Journal of Plastic, Reconstructive & Aesthetic Surgery (2020) 000, 1–9

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals

J.A. Lohmeyer[a,b,*], V.L. Jakob[a], M. Keck[a,c], K. Wittig[a]

[a] *Department of Plastic, Reconstructive and Aesthetic Surgery, Agaplesion Diakonieklinikum Hamburg, Hohe Weide 17, 20259 Hamburg, Germany*
[b] *Department of Plastic Surgery and Hand Surgery, Klinikum rechts der Isar, Technical University Munich, Ismaninger Str. 22, 81675 Munich, Germany*
[c] *Clinic of Plastic Surgery, Hand Surgery, Burn Unit, University Hospital of Schleswig-Holstein, University of Lübeck, Ratzeburger Allee 160, 23562 Lübeck, Germany*

Received 4 March 2020; accepted 12 November 2020
Available online xxx

KEYWORDS
Periprosthetic infection;
Breast augmentation;
Breast reconstruction;
Breast implant;
Antibiotics

Summary Periprosthetic infections are feared complications in esthetic and reconstructive breast surgery. The purpose of our study is to evaluate our institution's specific culture data and to identify most common organisms and suitable antibiotics for prophylaxis and first-line treatment.

We evaluated all patients with a change or removal of breast implants from 01.01.2012 to 31.12.2017 retrospectively. Based on the medical records, the surgical indications were identified and specifically analyzed for signs of infection, reasons for primary and secondary surgery, and all available microbiological data of these interventions.

A total of 666 implant removals or exchanges were performed in 431 patients. Microbiological smears were gathered from 291 patients (449 implants). Bacteria were cultured from 63 implants (56 patients). In six additional patients (ten implants), a periprosthetic infection was seen, without bacteria detection. Advanced capsular contracture correlated with a higher proportion of positive swabs ($p<0.05$). In 11.5% of smears, bacterial contamination was found despite absence of clinical signs of infection. Coagulase-negative staphylococci were the dominant pathogen in clinical inapparent infections, while *Staphylococcus aureus* was when there was clinical evidence of infection. All pathogens were sensitive to vancomycin.

Parts of this article have been presented at the following meetings/conferences: 1. Annual conference of the German Society of Plastic, Reconstructive and Aesthetic Surgeons (DGPRÄC) in Hamburg, Germany, 26 September 2019. 2. Annual Meeting of the German Society for Senology 28 June 2019 in Berlin, Germany.

*Corresponding author at: Department of Plastic Reconstructive and Aesthetic Surgery, Agaplesion Diakonieklinikum Hamburg, Hohe Weide 17, 20259 Hamburg, Germany.
E-mail address: lohmeyer@d-k-h.de (J.A. Lohmeyer).

https://doi.org/10.1016/j.bjps.2020.11.005

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

In the majority of cases, bacterial contamination was an incidental finding, which was more common in the presence of advanced capsular contracture. In our institution, cefuroxime and amoxicillin/clavulanic acid have been proven to be reasonable choices for prevention and treatment of periprosthetic infections. In the treatment of fulminant infections and for the prophylaxis during implant replacement due to advanced capsular contracture, vancomycin became our first choice.

Introduction

Periprosthetic infections are rare but dreaded complications in esthetic and reconstructive breast surgery. The incidence of periprosthetic infections in primary breast augmentation is 0.3-2%,[1-4] in breast reconstruction on average 5.8%, in some studies even up to 29%.[5-9] The consequences for patients are often considerable and lengthy. They include an extended treatment time, often the necessity of implant removal and at least temporarily esthetically unsatisfactory results. In reconstructive surgery, there is also a risk of delaying the onset of adjuvant radiochemotherapy.

The prevention of intraoperative contamination and postoperative infections is of utmost importance in implant surgery. In breast surgery, various recommendations evolved to minimize the risk of bacterial contamination.[10] Preoperative antibiotics are known to reduce perioperative infections.[11,12] However, the relevant pathogen spectrum and the expected resistances must be taken into account.

The aim of this work is to provide a recommendation for prophylactic and therapeutic antibiotic treatment by working up the proven implant site infections and contaminations of our patients' swab test. The main focus was set on the germ spectrum and resistances.

Patients and methods

After obtaining approval from the local ethical board (WF-065/19), a retrospective chart review was performed. The observation period was from 01 January 2012 to 31 December 2017. To identify breast implant removals and replacements, we performed a systematic search using the documented procedure codes for the removal and replacement of a mammary prostheses or skin expanders. For all cases found, patient records were assessed to check whether swab results were available from the implant site and whether there was clinical suspicion of infection. The criteria of infection were purulent secretion, spontaneous dehiscence, rapidly developing pain, circumscribed chest erythema or fluid accumulation.

Antibiotic resistances were evaluated for cefuroxime, cefotaxime, ampicillin/sulbactam, piperacillin/tazobactam, imipenem, vancomycin, ciprofloxacin, clindamycin, and gentamicin.

Further information on the course of the disease, previous treatment, preoperative diagnostics (leukocyte count, C-reactive protein (CRP)), and patient's specifics were recorded from the patient file and electronic documentation, if available.

We assessed the influence of diabetes, radiation therapy, esthetic vs. reconstructive indication for surgery, administration of an ADM or net, and active smoking on bacterial contamination and on the occurrence of suspected periprosthetic infections. The chi-square test was used to determine statistical significance levels for categorical data (variables), whereas for comparison of metric data (variables) either a t-test or a Mann-Whitney-U-test was performed. A p-value of <0.05 was considered significant.

In order to investigate whether complete capsulectomy in case of bacterial colonization makes a recurrence of capsular contracture less likely, these patients were contacted by telephone and interviewed about complaints and later surgery.

In our clinic, the preoperative intravenous single-shot administration of 1.5 g cefuroxime is standardized in all breast surgeries. In case of known allergies, clindamycin is given if tolerated. The new implants are inserted after rinsing of the implant site with 1:1 diluted Betadine solution. We basically stick to the 14-point plan of Adams to prevent infection.[10] In implant reconstruction, a drain is usually placed, whereas we generally do without it in primary augmentation.

The swabs from the implant sites are taken immediately after the capsule has been opened. From November 2016 we added a strip of capsule to the culture. At the same time, the culture medium was changed from agar-gel to liquid Amies medium (eSwab™).

Results

Between January 1, 2012 and December 31, 2017, 666 breast implants were removed from 431 patients in our clinic. A total of 449 swabs were taken from implant sites in 291 patients. We found a positive culture in swabs from 63 implant sites in 56 patients (14.0% and 19.2%, respectively). The indications for implant removal or replacement in all patients and in the group with smear tests and in cases of clinical suspicion of periprosthetic infection are summarized in Table 1.

Bacterial growth was found in 14 of 24 implants with suspected infection (58.3%). In those without suspected infection, however, bacterial growth was still found in 49 out of 425 implant sites (11.5%). The signs of infection ranged from narrowly circumscribed to extensive redness, with or without swelling of the breast. Out of 24 patients, 10 received antibiotic treatment on average 10 days prior to implant removal (4x ciprofloxacin, 4x amoxicillin/clavulanic acid, 1x cefuroxime, 1x antibiotic not specified. Out of 10 patients, 4 with prior antibiotic treatment had sterile swabs (com-

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

Table 1 Indications for implant removal or change.

Indications for implant removal or change	Number of implants		Number of implants with swabs		Number of implants with bacteria detection	
	Esthetic (%)	Reconstructive (%)	Esthetic (%)	Reconstructive (%)	Esthetic (%)	Reconstructive (%)
Capsular contracture	172 (50.7%)	171 (52.3%)	106 (46.9%)	118 (52.9%)	19 (57.6%)	12 (40.0%)
Implant rupture	76 (22.4%)	31 (9.5%)	55 (24.3%)	20 (9.0%)	8 (24.2%)	2 (6.7%)
Implant dislocation	22 (6.5%)	29 (8.9%)	14 (6.2%)	19 (8.5%)	-	2 (6.7%)
Planned secondary autologous reconstruction	-	31 (9.5%)	-	18 (8.1%)	-	-
Breast asymmetry	17 (5.0%)	14 (4.3%)	4 (1.8%)	10 (4.5%)	-	1 (3.3%)
PIP-Implantat	17 (5.0%)	2 (0.6%)	15 (6.6%)	1 (0.4%)	-	-
Planned change from expander to implant	2 (0.6%)	14 (4.3%)	2 (0.9%)	9 (4.0%)	-	1 (3.3%)
Suspected periprosthetic infection	12 (3.5%)	12 (3.7%)	12 (5.3%)	12 (5.4%)	6 (18.2%)	8 (26.7%)
Ptosis mammae	12 (3.5%)	-	12 (5.3%)	-	-	-
Skin necrosis	-	9 (2.8%)	-	9 (4.0%)	-	2 (6.7%)
Breast tumor	3 (0.9%)	7 (2.1%)	3 (1.3%)	3 (1.3%)	-	1 (3.3)
Hematoma	5 (1.5%)	1 (0.3%)	2 (0.9%)	1 (0.4%)	-	1 (3.3%)
BRCA 1 or 2 -Mutation	-	4 (1.2%)	-	2 (0.9%)	-	-
Seroma	-	2 (0.6%)	-	1 (0.4%)	-	-
Siliconome	1 (0.3%)	-	1 (0.4%)	-	-	-
Total	**339**	**327**	**226**	**223**	**33**	**30**

pared to 6 of 14 without prior antibiotic treatment). In 6 out of 10 swabs, the previously given antibiotic was tested. Of these, 3 were sensitive and 3 were resistant.

Looking at both time intervals before and after the change of the smear medium and capsule addition, a significant increase in positive smears was observed ($p<0.05$). In the first interval, 22 of 283 (7.2%) smears were positive in cases without clinical signs of infection, whereas 27 of 93 (22.5%) were positive in the second.

Clinical apparent infections occurred on average 1.5 months (2 days to 3 years) after implantation. In cases with positive swabs but no sign of infection, the median interval between implant placement and removal was 6.8 years (2 days to 10.5 years). The revision two days after implantation was due to a postoperative hematoma.

In the laboratory diagnostics before implant removal, mean leukocyte count was 9.9/nl with suspected infection, and 7.9/nl with positive detection of bacteria without any signs of infection (standard value 3.5-10/nl, $p>0.05$). CRP averaged 51.3 mg/l and 5.0 mg/l respectively ($p<0.05$, standard value <5 mg/l).

Staphylococcus aureus was detected as a pathogen in more than half of the cases with clinical suspicion of infection, followed by coagulase-negative staphylococci (CNS) and enterococci. Methicillin-resistant *Staphylococcus aureus* was not seen. In cases without any clinical signs of infection, CNS followed by Propioni bacteria and *Staphylococcus aureus* were most frequently detected (Figure 1). We did not see any correlation between time point and the causative organism.

Vancomycin was the only antibiotic that worked on all bacteria without any resistances. In cases of clinically apparent infections, levofloxacin and ciprofloxacin showed below-average efficacy, while the other antibiotics tested reached at least 80% of the bacteria.

In cases without clinical signs of infection, all antibiotics tested showed at least 80% efficacy (Figure 2).

We saw a significant correlation between the degree of capsular contracture and bacteria detection ($p<0.05$). In low-grade capsular contracture Baker class 1 or 2, three out of 29 swabs were positive (10.3%), whereas in Baker 3 and 4, 41 of 281 were positive (14.6%).

The implant position was documented in 171 of 226 primary augmentations cases.

In the primary esthetic cases, positive cultures were seen in 22 of 100 subglandular implant pockets (22.0%) and 7 of

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

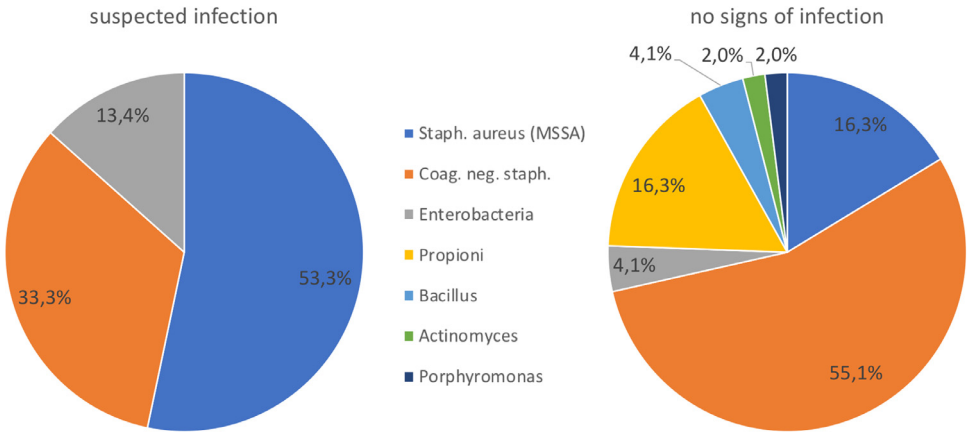

Figure 1 Distribution of detected bacteria in the case of apparent infections or as a random finding without signs of infection.

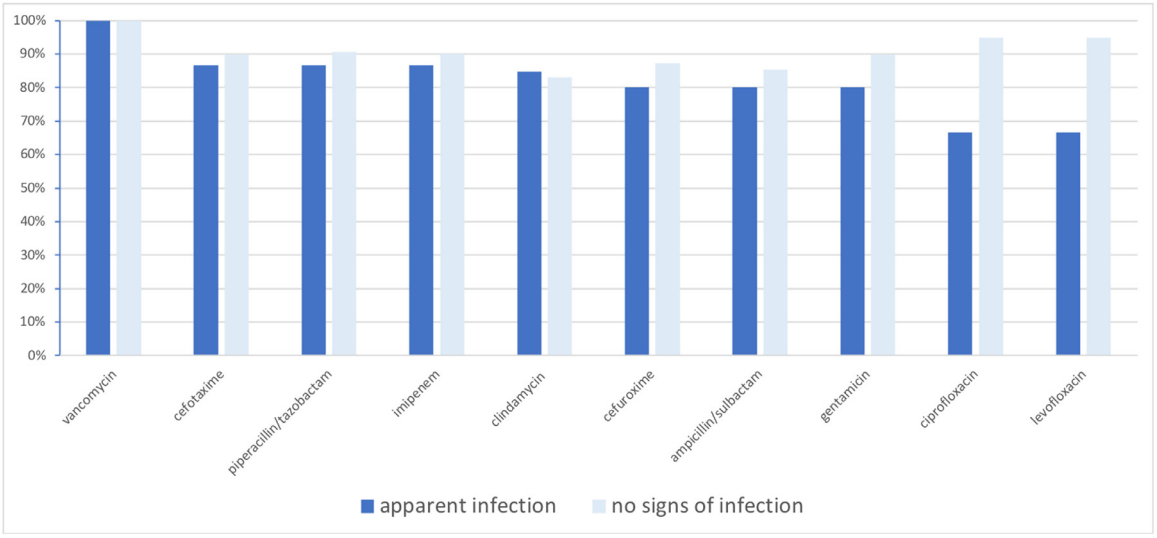

Figure 2 Resistance testing subdivided according to clinical infection and colonization in case of inconspicuous clinical signs.

71 subpectoral implant pockets (9.9%). However, the difference was not significant ($p = 0.073$). The frequency of bacterial detection did not depend on whether the previous operation was an initial augmentation or an implant change. The average implant size was 270 cc (range 100-600 cc) and did not correlate with bacterial contamination. An additional net or a cellular dermal matrix was not introduced in any of the cases.

In all 19 patients (24 implants) with suspected implant site infection, implant removal with complete capsulectomy was performed.

In those 43 patients (49 implants), in whom bacteria detection was completely unexpected, we performed a direct change of 23 implants, simple implant removal in 15 cases, 3 autologous fat grafts, and 8 autologous reconstructions each. Out of 19 patients (23 implants) in which we performed a direct implant exchange despite bacterial colonization, we were able to interview 17 about their further course after an average of 51 months (28–95 months). Out of 17, 7 reported a new induration of the breast in the sense of an advanced capsular contracture, but only three chose surgical revision. Three out of 10 patients with complete capsulectomy reported new capsular contracture (30%), as did 4 out of 7 with incomplete capsulectomy (57%, $p > 0.05$).

Diabetes, radiation therapy, esthetic vs. reconstructive indication for surgery, administration of an ADM or net, and active smoking showed no significant influence on bacterial contamination or on the occurrence of suspected periprosthetic infections. ADMs have been used in 5 cases where a swab was taken. None showed bacterial contamination (Table 2).

Discussion

Periprosthetic infections are one of the most dreaded complications in breast implant surgery. The incidence in primary breast augmentation is reported to be 0.3-2%,[1-4] in breast reconstruction on average 5.8%, in some studies even up to 29%.[5-9] The higher rate of infections in reconstructive surgery is most probably caused by tissue ischemia with skin-saving mastectomy, the severing of the mammary gland tissue and thus the opening of the glandular ducts, the su-

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

Table 2 Influencing factors on inapparent and apparent periprosthetic infections.

Influencing factors, number of patients with swabs taken	Positive swabs without suspected periprosthetic infection		Implants with suspected periprosthetic infection	
	n (%)	*p*-value	*n* (%)	*p*-value
Esthetic ($n=226$)	27 (11.9%)	0.480	12 (5.3%)	0.973
Reconstructive ($n=223$)	22 (9.9%)		12 (5.4%)	
Radiation therapy (reconstructive)				
yes ($n=86$)	8 (9.3%)	0.821	4 (4.7%)	0.628
no ($n=129$)	13 (10.1%)		8 (6.2%)	
unclear ($n=8$)				
ADM or resorbable net (reconstructive)				
yes ($n=5$)	0 (0.0%)	0.440	0 (0.0%)	0.590
no ($n=218$)	22 (10.1%)		12 (5.5%)	
unclear ($n=0$)				
Active smoking (esthetic and reconstructive)	18 (10.9%)	0.949	11 (6.7%)	0.347
yes ($n=165$)	31 (11.0%)		13 (4.6%)	
no ($n=283$)				
unclear ($n=1$)				
Diabetes mellitus (esthetic and reconstructive)	0 (0.0%)	0.333	0 (0.0%)	0.524
yes ($n=7$)	49 (11.2%)		24 (5.5%)	
no ($n=438$)				
unclear ($n=4$)				

perficial implant position, and possible preoperative radiotherapy.[13]

When postoperative infections occur after the insertion of breast implants, a distinction must be made between superficial and deep periprosthetic infections. In this study, only periprosthetic infections or contaminations were analyzed. The study will help to offer targeted antibiotic perioperative prophylaxis as well as recommendations for targeted empirical treatment of periprosthetic infections prior to the availability of the individual antibiogram.

Early infections usually occur in the first postoperative month. Accompanying symptoms are fever, acute pain, one-sided breast swelling, and circumscribed chest erythema.[14] The data on the occurrence of late infections is much weaker, as patients often no longer appear at the primary care provider. Oligo- or asymptomatic so-called low-grade infections have to be distinguished from clinically apparent late infections. Some periprosthetic infections only occur after years or even decades. The cause of the contamination is often unclear. In addition to the spread of germs from the patient's skin or milk ducts, septic spreads of infectious foci are also discussed.[13]

A very rare but life-threatening form of acute infection is the toxic shock syndrome (TSS), which occurs on average four days after implantation and is characterized by septic shock with comparatively inconspicuous local findings.[15]

In our study, the median time interval between insertion and removal of the implants was 1.5 months in case of clinical suspicion of infection, and 6.8 years in patients without clinical suspicion of infection. In 29% of the reported cases, first signs of infection occurred more than 3 months after surgery. The literature describes an average latency of 22 days to 12 months between implantation and the occurrence of signs of infection.[1,16,17] Ten out of 24 cultures in patients with clinical infections failed to detect bacteria in our study (42%). In other works, this rate was 13–30%.[5,18,19]

The pathogens predominantly detected with suspected periprosthetic infection in our study were methicillin-sensitive *Staphylococcus aureus* and CNS, and CNS and Propioni bacteria in clinically inapparent infections respectively.

The specific germ spectrum of periprosthetic infections in breast surgery was mainly evaluated in studies at US and European centers. In one study, CNS were predominantly found.[19] However, *Staphylococcus aureus* was isolated most frequently with 37–68% CNS.[5,8,18,20] Up to two-thirds were methicillin resistant. Higher rates of MRSA were predominately found in US studies.[5,18,20] Gram-negative rods, mainly *Pseudomonas aeruginosa*, are usually isolated much less frequently. In two studies, however, pseudomonas was found to be the second most common.[5,8] Infections with atypical mycobacteria are extremely rare and are not detected in routine bacteriology. In case of suspicion, e.g. in case of resistance to common antibiotics, a complementary Ziehl-Neelsen staining and mycobacterial culture should be considered.[21] The results of the resistance tests can only be transferred to other regions or countries to a very limited extent.

CNS are the main pathogens of the physiological skin flora. In a study of tissue samples of the mammary gland in breast reduction, CNS were detected in 53% of the samples. Propioni bacterium acnes are the most frequently detected anaerobic pathogen.[22]

Highly sensitive detection methods (culture of the sonication fluid of the implant surface) can detect bacteria in up to 45% of all implant capsules, with a significantly higher incidence in advanced capsular contracture (Baker 3 and 4).[23] Other studies confirmed the higher incidence of

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

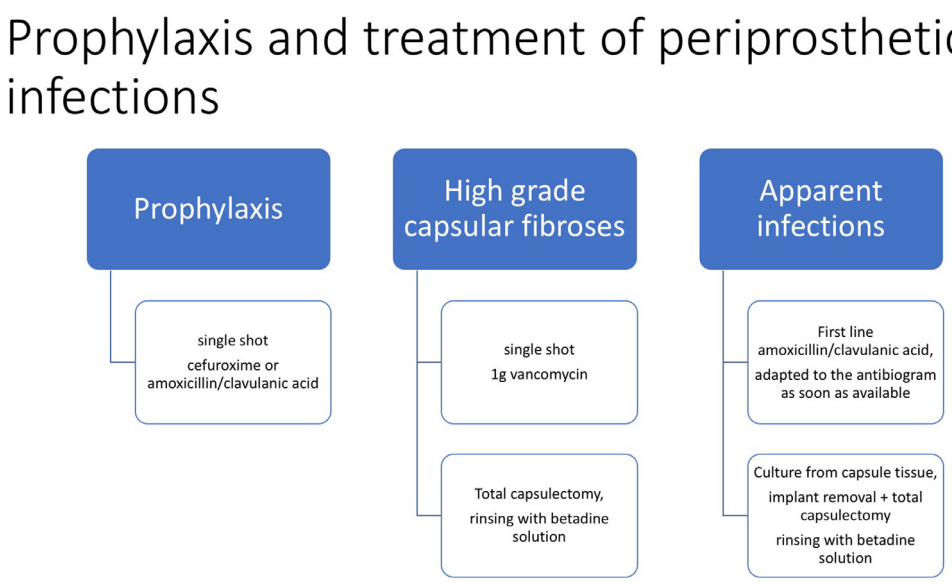

Figure 3 Therapy recommendation for the prophylaxis and therapy of periprosthetic infections.

positive cultures with skin flora in advanced capsular contracture[24,25]. Recent studies have also suggested that the chronic subclinical infection is associated with the development of breast implant-associated anaplastic large cell lymphomas (BIA-ALCL).[26]

In our patient population, positive smear results were observed in 11.5% of explanted implants without any clinical signs of infection (49 of 425 implants in 43 of 272 patients). In the time period after we started adding capsular tissue to the swab for culture, the incidence increased to 22.5% (27of 93 implants in 25 of 57 patients).

Our study exhibited a bacterial sensitivity of 100% to vancomycin, which varied in other studies from 66 to 100%.[5,19,20] While we only saw few resistances for cefuroxime and amoxicillin/clavulanic acid, in some US studies, the sensitivity was less than 70%, even down to 30% for amoxicillin/clavulanic acid or their standard cephalosporine.[5,20] Unfortunately, the cluster of tested antibiotics varied considerably even within single institutions.

Due to the limited sensitivity to clindamycin and ciprofloxacin in all studies, the use of broad-spectrum antibiotics as vancomycin should be considered in the treatment of periprosthetic infections with allergies to penicillin or cephalosporins.

We highly agree with Prantl et al. who supported the use of Vancomycin as a prophylactic antibiotic for implant replacement, due to the broader spectrum of microorganisms found in late infections, that are held responsible for the formation of advanced capsular contracture (Figure 3).[27]

One limitation of this study is that only 67% of implant pockets had diagnostic swabs. There are two main reasons for this. First, at the beginning of the examination interval, one of the main surgeons did not usually take a smear in the absence of suspected infection. Second, patients often did not want to have a smear test if they had to pay for it privately. Nevertheless, all patients with signs of infection received a smear test without exception. Another factor influencing germ detection and resistance formation is the preoperative antibiotic administration, which was carried out in 10 of 24 patients in our cohort. In six tests for the individual antibiotic, resistance was observed in half of the patients. However, four out of ten post-therapeutic swabs were sterile. We did not observe any significant influence of tested factors such as smoking and radiation therapy on the occurrence of bacterial contamination or apparent periprosthetic infection. However, existing relationships could be obscured by the small case size.

Risk factors

Various risk factors for the development of postoperative infections in breast implant surgery are listed in the literature. The most important influence is whether the procedure of implant placement is esthetic or reconstructive and whether radiotherapy preceded.[17,28-32]

However, an increased incidence of postoperative infections has also been described for adjuvant chemotherapy,[9,33] nicotine abuse,[29,32,33] axillary dissection,[31] obesity (BMI>30),[29,34] breast size during reconstruction,[28] implant change versus initial implantation[8,28] and insertion of drainage during esthetic augmentation.[1,3] In reconstructive breast surgery, even in larger studies, there were no indications of increased infection rates when drains were placed.[35]

Infection prophylaxis

The top priority to prevent infection is the meticulous compliance with the intraoperative sterility of operation field and implant. We basically stick to the 14-point plan of Adams.[10] Drains are generally not used for esthetic augmentation.

Compared to the use of physiological saline solution in a meta-analysis of 1786 patients, implant wetting with Povidone-iodine resulted in a reduction of the capsular

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

contracture Baker 3/4 from 8.9% to 2.7%.[36] It seems certain that flushing the implant site with an antibiotic solution reduces the rate of postoperative periprosthetic infections.[1,37] Araco et al. described in a retrospective study of primary augmentations in 3002 patients a 4-fold reduction of the infection risk by flushing the implant pocket with cefuroxime or erythromycin.[1] The use of Povidone-iodine in combination with perioperative prophylactic antibiotics seems to be more efficient than the sole administration of antibiotics.[38]

Systemic antibiotic administration is generally recommended and has been shown to reduce the rate of infection in reconstructive and esthetic breast surgeries.[12] Compared to single-shot administration, the continuation of antibiotic administration shows no advantages.[3,7] Since secondary bacteremia is also discussed as the cause of late infections, prophylactic antibiotics should be considered for women with breast implants, during dental or septic procedures.[13]

Diagnostics and therapy

The symptoms and clinical signs of a periprosthetic infection often vary considerably. Patients often complain of pain and tightness in the affected chest. Clinical signs are redness and warmth of the breast, swelling and postoperative seromas. Leukocytosis, an increase in CRP and fever, can also occur.

Leukocyte count or CRP often does show normal levels in subclinical or acute infections. Seng et al. found pathological values in 13% of cases.[8] In clinically apparent infections, CRP elevation was more significant in our study. Low-grade infections without clinical signs of infection were accompanied by infection parameters ranging from normal to slightly elevated.

Various measures are recommended for the diagnosis and treatment of suspected periprosthetic infections. Ultrasound-guided puncture of the exudate may be performed, with the risk of an iatrogenic lesion of the implant. The exudate should be incubated for 10 days and, in addition to the standard test for pathogens and resistance, a culture of acid-resistant rods should also be considered. In late seromas, immunohistochemical examination for CD30 is also recommended to exclude BIA-ALCL[26,39].

With mild clinical symptoms and regular laboratory infection parameters, a single dose of antibiotics may cause the infection to subside.[32] Various studies described successful antibiotic treatment with or without implant removal in subclinical or oligosymptomatic infections. The success rate with administration of antibiotics alone is reported to be 25–43%.[28,32] In the case of suspected acute infection, implant removal with secondary reconstruction is generally indicated.[8,13]

In 1979, Courtiss et al. described a success rate of 45% in a series of 41 infected breast implants under conservative treatment alone, with almost one-third developing capsule contractures.[40] After primarily reconstructive implant placement, Feldman et al. reported a 75% success rate with systemic antibiotics alone for treating infections.[18]

With a single-stage implant change, a success rate of 62 to 94% was indicated in larger series, although bias was given by only considering implant preservation for minor infections.[16,17] In most cases, no data on long-term follow-up after implant preservation are available to date.

Several recommendations regarding whether or not to remove the implant capsule have been made. While Pittet et al. do not recommend systematic removal of the implant capsule in the presence of an infection,[16] we would generally recommend this to reduce the bacteria load in the tissue. This is also supported by the reported high success rates of other studies.[17]

Prince et al. recommend administering antibiotics for 4-6 weeks for septic implant changes.[16] In our hands, preoperatively started antibiotic therapy is continued for 10 days postoperatively after implant removal. If the swab test comes up with a positive finding, in patients without clinical signs of infection, we do not start antibiotic therapy later on. In our study, in none of the reported cases with positive swabs with implant replacement or removal, a clinically apparent infection occurred postoperatively, with a follow-up interval of at least 6 months. We saw recurrent capsular contracture after 4 years in 27% when the capsule had been completely removed and 57% when not.

The high proportion of secondary referrals in our patient population, in particular among patients with suspected infections, did not allow a reliable evaluation of the primary infection rate.

Large-scale studies are difficult to implement in breast surgery due to the rarity and heterogeneity of periprosthetic infections. In addition, bacteria detection and resistance levels can vary considerably both regionally and among individual institutions. Consequently, the continuous evaluation of everyone's own or regional specific microbiological data should be a prerequisite for proper quality management.

Conclusion

Staphylococcus aureus and CNS are generally the most common pathogens of acute periprosthetic infections. *Staphylococcus epidermidis* and Propioni bacteria seem to be mainly responsible for subclinical infections and thus likely to play a role in capsular contracture.

Antibiotic prophylaxis and empirical treatment of infections should take regional resistance levels into account. In our hands single-shot antibiotics are administered with cefuroxime or amoxicillin/clavulanic acid. In case of high-grade capsular contracture, we recommend single-shot antibiotic prophylaxis with 1 g vancomycin, complete capsulectomy and thorough rinsing of the implant pocket with diluted betadine solution.

For the therapy of apparent infections, medication must be checked upon receipt of an antibiogram. In the case of a foudroyant course of infection, we would start the treatment empirically with vancomycin.

The culture from capsule tissue is preferable to the classical smear because of its better sensitivity. Sole antibiotic therapy can be tried with the first onset of clinical signs of infection. In case of persistent symptoms or recurrence, we would continue to prioritize the removal of the implant with secondary reconstruction. With thorough debridement and only mild symptoms, however, a one-stage implant change may also be considered.

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

Declaration of Competing Interest

None.

Funding

None.

Ethical approval

Approval from the local ethical board (WF-065/19).

Literature

1. Araco A, Gravante G, Araco F, et al. Infections of breast implants in aesthetic breast augmentations: a single-center review of 3,002 patients. *Aesthetic Plast Surg* 2007;**31**:325–9.
2. Henriksen TF, Fryzek JP, Holmich LR, et al. Surgical intervention and capsular contracture after breast augmentation: a prospective study of risk factors. *Ann Plast Surg* 2005;**54**:343–51.
3. Khan UD. Breast augmentation, antibiotic prophylaxis, and infection: comparative analysis of 1,628 primary augmentation mammoplasties assessing the role and efficacy of antibiotics prophylaxis duration. *Aesthetic Plast Surg* 2010;**34**:42–7.
4. Kjoller K, Holmich LR, Jacobsen PH, et al. Epidemiological investigation of local complications after cosmetic breast implant surgery in Denmark. *Ann Plast Surg* 2002;**48**:229–37.
5. Chidester JR, Danci I, Lewis P, et al. Antibiogram for periprosthetic infections: a tool for better informed selection of empiric antibiotics for surgical site infections. *Ann Plast Surg* 2016;**76**(Suppl 3):S158–61.
6. Hvilsom GB, Holmich LR, Steding-Jessen M, et al. Delayed breast implant reconstruction: is radiation therapy associated with capsular contracture or reoperations? *Ann Plast Surg* 2012;**68**:246–52.
7. Phillips BT, Bishawi M, Dagum AB, Khan SU, Bui DT. A systematic review of antibiotic use and infection in breast reconstruction: what is the evidence? *Plast Reconstr Surg* 2013;**131**:1–13.
8. Seng P, Bayle S, Alliez A, et al. The microbial epidemiology of breast implant infections in a regional referral centre for plastic and reconstructive surgery in the south of France. *Int J Infect Dis* 2015;**35**:62–6.
9. Warren Peled A, Itakura K, Foster RD, et al. Impact of chemotherapy on postoperative complications after mastectomy and immediate breast reconstruction. *Arch Surg* 2010;**145**:880–5.
10. Adams WP Jr, Calobrace MB. Discussion: the questionable role of antibiotic irrigation in breast augmentation. *Plast Reconstr Surg* 2019;**144**:253–7.
11. Amland PF, Andenaes K, Samdal F, et al. A prospective, double-blind, placebo-controlled trial of a single dose of azithromycin on postoperative wound infections in plastic surgery. *Plast Reconstr Surg* 1995;**96**:1378–83.
12. Hardwicke JT, Bechar J, Skillman JM. Are systemic antibiotics indicated in aesthetic breast surgery? A systematic review of the literature. *Plast Reconstr Surg* 2013;**131**:1395–403.
13. Pittet B, Montandon D, Pittet D. Infection in breast implants. *Lancet Infect Dis* 2005;**5**:94–106.
14. Brand KG. Infection of mammary prostheses: a survey and the question of prevention. *Ann Plast Surg* 1993;**30**:289–95.
15. Holm C, Muhlbauer W. Toxic shock syndrome in plastic surgery patients: case report and review of the literature. *Aesthetic Plast Surg* 1998;**22**:180–4.
16. Prince MD, Suber JS, Aya-Ay ML, et al. Prosthesis salvage in breast reconstruction patients with periprosthetic infection and exposure. *Plast Reconstr Surg* 2012;**129**:42–8.
17. Spear SL, Seruya M. Management of the infected or exposed breast prosthesis: a single surgeon's 15-year experience with 69 patients. *Plast Reconstr Surg* 2010;**125**:1074–84.
18. Feldman EM, Kontoyiannis DP, Sharabi SE, et al. Breast implant infections: is cefazolin enough? *Plast Reconstr Surg* 2010;**126**:779–85.
19. Weichman KE, Levine SM, Wilson SC, Choi M, Karp NS. Antibiotic selection for the treatment of infectious complications of implant-based breast reconstruction. *Ann Plast Surg* 2013;**71**:140–3.
20. Cohen JB, Carroll C, Tenenbaum MM, Myckatyn TM. Breast implant-associated infections: the role of the national surgical quality improvement program and the local microbiome. *Plast Reconstr Surg* 2015;**136**:921–9.
21. Vinh DC, Rendina A, Turner R, Embil JM. Breast implant infection with mycobacterium fortuitum group: report of case and review. *J Infect* 2006;**52**:e63–7.
22. Thornton JW, Argenta LC, McClatchey KD, Marks MW. Studies on the endogenous flora of the human breast. *Ann Plast Surg* 1988;**20**:39–42.
23. Rieger UM, Mesina J, Kalbermatten DF, et al. Bacterial biofilms and capsular contracture in patients with breast implants. *Br J Surg* 2013;**100**:768–74.
24. Netscher DT, Weizer G, Wigoda P, et al. Clinical relevance of positive breast periprosthetic cultures without overt infection. *Plast Reconstr Surg* 1995;**96**:1125–9.
25. Pajkos A, Deva AK, Vickery K, et al. Detection of subclinical infection in significant breast implant capsules. *Plast Reconstr Surg* 2003;**111**:1605–11.
26. Leberfinger AN, Behar BJ, Williams NC, et al. Breast implant-associated anaplastic large cell lymphoma: a systematic review. *JAMA Surg* 2017;**152**:1161–8.
27. Prantl L, Momeni A, Brebant A, et al. Recommendations for the use of antibiotics in primary and secondary esthetic breast surgery. *PRS Global Open* 2020;**8**.
28. Francis SH, Ruberg RL, Stevenson KB, et al. Independent risk factors for infection in tissue expander breast reconstruction. *Plast Reconstr Surg* 2009;**124**:1790–6.
29. Gfrerer L, Mattos D, Mastroianni M, et al. Assessment of patient factors, surgeons, and surgeon teams in immediate implant-based breast reconstruction outcomes. *Plast Reconstr Surg* 2015;**135:** 245e–252e.
30. Krueger EA, Wilkins EG, Strawderman M, et al. Complications and patient satisfaction following expander/implant breast reconstruction with and without radiotherapy. *Int J Radiat Oncol Biol Phys* 2001;**49**:713–21.
31. Nahabedian MY, Tsangaris T, Momen B, Manson PN. Infectious complications following breast reconstruction with expanders and implants. *Plast Reconstr Surg* 2003;**112**:467–76.
32. Reish RG, Damjanovic B, Austen WG Jr, et al. Infection following implant-based reconstruction in 1952 consecutive breast reconstructions: salvage rates and predictors of success. *Plast Reconstr Surg* 2013;**131**:1223–30.
33. Disa JJ, Ad-El DD, Cohen SM, Cordeiro PG, Hidalgo DA. The premature removal of tissue expanders in breast reconstruction. *Plast Reconstr Surg* 1999;**104**:1662–5.
34. Pinsolle V, Grinfeder C, Mathoulin-Pelissier S, Faucher A. Complications analysis of 266 immediate breast reconstructions. *J Plast Reconstr Aesthet Surg* 2006;**59**:1017–24.
35. McCarthy CM, Disa JJ, Pusic AL, Mehrara BJ, Cordeiro PG. The effect of closed-suction drains on the incidence of local wound complications following tissue expander/implant reconstruction: a cohort study. *Plast Reconstr Surg* 2007;**119**:2018–22.
36. Yalanis GC, Liu EW, Cheng HT. Efficacy and safety of povidone-iodine irrigation in reducing the risk of capsular contrac-

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005

ture in aesthetic breast augmentation: a systematic review and meta-analysis. *Plast Reconstr Surg* 2015;**136**:687–98.
37. Pfeiffer P, Jorgensen S, Kristiansen TB, Jorgensen A, Holmich LR. Protective effect of topical antibiotics in breast augmentation. *Plast Reconstr Surg* 2009;**124**:629–34.
38. Giordano S, Peltoniemi H, Lilius P, Salmi A. Povidone-iodine combined with antibiotic topical irrigation to reduce capsular contracture in cosmetic breast augmentation: a comparative study. *Aesthet Surg J* 2013;**33**:675–80.
39. Ramos-Gallardo G, Cuenca-Pardo J, Rodriguez-Olivares E, et al. Breast implant and anaplastic large cell lymphoma meta-analysis. *J Investig Surg* 2017;**30**:55–65.
40. Courtiss EH, Goldwyn RM, Anastasi GW. The fate of breast implants with infections around them. *Plast Reconstr Surg* 1979;**63**:812–16.

Please cite this article as: J.A. Lohmeyer, V.L. Jakob and M. Keck et al., Antibiotic treatment and prophylaxis of periprosthetic infections: Evaluation of 666 consecutive breast implant removals, Journal of Plastic, Reconstructive & Aesthetic Surgery, https://doi.org/10.1016/j.bjps.2020.11.005