplained persistent complaints after artificial material placement was 42.6%. Younger age and a lower BMI at primary surgery were risk factors for *C. acnes* infections. Furthermore, cultivation time

was not significantly different between true infections and contaminations.

We recommend that orthopedic surgeons should consider low-grade *C. acnes* infections in patients with unexplained persistent shoulder complains following shoulder surgery, like pain and/or stiffness.

Compliance with ethical standards

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