



Use of Antimicrobial Irrigation and Incidence of Capsular Contracture in Breast Augmentation and Immediate Implant-Based Breast Reconstruction



Giuzio Federica^{1,2,5} · Fabrizio Tommaso³ · Catalano Alessia⁴ · Ceccarini Agostino⁵ · Bodog Florian⁶ · Giuliani Antonio⁷ · Massariello Domenico Nicola⁸ · Raweh Abdallah⁹ · Saturnino Carmela¹ · Svolacchia Lorenzo¹⁰ · Brongo Sergio¹¹

Received: 25 April 2023 / Accepted: 4 June 2023 / Published online: 6 July 2023
© The Author(s) 2023

Abstract Capsular contracture (CC) is one of the most common complications of implant-based breast reconstruction or augmentation surgery. Common risk factors of CC include biofilm, surgical site infections, history of prior CC or fibrosis, history of radiation therapy, and implant characteristics. Though bacterial contamination of breast prostheses is associated with adverse sequelae, there are not universally accepted guidelines and limited best practice

recommendations for antimicrobial breast pocket irrigation. Despite advanced molecular biology, the exact mechanism of this complication is not fully understood. Interventions that decrease the rate of CC include antibiotic prophylaxis or irrigation, acellular dermal matrix, leukotriene inhibitors, surgical techniques, and others. However, there is inconsistent evidence supporting these risk factors, and the current data was based on broad heterogeneous studies. The objective of this review was to provide a summary of the current data of contributing risk factors as well as preventative and treatment measures for CC.

✉ Brongo Sergio
sergiobrongo@gmail.com

Giuzio Federica
federica.giuzio@unibas.it

Fabrizio Tommaso
tommaso.fabrizio@crob.it

Catalano Alessia
alessia.catalano@uniba.it

Ceccarini Agostino
agostino.ceccarini@iss.sm

Bodog Florian
fbodog@gmail.com

Giuliani Antonio
giuldoc@hotmail.com

Massariello Domenico Nicola
mimmomassariello@yahoo.it

Raweh Abdallah
prof.raweh@icloud.com

Saturnino Carmela
carmela.saturnino@unibas.it

Svolacchia Lorenzo
lorenzo.svolacchia@gmail.com

¹ Department of Sciences, University of Basilicata, Potenza, Italy

² Spinoff TNcKILLERS s.r.l, Ateneo Lucano street 10, 85100 Potenza, Italy

³ Department of Plastic Surgery, IRCCS, Referral Cancer Center of Basilicata, Rionero in Vulture, PZ, Italy

⁴ Department of Pharmacy-Drug Sciences, University of Bari “Aldo Moro”, Bari, Italy

⁵ U.O.C. Primary Care and Territorial Health, Social and Health Department, State Hospital, Falciano, Republic of San Marino

⁶ Department of Surgery, Faculty of Medicine and Pharmacy, University of Oradea, Oradea, Romania

⁷ U.O.C. of General and Emergency Surgery A.O.R. “San Carlo”, Potenza, Basilicata, Italy

⁸ U.O.S.D of Plastic Surgery A.O.R “San Carlo”, Potenza, Italy

⁹ Cardiac Surgery Department, Yas Clinic, Abu Dhabi, United Arab Emirates

¹⁰ Departments of Medical-Surgical Sciences and Biotechnologies, La Sapienza University, Rome, Italy

¹¹ Department of Plastic Surgery, University of Salerno, Campania, Italy

Level of Evidence III This journal requires that authors assign a level of evidence to each article. For a full description of these evidence-based medicine ratings, please refer to the Table of Contents or the online Instructions to Authors <http://www.springer.com/00266>

Keywords Capsular contracture · Breast implant · Breast reconstruction · Topical antibiotics · Surgical site infections

Introduction

Breast cancer is the most frequently diagnosed cancer in women around the world, and up to 41% of patients who undergo mastectomy receive breast reconstruction [1]. Breast implant has been present since the 1960s, and 65% of reconstruction surgery is implant-based in the United States [2]. The main goals of breast reconstruction are to reshape the breast due to tissue loss following breast cancer; to revise and fix the previous reconstruction surgery; and to augment the breast volume for cosmetic purposes. Along with its advantages for physical and psychological satisfaction given for the patients, complication rates are high following implant-based breast reconstruction especially for capsular contracture.

CC is a distressing complication of breast implant surgery and often requires revision operation. Up to half of the patients develop CC, and 30% of them suffer from CC with Baker rates III and IV following implant-based breast reconstruction [3, 4].

Risk factors found to be associated with CC include previous capsular fibrosis, radiation therapy, contamination with biofilm-producing bacteria, surgical site infections (SSI), and immune response to the foreign material [3, 5]. The expression of toll-like receptor 4 is also seen in peri-implant tissue fibrosis and may play a role in myofibroblast differentiation to induce CC development [6]. The exact mechanism of the pathophysiology of CC formation is still unknown. An infection has been linked with the formation of CC extensively. Generally, breast surgery is considered to be a clean surgery but the postoperative SSI rate rises by 2–2.9% in augmentation and is the most common cause of readmission [7, 8]. The common organisms identified are *Staphylococcus epidermidis* and *S. aureus*, *Escherichia*, *Pseudomonas*, *Propionibacterium*, and *Corynebacterium* [9, 10].

This study aims to review the risk factors associated with CC and to outline the available preventative and treatment measures to reduce the rate of CC.

Methods

A comprehensive literature review was completed to create a list of pocket irrigation solutions currently described in the literature. We identified 413 publications total from PubMed search and excluded 397 publications due to not corresponding to our topic. Fifteen studies were ultimately selected and included in our review.

Results

Preoperative skin antiseptic agents are known to reduce postoperative complications. CC rate is reduced with povidone-iodine and antimicrobial irrigations [11]; however, chlorhexidine gluconate was found to be more effective than povidone-iodine for reduction of biofilm-related CC [12].

In 1986, Burkhardt et al. described the relationship between bacterial contamination and implant-related comorbidity; they demonstrated that the use of local antimicrobial agents in and around retromammary implants improved surgical outcomes, with an incidence of capsular contracture 7 times less than the control group [13].

Pocket irrigation with Betadine (Purdue Frederick, Stamford, Conn.) became a standard in practice as the literature increasingly supported the role of microorganisms as the basis of capsular contracture. In 2000, the FDA deemed the use of Betadine for breast pocket irrigation contraindicated, citing that exposure may lead to early implant failure [14].

Following the 2000 FDA ban on Betadine, Adams et al. proposed a triple antibiotic solution (TAS) composed of 50,000 U Bacitracin, 1 g Ancef, and 80 mg Gentamicin and recommended a pocket contact time of 5 minutes. Subsequent studies demonstrated that TAS is associated with a rate of capsular contracture 4 to 5 times lower in breast augmentation patients [15].

The FDA subsequently removed the warning on the use of Betadine with breast implants in 2017 [16]. Consequently, in early 2018, Jewell and Adams [17] updated a 14-point plan originally published in 2013 designed to decrease bacterial bioburden in breast implant surgery, including pocket irrigation with TAS, TAS + Betadine, or $\geq 50\%$ Betadine [18]. Adams suggests the need for consensus among plastic surgeons regarding pocket irrigation and further recommends that surgeons “should simply utilize the proven ingredients and ratios as recommended [19]”. Table 1 summarizes the mechanisms of action of individual antimicrobial agents according to the main guidelines of the American Society of Plastic Surgery [20].

Staphylococci species are the most common axillary flora, and antibiotics targeted at these species do not show a significant impact on SSI [21]. Preoperative prophylaxis has not significantly reduced SSI in breast cancer surgery [22], and prolonged postoperative antibiotic prophylaxis also has not shown to decrease implant loss or highly virulent infections [23]. Patient compliance plays an important role in preventing SSI, and medication non-compliance doubles the risk of infection in breast surgery [24]. In primary breast augmentation, most organisms in acute infections are Gram-positives and are adequately covered by a single dose of IV cephalosporin; clindamycin or vancomycin is recommended in individuals with β -lactam allergies. The antibiotic is broadened with fluoroquinolones or vancomycin in late infections or secondary surgeries due to mixed organisms with both Gram-positives and Gram-negatives [8].

Post-mastectomy radiation therapy leads to higher rates of CC [25]. Several studies report that patients who had radiation therapy are more likely to experience reconstruction failure due to complications. The expression of Thy1 (CD90), which has an important role in scar tissue

formation, is shown to be increased by radiation; thus, targeting the Thy1 receptor may decrease the rate of radiation-induced fibroproliferation of capsular tissue [26]. Muscle fibrosis is another possible contributor to CC in irradiated patients with subpectoral implant placement vs. prepectoral implant placement [27].

Breast implant characteristics especially implant surface seem to play a role in CC. Studies have analyzed that smooth implants, compared to textured implants, are significantly associated with CC, and the choice of the textured implant may reduce the risk of CC [28]. Moreover, microtextured implants may have lower rates of CC compared to macrotextured implants. However, macrotextured implants have been associated with increased risk of anaplastic large-cell lymphoma (ALCL) significantly compared to smooth or microtextured implants [29, 30]. Breast implant-associated ALCL is a rare complication and may have an infectious cause as seen by the bacterial biofilm on the implant [31].

LTE (Leukotriene) antagonists have been known to prevent and treat CC. Multiple studies have found that the patients who used LTE antagonists, either montelukast or

Table 1. Antimicrobial agents preferred among american society of plastic surgery (ASPS) survey respondents

Antimicrobial agents	Mechanism of action	Spectrum
Benzalkonium chloride	Degrades cell wall causing leakage of cellular contents; surfactant properties; solution uses mechanical debridement with a pulse lavage device	More effective against Gram positive than Gram negative
0.1%/0.1% Polyhexanide/ Betaine soap		
0.05% aqueous chlorhexidine Gluconate	Biguanide that disrupts cell walls and precipitates cellular proteins; binds to cell walls and alters osmotic equilibrium	Gram-negative and Gram-positive
0.05% chlorhexidine gluconate soap	At physiological pH, chlorhexidine salts dissociate and release positively charged chlorhexidine cation which binds to negatively charged bacterial cell walls	Broad antimicrobial coverage
Hydrogen peroxide	Oxidant; causes tissue toxicity via corrosive damage, oxygen gas formation, and lipid peroxidation	Broad coverage against viruses, bacteria, yeasts, and bacterial spores
Iodine-containing salts 10% povidone-iodine: I-PVP	Causes protein denaturation and precipitation of bacteria; toxic toward human fibroblasts	Viruses, bacteria, spores, fungi, and protozoa
Ammonium chlorides (bleaches) 0.25% sodium hypochlorite	Increases pH and interferes with cytoplasmic membrane integrity; interferes with cellular metabolism and phospholipid degradation	Broad coverage; dose-dependent toxicity against macrophages
0.4% sodium oxochlorosene	Oxidation and hypochlorination, and thereby destruction, of protoplasmic contents	Broad coverage
0.025% hypochlorous acid	Replicates oxidative burst that occurs in white blood cells with the release of hypochlorous acid	Broad coverage against Gram-positive and Gram-negative bacteria and fungi
Cefazolin Gentamicin (Anacef)	Inhibits cell wall synthesis Binds the 30S subunit of bactericidal ribosome, interrupting protein synthesis	Broad coverage against Gram-negative and Gram-positive organisms; concentration dependent
Bacitracin	Disrupts bacterial cell wall synthesis and inhibits cell enzymes	Most Gram-positive organisms
Polymyxin B	Binds to cell membrane and alters structure, making it permeable	Resistant Gram-negative microbes except Proteus and Neisseria genera
Vancomycin	Inhibits cell wall synthesis	Gram-positive bacteria

zafirlukast, have significantly decreased rate of CC compared to the control group [32, 33]. Although there is a short-term benefit in CC reduction rates with the use of LTE antagonists, its long-term side effects such as liver damage are not known in depth [34].

Discussion

The purpose of this review was to analyze the risk factors, etiology, and preventions for CC and to provide recommendations according to the current literature. The routine use of antimicrobial pocket irrigation and implant soaking agents, inframammary fold incision technique, and sub-muscular implant placement have led to decreased rates of capsular contracture [28]. The most preferred incision location among all survey respondents was within the inframammary fold. This finding is supported by the literature which demonstrates that the inframammary approach has been associated with a statistically significant reduction in capsular contracture [35]. Also in accordance with the literature, the most favored implant placement was in a submuscular pocket. This is likely due to its association with lower rates of infection and capsular contracture as predicted by Burkhardt et al. in 1986 [13]. Despite the strong association between bacteria and surgical complications, there appear to be no universally accepted, evidence-based best practice guidelines regarding antimicrobial breast pocket irrigation practices and only a grade D (level V evidence) guidelines for perioperative antibiotic practices. The current literature regarding pocket irrigation presents a confusing and conflicting picture regarding recommended solutions [36]. Much of the recent literature on pocket irrigation and implant soaking practices supports the use of TAS. However, studies have identified superior efficacy of Betadine-containing irrigations. Additionally, 1 study found non-Betadine containing TAS and 0.05% chlorhexidine to be most effective [37, 38]. Despite support in the literature for the use of TAS and TAS + Betadine, only 63% of respondents utilize TAS, TAS + Betadine (“Betadine Quadruple”), or TAS + Betadine without Bacitracin (“Betadine Triple”) as a pocket irrigant in their cosmetic cases. In all, over 35 distinct pocket irrigation solutions were identified among ASPS members during augmentation mammoplasty [39, 40]. Fisher reintroduced the concept of time-dependent efficacy of irrigation solutions in breast augmentation [39]. Pharmacologically, the efficacy of some antibiotics, such as Ancef, is dependent on time rather than concentration, such as with Gentamycin [41–44]. In contrast to reconstructive and implant-salvage procedures where evacuative drain placement is routine, pocket irrigation dwell time may be less significant in augmentation

mammoplasty when the solution is left in the pocket, as suggested by Adams, thereby achieving prolonged exposure times [45, 46].

Conclusions

CC is most likely to be multifactorial, and the exact mechanism of pathogenesis of CC formation is unknown. The available evidence on risk factors associated with CC is weak and inconclusive. Our review suggests that infectious cause may be the strongest risk factor of CC etiology, and further studies on this aspect are required. The current literature data on prevention and treatment of CC is heterogeneous, and results are controversial. Greater efforts in developing modern imaging and technologies will continue to provide advanced tools to understand the pathophysiology of CC in depth and further develop preventative and treatment interventions. According to the current literature, the incidence of SSI and CC has decreased with antibiotic prophylaxis, textured implant, ADM, leukotriene antagonists, and an open capsulotomy; however, these interventions have not been proved. The important question to be addressed should be more focused on the pathogenesis of CC, which has been debatable. It is important to carefully evaluate the pathophysiological mechanism underlying capsular contracture. Etoricoxib (cox-2 inhibitor) and zafirlukast (leukotriene inhibitor) have proven effective overall in prevent and reduce periprosthetic capsular contracture. The activity of cox-2 inhibitors was greater than leukotriene inhibitors. However, the potential cardiotoxicity of the former, as opposed to the very low side effects of the latter make zafirlukast preferred as the drug of first choice in post oncological breast reconstruction with prosthetic materials. All the patients treated with Accoleit® -zafirlukast showed no intolerance or reaction no adverse drug, this in support of the relative safety of one of its off label use [43]. It is currently necessary to investigate how to prevent capsular contracture or to minimize the risk of onset. At present, further studies and investigations of a pharmacological, surgical and pathological nature need to be carried out.

Funding Open access funding provided by Università degli Studi di Salerno within the CRUI-CARE Agreement. No funding was received for this article.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

Ethical Approval This material is the authors' own original work, which has not been previously published elsewhere. This study was

performed in accordance with research ethical guidelines. There are no human subjects in this article and informed consent is not applicable. All authors have contributed to the paper and have given permission for their names to be included as co-authors. This manuscript is not submitted to or is currently under review at any other journal.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Panchal H, Matros E (2017) Current trends in post-mastectomy breast reconstruction. *Plast Reconstr Surg* 140:7–13
- Bertozzi N, Pesce M, Santi P, Raposio E (2017) One-stage immediate breast reconstruction: a concise review. *Biomed Res Int* 2017:1–12
- Galdiero M, Larocca F, Iovene MR et al (2018) Microbial evaluation in capsular contracture of breast implants. *Plast Reconstr Surg* 141:23–30
- Tanner B (2018) Low rate of capsular contracture in a series of 214 consecutive primary and revision breast augmentations using microtextured implants. *JPRAS Open*. 15:66–73
- Ajdic D, Zoghbi Y, Gerth D, Panthaki ZJ, Thaller S (2016) The relationship of bacterial biofilms and capsular contracture in breast implants. *Aesthet Surg J* 36:297–309
- Segreto F, Carotti S, Tosi D, Pendolino AL, Marangi GF, Morini S, Persichetti P (2016) Toll-like receptor 4 expression in human breast implant capsules: localization and correlation with estrogen receptors. *Plast Reconstr Surg* 137:792–798
- Olsen MA, Nickel KB, Fox IK et al (2015) Incidence of surgical site infection following mastectomy with and without immediate reconstruction using private insurer claims data. *Infect Control Hosp Epidemiol* 36:907–914
- Prantl L, Momeni A, Brebant V, Kuehlmann B, Heine N, Biermann N, Brix E (2020) Recommendations for the use of antibiotics in primary and secondary esthetic breast surgery. *Plast Reconstr Surg Glob Open* 8:2590
- Palubicka A, Jaworski R, Wekwejt M, Swieczko-Zurek B, Pikula M, Jaskiewicz J, Zielinski J (2019) Surgical site infection after breast surgery: a retrospective analysis of 5-year postoperative data from a single center in Poland. *Medicina (Kaunas)* 55:512
- Cohen JB, Carroll C, Tenenbaum MM, Myckatyn TM (2015) Breast implant-associated infections: the role of the national surgical quality improvement program and the local microbiome. *Plast Reconstr Surg* 136:921–929
- Yalanis GC, Liu EW, Cheng HT (2015) Efficacy and safety of povidone-iodine irrigation in reducing the risk of capsular contracture in aesthetic breast augmentation: a systematic review and meta-analysis. *Plast Reconstr Surg* 136:687–698
- Carvajal J, Carvajal M, Hernández G (2019) Back to basics: could the preoperative skin antiseptic agent help prevent biofilm-related capsular contracture? *Aesthet Surg J* 12:848–859
- Burkhardt BR, Dempsey PD, Schnur PL et al (1986) Capsular contracture: a prospective study of the effect of local antibacterial agents. *Plast Reconstr Surg* 77:919–932
- Brandon HJ, Young VL, Jerina KL et al (2002) Mechanical analysis of explanted saline-filled breast implants exposed to betadine pock-et irrigation. *Aesthet Surg J* 22:438–445
- Adams WP Jr, Conner WC, Barton FE Jr et al (2001) Optimizing breast-pocket irrigation: the post-betadine era. *Plast Reconstr Surg* 107:1596–1601
- U.S. Food and Drug Administration (2017) Premarket Approval. Available at <https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma.cfm?ID=402786>. Accessed 9 Oct 2018
- Jewell ML, Adams WP Jr (2018) Betadine and breast implants. *Aesthet Surg J* 38:623–626
- Deva AK, Adams WP Jr, Vickery K (2013) The role of bacterial bio-films in device-associated infection. *Plast Reconstr Surg* 132:1319–1328
- Adams WP Jr (2018) Commentary on: surgical site irrigation in plastic surgery: what is essential? *Aesthet Surg J* 38:276–278
- Viola GM, Rolston KV, Butler C et al (2019) Evaluation of current perioperative antimicrobial regimens for the prevention of surgical site infections in breast implant-based reconstructive surgeries. *Plast Reconstr Surg Glob Open* 7:2342
- Zhang H, Wang Y, Yang S, Zhang Y (2020) Peri-operative antibiotic prophylaxis does not reduce surgical site infection in breast cancer. *Surg Infect (Larchmt)* 21:268–274
- Monroig K, Ghosh K, Marquez JE et al (2020) Do postoperative prophylactic antibiotics reduce highly virulent infections?: an analysis of 660 tissue expander breast reconstructions. *Ann Plast Surg* 85:S50–S53
- Gil Conesa M, Climent Martínez NM, Del Moral Luque JA, Durán Poveda M, Rodríguez Villar D, Rodríguez Caravaca G (2019) Evaluation of compliance with the antibiotic prophylaxis protocol in breast surgery and its effect on the incidence of surgical infection. *An Sist Sanit Navar* 23:139–146
- Olinger TA, Berlin NL, Qi J et al (2020) Outcomes of immediate implant-based mastectomy reconstruction in women with previous breast radiation. *Plast Reconstr Surg* 145:1029e–1036e
- Hansen TC, Woeller CF, Lacy SH, Koltz PF, Langstein HN, Phipps RP (2017) Thy1 (CD90) expression is elevated in radiation-induced periprosthetic capsular contracture: implication for novel therapeutics. *Plast Reconstr Surg* 140:316–326
- Sobti N, Weitzman RE, Nealon KP et al (2020) Evaluation of capsular contracture following immediate prepectoral versus subpectoral direct-to-implant breast reconstruction. *Sci Rep* 10:1137
- Calobrace MB, Stevens WG, Capizzi PJ, Cohen R, Godinez T, Beckstrand M (2018) Risk factor analysis for capsular contracture: a 10-year sientra study using round, smooth, and textured implants for breast augmentation. *Plast Reconstr Surg* 141:20–28
- Adams WP Jr, Culbertson EJ, Deva AK et al (2017) Macrot textured breast implants with defined steps to minimize bacterial contamination around the device: experience in 42,000 implants. *Plast Reconstr Surg* 427:431
- Loch-Wilkinson A, Beath KJ, Knight RJW et al (2017) Breast implant-associated anaplastic large cell lymphoma in Australia and New Zealand: high-surface-area textured implants are associated with increased risk. *Plast Reconstr Surg* 140:645–654
- Hu H, Johani K, Almatroudi A et al (2016) Bacterial biofilm infection detected in breast implant-associated anaplastic large-cell lymphoma. *Plast Reconstr Surg* 137:1659–1669
- Wang Y, Tian J, Liu J (2020) Suppressive effect of leukotriene antagonists on capsular contracture in patients who underwent breast surgery with prosthesis: a meta-analysis. *Plast Reconstr Surg* 145:901–911

32. Bresnick SD (2017) Prophylactic leukotriene inhibitor therapy for the reduction of capsular contracture in primary silicone breast augmentation: experience with over 1100 cases. *Plast Reconstr Surg* 139:379–385
33. Graf R, Ascenco AF, Freitas Rda S et al (2015) Prevention of capsular contracture using leukotriene antagonists. *Plast Reconstr Surg* 136:592–596
34. Schwartz MR (2017) Evidence-based medicine: breast augmentation. *Plast Reconstr Surg* 140:109e–119e
35. American Society of Plastic Surgeons (2013) Evidence-Based Clinical Practice Guideline: Breast Reconstruction with Expanders and Implants. Available at <https://www.plasticsurgery.org/Documents/Health-Policy/Guidelines/guideline-2013-breast-recon-expanders-implants.pdf>. Accessed 17 Sept 2018
36. Hu H, Sleiman J, Johani K et al (2018) Hypochlorous acid versus povi-done-iodine containing irrigants: which antiseptic is more effective for breast implant pocket irrigation? *Aesthet Surg J* 38:723–727
37. Zhadan O, Becker H (2018) Surgical site irrigation in plastic surgery. *Aesthet Surg J* 38:265–273
38. Fisher J, Porter RS (2018) Commentary on: surgical site irrigation in plastic surgery: what is essential? *Aesthet Surg J* 38:274–275
39. Adams WP Jr, Rios JL, Smith SJ (2006) Enhancing patient outcomes in aesthetic and reconstructive breast surgery using triple antibiotic breast irrigation: six-year prospective clinical study. *Plast Reconstr Surg* 117:30–36
40. Brindle CT, Porter S, Bijlani K et al (2018) Preliminary results of the use of a stabilized hypochlorous acid solution in the management of *Ralstonia pickettii* biofilm on silicone breast implants. *Aesthet Surg J* 38(suppl 2):S52–S61
41. McKinnon PS, Davis SL (2004) Pharmacokinetic and pharmacodynamic issues in the treatment of bacterial infectious diseases. *Eur J Clin Microbiol Infect Dis* 23:271–288
42. Scuderi N, Mazzocchi M, Fioramonti P, Bistoni G (2006) The effects of zafirlukast on capsular contracture: preliminary report. *Aesthetic Plast Surg* 30(5):513–520
43. Corrado R, Brongo S, Pagliara D, Cuomo R, Abbinante G, Campitiello N, Santanelli F, Chessa D (2014) Infections in breast implants: a review with a focus on developing countries. *J Infect Dev Ctries* 8(9):1089–1095. <https://doi.org/10.3855/jidc.3898>
44. Jianu DM, Săndulescu O, Streinu-Cercel A, Berciu I, Blidaru A, Filipescu Vartic M, Cobani O, Jianu ȘA, Tălăpan D, Dorobăț O, Stăniceanu F, Streinu-Cercel A (2016) Microbiologic safety of the transareolar approach in breast augmentation. *Aesthet Surg J* 36(1):51–57
45. Galdiero M, Larocca F, Iovene MR, Francesca M, Pieretti G, D’Orlando V, Franci G, Ferraro G, d’Andrea F, Nicoletti GF (2018) Microbial evaluation in capsular contracture of breast implants. *Plast Reconstr Surg* 141(1):23–30
46. Epps MT, Langsdon S, Pels TK, Lee TM, Thurston T, Brzeziński MA (2019) Antimicrobial irrigation and technique during breast augmentation: survey of current practice. *Plast Reconstr Surg Glob Open* 7(8):e2310

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.