The Evolution of Breast Implant Infections: *Serratia marcescens* Is an Emerging Pathogen in Implant-Based Breast Reconstruction

L'évolution des infections causées par les implants mammaires : le *Serratia marcescens*, un agent pathogène en émergence dans la reconstruction mammaire par implant

Jane L. Gui, BS¹, and Kant Y. Lin, MD, FACS²

Abstract

The flora of implant-based breast infections has changed over the last decade, including at our institution. A 10-year retrospective chart review was performed on 561 implant-based breast reconstructions in 378 patients performed by a single surgeon in an academic university hospital setting. Thirty-two breast infections requiring explantation of the implants occurred during those 10 years. During that time frame, a new pre- and peri-operative protocol was implemented in an effort to diminish infections. We believe that this protocol played a major role in the evolution of changing breast periprosthetic infection flora, from nearly one-third being gram-negative infections to 100% being gram-negative infections. Gram-negative antibiotic coverage should be considered in light of these evolving trends to prevent infections particularly with *Serratia marcescens*. This may be especially important in patients with BRCA1/2 or ATM mutations. Diabetic patients are more likely to develop Methicillin-resistant *Staphylococcus aureus* (MRSA) infections and preoperative MRSA decolonization is essential in these patients. Many patients have late-onset breast periprosthetic infection, the majority of which occurred after 30 days. Regular follow-up and patient education is important to provide timely treatment.

Résumé

La flore des infections mammaires par implant s'est modifiée depuis dix ans, y compris dans l'établissement des auteurs. Dans un hôpital universitaire, un chirurgien a procédé à une analyse rétrospective sur dix ans des dossiers de 561 reconstructions mammaires par implant réalisées chez 378 patientes. Pendant ces dix ans, 32 infections mammaires ont entraîné l'explantation des implants. Un nouveau protocole préopératoire et périopératoire a été adopté au cours de cette période, afin de réduire les infections. Les auteurs sont d'avis que ce protocole a joué un rôle majeur dans l'évolution de la flore des infections mammaires périprothétiques, qui sont passées de près du tiers à 100 % d'infections à Gram négatif. Il faudrait examiner la couverture antibiotique de ces infections à la lumière de ces tendances afin de prévenir les infections, notamment celles à *Serratia marcescens*. Cette décision serait particulièrement importante pour les patientes présentant des mutations BRCA1/2 ou ATM. Les patientes diabétiques sont plus susceptibles de contracter des infections à *Staphylococcus aureus* résistantes à la méthicilline (SARM); la décolonisation préopératoire à SARM est essentielle dans ce cas. De nombreuses patientes ont souffert d'une infection mammaire périprothétique tardive, dont la majorité s'est déclarée plus de 30 jours après l'implant. Il est important d'assurer un suivi régulier et d'éduquer les patientes pour pouvoir leur offrir un traitement au moment opportun.

¹ Department of Plastic Surgery, University of Virginia, Charlottesville, VA, USA

² Department of Plastic Surgery, University of Kentucky, Lexington, KY, USA

Corresponding Author:

Jane L. Gui, University of Virginia, 1300 Jefferson Park Ave, Charlottesville, VA 22903, USA.

Email: janelgui@gmail.com

Plastic Surgery
2019, Vol. 27(2) 182-188
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DOI: 10.1177/2292550319826098
journals.sagepub.com/home/psg

Keywords

breast implant, implant infection, *Serratia marcescens*, gram-negative infection, MRSA infection, infectious flora of breast implant, breast periprosthetic infection

Introduction

Breast reconstruction after mastectomy has become more prevalent as the number of breast cancer cases increases and prophylactic mastectomy surgeries increase.¹⁻³ It is estimated that 246 660 new cases of invasive breast cancer will be diagnosed in women in 2016 and that the number will increase to 252 710 in 2017.^{2,3} According to 2016 Reconstructive Plastic Surgery Statistics, there were 109 256 breast reconstructions in 2016, a 3% increase from 2015 and a 39% increase from 2010.⁴ Of the 109 256 breast reconstructions, 76% of them involved silicone implants and 72% involved tissue expander (TE) and secondary implants.⁴ Infection is one of the major complications of implant-based breast reconstruction.⁵ The rate of infection of implant-based breast reconstructions has been reported to range from 1.5% to 12.7%.^{5,6} Due to the morbidity of breast periprosthetic infection, various practices have been developed in an effort to prevent these infections.⁷ In this study, we sought to characterize infections in patients who had undergone implant-based breast reconstructions, requiring explant performed by a single surgeon over a 10-year period at an academic university hospital. We also investigated whether the adoption of a new protocol that employed additional methods to decolonize bacteria was successful in eradicating infections or simply changed the flora of the infections. Other risk factors that could increase the risk of infection, such as diabetes mellitus (DM), hypertension, use of acellular dermal matrix (ADM), age, body mass index (BMI), chemotherapy, radiation and so on, were also examined in their roles on the evolution of the microbiology of breast periprosthetic infection.

Method

Data Collection

A retrospective chart review of all implant-based breast reconstructions including TE insertion, as well as direct-to-silicone implant placement, performed by a single surgeon in both immediate and delayed fashion from 2007 to 2016, was performed. In this study, breast periprosthetic infection was defined as erythema and warmth of the breast accompanied with elevated white blood cell counts. We have included only patients who failed intravenous (IV) antibiotic treatment and in whom clinical course warranted explantation. Breast periprosthetic infection secondary to nonhealing wound, wound dehiscence, or flap necrosis leading to implant exposure was excluded. Possible risk factors examined were old versus new protocol, use of ADM, smoking status, American Society of Anesthesiologists (ASA) score, genetic mutation carriers (BRCA1, BRCA2, and ATM), prophylactic versus nonprophylactic mastectomy, history of radiation, history of

chemotherapy, DM, vascular disease (including peripheral vascular disease, cerebrovascular events, myocardial infarction), coronary artery disease (CAD), hypertension, BMI, and age at the time of the breast reconstruction. We also collected the dates of stage I breast reconstruction, dates of Jackson-Pratt (JP) drain removal, dates of clinical manifestation of infection, and dates of explantation. These dates were used to characterize the time frame of infection and whether the length of drain placement had any role in the type of infection.

Changes in the Pre- and Peri-Operative Protocols

A new protocol to combat breast periprosthetic infection was implemented in 2015. This protocol included preoperative total body chlorhexidine soap wash for 3 consecutive days and intranasal topical mupirocin for 5 days to reduce methicillin-susceptible *Staphylococcus aureus* and Methicillin-resistant *Staphylococcus aureus* (MRSA) colonization. Intraoperatively, povidone-iodine was discontinued and chlorhexidine-alcohol was used to prepare patients. Only ADM with sterility assurance level of 10^{-3} was used since the start of the new protocol; it was soaked in triple antibiotic solution (cefazolin, bacitracin, gentamicin) and washed of all preservative solution prior to usage. All surgical personnel were doubled gloved and new outer layer gloves were placed just prior to any handling of the implants. Triple antibiotics were used to irrigate the subpectoral pocket. Another new practice was that before the insertion of the TE or implant, the chest wall was repped with chlorhexidine-alcohol around the incision. Channel suction drains were placed in both the subpectoral and the subcutaneous planes through separate stab incisions on the skin and the exit sites were sealed with Dermabond. The drains were removed when their daily output decreased to less than 30 mL; however, unlike the previous protocol, they were removed by post-op day 21 regardless of the output. The patients remained on oral antibiotic therapy as long as drains were in place.

Data Analysis

SPSS (IBM SPSS Statistics version 23) was used to perform Fisher exact test to compare nominal variables including protocol, ADM use, smoker status, ASA score, genetic mutations, prophylactic versus nonprophylactic mastectomy, history of radiation, history of chemotherapy, DM, vascular disease, CAD, and hypertension. Independent-samples *t* test in SPSS was used to compare continuous values, which include BMI, age, post-op days at the time of explantation, and days of JP drain use. Sterile cultures were excluded from comparison analysis since the type of infection could not be confirmed.

Table 1. Implant-Based Breast Infections Over Ten Years—Pre versus Post-Protocol.

Organisms	Pre-Protocol (2007-March 2015)	Post-Protocol (March 2015- 2016)	Total Number Over 10 Years
MSSA	8	0	8
MRSA	4	0	4
Coagulase-negative Staphylococcus	1	0	1
<i>Serratia marcescens</i>	3	3	6
<i>Pseudomonas aeruginosa</i>	4	0	4
Enterobacter	2	0	2
Sterile	7	0	7
Total # of infections	29	3	32
Total # of patients	481	80	561
Rate of infection (%)	6.0	3.8	5.7

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

Results

Characterization of Breast Periprosthetic Infections

Five hundred sixty-one implant-based breast reconstructions in 378 patients performed by a single surgeon over a 10-year period from 2007 to 2016 at University of Virginia Medical Center (Table 1) were included in the study. Thirty-two primary breast periprosthetic infections involving 28 patients required implant removal during that time. The rate of infection was 6% in the preprotocol period (from 2007 to March of 2015) and decreased to 3.8% in the post-protocol period (March of 2015 to the end of 2016). From March 2015 to 2016, under the new protocol, all 3 infections were *Serratia marcescens* (Table 1). Only gram-negative infections were seen after implementing the new protocol (Table 1; Figure 1). Gram-negative infection went from 31% to 100% of all infections, while there were no new gram-positive infections (Table 1; Figure 1).

Statistical Significance

There was a statistically significant association between *Serratia* infection and the new protocol (Fisher exact test, $P = .009$, $N = 25$). Fourteen percent of pre-protocol infections were due to *Serratia* compared to 100% of post-protocol infections.

Diabetes mellitus was found to be associated with MRSA breast periprosthetic infection. The rate of DM was 75% among patients who were infected with MRSA, while the rate of DM was 14% among patients who were infected with other organisms (Fisher exact test, $P = .031$, $N = 25$, odd ratio = 18, confidence interval [CI] = 1.4-236).

Having genetic mutations including BRCA1, BRCA2, and ATM was also associated with developing a *Serratia* infection (Fisher exact test: $P = .015$, $N = 25$, odd ratio = 17, CI = 1.8-160).

The mean post-op day at the time of explantation for gram-positive infections and gram-negative infections were 195 (range: 17-1488) and 116 (range: 12-473), respectively. The

average time to development of infection was higher in the gram-positive group, though not statistically significant ($P = .36$). Only 31% of them occurred within a 30-day period (Table 2). Almost a third of the infections occurred outside of the 90-day window (Table 2). Table 3 illustrates the timing and organisms recovered from 32 breast periprosthetic infections.

Body mass index, age, use of ADM, smoking status, ASA score, prophylactic versus nonprophylactic mastectomy, history of radiation, history of chemotherapy, vascular disease, CAD, and hypertension were not associated with increased risk of any specific type of infection.

Discussion

The flora of breast periprosthetic infections and their timing are changing. Studies performed in different eras have shown a trend toward increasing percentage of gram-negative infection and decreasing percentage of gram-positive infection (Table 4). In 1970, a worldwide survey on 10 941 patients by 265 surgeons found the infections were predominantly *S albus* and *S aureus*.⁸ For patients who received breast implant-based reconstructions from 1997 to 2000, Nahabedian et al found 70% of their infections to be *S aureus*, while 10% were gram negative.⁹ In a study that investigated the breast periprosthetic infection rate for both reconstructive and aesthetic procedures from 2001 to 2006 in 2 hospitals in Texas, 2.7% of breast implant infections required explant.¹⁰ Of 31 implants submitted for culture, 68% grew *S aureus*, 68% of these were MRSA, only 6% grew gram-negative organisms, and 26% were sterile.¹⁰ In a paper that studied 240 women who underwent reconstructive breast implant procedures from 2005 to 2007, they reported the rate of infection at 6.7%.¹¹ Seven (44%) out of 16 patients had gram-positive organism and 7 (44%) out of 16 patients grew gram-negative organisms.¹¹ Yao et al found that 23 (16%) out of 142 patients who underwent 2-stage implant-based breast reconstructions were culture positive.¹² Only 10 of these patients were symptomatic; 4 of them were gram-positive infection, while the other 6 were gram-negative infection including *Escherichia coli*, *Propionibacterium*, *Proteus*, *Pseudomonas*, and *S marcescens*.¹² The rate of gram-positive infection decreased from predominantly staphylococcus in the 1970s, to 70% in 1997 to 2000, to 68% in 2001 to 2006, to 44% in 2005 to 2007, and to 40% in 2007 to 2011. Meanwhile, there has been a rise in symptomatic gram-negative breast implant infections, from negligible to over 50% according to these series studies over the past 40 years. Our study exhibited the same trend.

From 2007 to 2015, 13 (45%) out of 29 infections were gram-positive and 9 (31%) out of 29 were gram-negative organisms. After the initiation of the new protocol (from 2015 to 2016), 3 (100%) out of 3 were gram-negative infections, specifically, *S marcescens*. The shift in the microbiology of breast infections is likely due to the fact that recent anti-infection protocols focus primarily on reducing gram-positive organisms. As we decolonize and treat *S aureus* and coagulase negative *Staphylococcus* infection, we may be actively

Figure 1. Number and percentage of gram-positive, gram-negative, and sterile cultures from breast periprosthetic infections during pre- versus post-protocol period (2007-2015 vs 2015-2016).

Table 2. Percentage of Breast Periprosthetic Infections Occurred at Various Time Period.

Time Period (Post-op Days)	Percentage of Infections Occurred
30 days	31%
90 days	65%
6 months	72%
12 months	84%

selecting for gram-negative breast implant infections and neglecting to cover for gram-negative organisms when selecting antibiotics. For future breast implant surgeries, preoperative antibiotics specifically covering gram-negative organisms should be considered to minimize the risk of gram-negative breast periprosthetic infections. The rate of gram-positive breast periprosthetic infections dropped since the implementation of the new protocol; this demonstrated the effectiveness of the new protocol in preventing gram-positive organism infection and should be continued in the future.

The frequency of *S. marcescens* infections after the implementation of new protocol was a particularly intriguing finding. *Serratia marcescens* is a gram-negative bacillus in the enterobacteriaceae family. It exists in water, soil, plants, animal, and insects and was first described by Bizio in 1819 after local farmers complained about the reddening of polenta in Padua, Italy, after a particularly hot and humid summer. It was originally thought to be nonpathogenic and was used repeatedly in medical experiments because its red pigmentation was easy for tracing.¹³ In 1919, 2 medical Corps officers sprayed 5 US army soldiers with *S. marcescens* at their throat, mouths, and lips. They were instructed to wash their utensils in warm water and transmission of *S. marcescens* was documented.¹⁴ This was one of the earliest studies that investigated how bacteria was transmitted from person to person. In 1937, *S. marcescens* was painted on the gums of dental patients before they received tooth extraction. Blood cultures were drawn afterward in an effort to show that organisms in the gingival crevice could be seeded into the bloodstream during tooth extraction.¹⁵

By the early 1970s, it became clear that *S. marcescens* had pathogenic potential. It was revealed to cause a multitude of infections including meningitis,¹⁶ urinary tract infections,¹⁷ sepsis, endocarditis,¹⁸ and wound infections.¹⁷ Data from SENTRY antimicrobial Surveillance Program from 2004 to 2008 revealed that *Serratia* species were isolated from 3.5%

of all patients hospitalized with pneumonia, 4.1% in the United States, 3.2% in Europe, and 2.4% in Latin America.^{19,20} There have been a large number of hospital outbreaks of *S. marcescens*-related infections reported. Therefore, *S. marcescens* infection is assumed to be nosocomial in origin.¹³ However, Laupland et al found that 65% of all infections caused by *Serratia* species were community based after conducting an extensive survey of *Serratia* infection in Canada.²¹ Therefore, our patients could have contracted *Serratia* from the hospital or post-operatively in the community.

Serratia is resistant to penicillin, clindamycin, cefazolin, cefuroxime, macrolides, tetracycline, and nitrofurantoin.¹³ Production of extended-spectrum beta-lactamases and carbapenemases has been described in *Serratia* species. Fluoroquinolones, aminoglycosides, Bactrim, Zosyn, and third and fourth generation cephalosporin are usually effective in treating *Serratia*.²² Generally, systemic *Serratia* infection is considered opportunistic, seen most frequently in immunosuppressed patients who are neutropenic.

Serratia infection in breast implant surgery is uncommon with only a few studies reporting its occurrence. Pegues et al reported a series of 6 implants removed secondary to *Serratia* infection thought to be due to lack of sterile technique and reuse of saline bags during expansion.²³ Nahabedian et al reported 1 case of *S. marcescens* out of 10 infections found in 168 implants.⁹ Franchelli et al found 2 out of 16 patients who were infected with *S. marcescens*.¹¹ Yao et al also found 2 out of 23 positive cultures were *S. marcescens*,¹² and both required explantation while all the other infections were effectively treated with antibiotics. In addition, these 2 patients had post-op chemotherapy with transient neutropenia.

In our study, all tissue expansions were performed in the clinic setting. The injection sites were prepped with chlorhexidine and the surgeons wore sterile gloves and face masks for the entire expansion procedure. A closed system for the expansion fluid was utilized with IV tubing connected to a bag of sterile saline and to the injection needle with a 3-way stock cock. The needles, IV lines, and saline bags were never reused.

While we did not find any association between *Serratia* infections with chemotherapy or radiation, we did find a statistically significant association between *Serratia* infections and the new protocol. One possible reason for the increased number of *Serratia* infections may be the change of nasal and cutaneous flora as a consequence of the new protocol.

Table 3. Timing (Days) and Organisms of Breast Periprosthetic Infections.

Number	Year	Organism	Implant to Infection	Implant to Explant	Recent Surgery to Infection	Recent Surgery to Explant
1	2007	MSSA	1482	1488	6	12
2	2008	Pseudomonas	73	84	73	84
3	2008	MSSA	17	17	17	17
4	2009	MSSA	818	825	26	33
5	2009	No growth	661	670	5	14
6	2010	Coagulase-negative staphylococcus	298	300	33	35
7	2010	Serratia	7	12	7	12
8	2010	Serratia	7	12	7	12
9	2010	No growth	59	148	59	148
10	2011	MSSA	19	27	19	27
11	2011	MRSA	16	24	16	24
12	2012	MSSA	650	655	10	15
13	2013	Pseudomonas	34	48	34	48
14	2013	MSSA	290	328	290	328
15	2013	Serratia	223	267	223	267
16	2013	MSSA	64	70	64	70
17	2013	Pseudomonas	127	147	127	147
18	2013	Pseudomonas	56	104	56	104
19	2013	No growth	63	79	63	79
20	2013	MRSA	25	63	25	63
21	2013	MRSA	90	107	90	107
22	2013	Enterobacter	467	473	467	473
23	2014	Enterobacter	26	28	26	28
24	2014	MSSA	59	66	59	66
25	2014	No growth	201	244	201	244
26	2014	MRSA	39	40	39	40
27	2015	No growth	21	35	21	35
28	2015	No growth	10	19	10	19
29	2015	No growth	31	32	31	32
30	2016	Serratia	43	87	43	87
31	2016	Serratia	66	107	66	107
32	2016	Serratia	24	32	24	32

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

Table 4. Studies Showing the Percentage of Gram-Positive and Gram-Negative Breast Periprosthetic Infections.

References	# of Patients	Year of Study	Rate of Infection	% Gram Positive	% Gram Negative
Cholnoky T de ⁸	10 941 (265 surgeons)	1970	2.50%	"Preponderantly <i>Staphylococcus albus</i> and <i>aureus</i> "	Not mentioned due to infrequency
Nahabedian et al ⁹	130 (168 implants)	1997-2000	7.70%	70% (<i>S aureus</i>)	10%
Feldman et al ¹⁰	962	2001-2006	11%	68% (MRSA and MSSA)	6%
Franchelli et al ¹¹	240	2005-2007	6.70%	7 (44%)/16 (6/16 <i>Staphylococcus</i>)	7 (44%)/16
Yao et al ¹²	142	2007-2011	7% symptomatic; 16% culture +	40%	60%

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

Decolonization of *S aureus* using chlorhexidine wash and nasal mupirocin may have provided opportunities for *Serratia* colonization. Long-term cutaneous colonization of *Serratia* in a health care worker causing a *Serratia* epidemic among intensive care unit patients has been reported.²⁴ Two cases of pink-colored breast milk caused by colonization of *Serratia* in the breast ducts were reported by del Valle et al in 2014.²⁵ Therefore, the source of *Serratia* infection in our patients may also

have been their native breast ducts or from cutaneous colonization.

We also found a statistically significant association between *Serratia* infection and having genetic mutations (BRCA1, BRCA2, and ATM) that predispose women to breast cancer, while there was no association between having genetic mutations and new protocol ($P = .113$). Having BRCA1, BRCA2, and ATM mutations may predispose patients to opportunistic

infection such as *Serratia*. Staples et al found that when compared to patients with residual ATM kinase activity, patients with complete loss of ATM kinase activity are more likely to develop recurrent sinopulmonary infections due to undetectable/low level of IgA.²⁶ Friedenson suggested that BRCA 1 and BRCA2 carriers are not only predisposed to breast cancer but also to infection-related cancers due to breast cancer mutations affecting innate immune response and their regulation.²⁷ Although lacking strong evidence, the higher rate of *Serratia* infections in BRCA1/2 and ATM mutation carriers could be due to their weakened immune systems.

Diabetes mellitus was found to be associated with MRSA infection in our population. It has been reported that DM is one of the most significant risk factors for MRSA colonization and subsequent infection.^{28,29} Several studies have shown the rate of MRSA colonization as high as 27% to 56.6% in diabetic patients, significantly greater than their nondiabetic controls.²⁸⁻³³ These results indicate that it is especially important for patients with diabetes to have preoperative decolonization of MRSA. Since these patients are prone to recolonization with MRSA, post-op prophylaxis against MRSA may be effective in preventing tissue expansion-related infections.

A final finding of this study relates to the time course of infections. In 1970, a worldwide survey on 10 941 patients by 265 surgeons found the infection rate to be 2.5% for all breast implant operation and 68% occurred within 1 month of the surgery.⁸ Franchelli et al have reported 94% of their infections occurred within 6 months, with an overall mean time to infection of 95 days.¹¹ We found that 72% of the infections occurred within 6 months of implant insertion and 84% infection occurred within 1 year of the first-stage breast reconstruction. Only 31% of breast infections happened within 30 days of surgery. Our results demonstrate there might be many late breast periprosthetic infections than previously recognized. One potential weakness about our data given this information about the protracted timing of infections is whether the follow-up period was sufficient in those patients treated in 2016 to reflect the true infection rate. Those treated in 2016 had at least a minimum of 6 months of follow-up and many had 1 year or more, and whereas it is possible that in the last 6 months additional infections may manifest, at the time of this report, there have not been any additional infections. Given this protracted time of vulnerability to infection however, yearly follow-up with patients and educating patients to look for the signs of breast infection would appear to be most prudent.

Conclusion

This study demonstrated the evolution of breast periprosthetic infections from predominantly gram-positive infections to mainly gram-negative infections after the implementation of the new protocol focusing on eradicating gram-positive organisms. Prevention from gram-negative infection may be particularly important in patients with BRCA1/2 or ATM mutations. Diabetic patients are more likely to develop MRSA infections and preoperative MRSA decolonization is essential in these

patients. Many patients have late-onset breast periprosthetic infections. Regular follow-up and patient education is important to provide timely treatment.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Wong SM, Freedman RA, Sagara Y, Aydogan F, Barry WT, Golshan M. Growing use of contralateral prophylactic mastectomy despite no improvement in long-term survival for invasive breast cancer. *Ann Surg*. 2017;265(3):581-589.
2. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2017. *CA Cancer J Clin*. 2017;67(1):7-30.
3. American Cancer Society. <https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2016.html>. Published 2016. Accessed September 15, 2017.
4. American Society of Plastic Surgeons. <https://www.plasticsurgery.org/news/plastic-surgery-statistics>. Published 2016. Accessed September 15, 2017.
5. Pittet D, Rohner P, Pittet B. Infection in breast implants. *Lancet Infect Dis*. 2005;5(8):463.
6. Olsen MA, Nickel KB, Fox IK, et al. Incidence of surgical site infection following mastectomy with and without immediate reconstruction using private insurer claims data. *Infect Control Hosp Epidemiol*. 2015;36(8):907-914.
7. Bode LG, Kluytmans JA, Wertheim HF, et al. Preventing surgical-site infections in nasal carriers of *Staphylococcus aureus*. *N Engl J Med*. 2010;362(1):9-17.
8. De Cholnoky T. Augmentation mammoplasty. Survey of complications in 10,941 patients by 265 surgeons. *Plast Reconstr Surg*. 1970;45(6):573-577.
9. Nahabedian MY, Tsangaris T, Momen B, Manson PN. Infectious complications following breast reconstruction with expanders and implants. *Plast Reconstr Surg*. 2003;467-476.
10. Feldman EM, Kontoyiannis DP, Sharabi SE, Lee E, Kaufman Y, Heller L. Breast implant infections: is cefazolin enough? *Plast Reconstr Surg*. 2010;126(3):779-785.
11. Franchelli S, Vassallo F, Porzio C, et al. Breast implant infections after surgical reconstruction in patients with breast cancer: assessment of risk factors and pathogens over extended post-operative observation. *Surg Infect (Larchmt)*. 2012;13(3):154-158.
12. Yao CA, Wang D, Kulber DA. The story of *Serratia marcescens*: pathologic risk factors in breast implant surgery. *Arch Plast Surg*. 2014;41(4):414-417.
13. Mahlen SD. *Serratia* infections: from military experiments to current practice. *Clin Microbiol Rev*. 2011;24(4):755-791.
14. Cumming JG. Sputum-borne disease transmission with epidemiologic and bacteriologic research. *Mil Surg*. 1920;46:150-165.

15. Burket LW, Burn CG. Bacteremias following dental extraction: demonstration of source of bacteria by means of a non-pathogen (*Serratia marcescens*). *J Dent Res*. 1937;16:521-530.
16. Aronson JD, Alderman I. The occurrence and bacteriological characteristics of *S. marcescens* from a case of meningitis. *J Bacteriol*. 1943;46(3):261-267.
17. Gale D, Sonnenwirth AC. Frequent human isolations of *Serratia marcescens*. *Arch Intern Med*. 1962;109:414-421.
18. Hawe AJ, Hughes MH. Bacterial endocarditis due to *Chromobacterium prodigiosum*. *Br Med J*. 1954;1(4868):968-970.
19. Anonymous. *Annual Epidemiological Report on Communicable Diseases in Europe*. Stockholm, Sweden: European Centre for Disease Prevention and Control; 2010.
20. Jones RN. Microbial etiologies of hospital-acquired bacterial pneumonia and ventilator-associated bacterial pneumonia. *Clin Infect Dis*. 2010; 51(suppl 1):S81-S87.
21. Laupland KB, Parkins MD, Gregson DB, Church DL, Ross T, Pitout JD. Population-based laboratory surveillance for *Serratia* species isolates in a large Canadian health region. *Eur J Clin Microbiol Infect Dis*. 2008;27(2):89-95.
22. Dowzicky MJ, Park CH. Update on antimicrobial susceptibility rates among gram-negative and gram-positive organisms in the United States: results from the Tigecycline Evaluation and Surveillance Trial (TEST) 2005 to 2007. *Clin Ther*. 2008;30(11):2040-2050.
23. Pegues DA, Shireley LA, Riddle CF, et al. *Serratia marcescens* surgical wound infection following breast reconstruction. *Am J Med*. 1991;91(3B):173S-178S.
24. Vries JJ, Baas WH, Ploeg KV, Heesink A, Degener JE, Arends JP. Outbreak of *Serratia marcescens* colonization and infection traced to a healthcare worker with long-term carriage on the hands. *Infect Control Hosp Epidemiol*. 2006;27(11):1153-1158.
25. Del Valle CA, Salinas ET. Pink breast milk: *Serratia marcescens* colonization. *AJP Rep*. 2014;4(2):e101-e104.
26. Staples ER, McDermott EM, Reiman A, et al. Immunodeficiency in ataxia telangiectasia is correlated strongly with the presence of two null mutations in the ataxia telangiectasia mutated gene. *Clin Exp Immunol*. 2008;153(2):214-220.
27. Friedenson B. Mutations in components of antiviral or microbial defense as a basis for breast cancer. *Funct Integr Genomics*. 2013; 13(4):411-424.
28. Kutlu SS, Cevahir N, Akalin S, et al. Prevalence and risk factors for methicillin-resistant *Staphylococcus aureus* colonization in a diabetic outpatient population: a prospective cohort study. *Am J Infect Control*. 2012;40(4):365-368.
29. Lin J, Xu P, Peng Y, et al. Prevalence and characteristics of *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus* nasal colonization among a community-based diabetes population in Foshan, China. *J Diabetes Investig*. 2016;8(3):383-391.
30. Lipsky BA, Pecoraro RE, Chen MS, Koepsell TD. Factors affecting staphylococcal colonization among NIDDM outpatients. *Diabetes Care*. 1987;10(4):483-486.
31. Chandler PT, Chandler SD. Pathogenic carrier rate in diabetes mellitus. *Am J Med Sci*. 1977;273(3):259-265.
32. Boyko EJ, Lipsky BA, Sandoval R, et al. NIDDM and prevalence of nasal *Staphylococcus aureus* colonization. San Luis Valley Diabetes Study. *Diabetes Care*. 1989;12(3):189-192.
33. Ahluwalia A, Sood A, Lakshmy R, Kapil A, Pandey RM. Nasal colonization with *Staphylococcus aureus* in patients with diabetes mellitus. *Diabet Med*. 2000;17(6):487-488.