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EPIDEMIOLOGY

Body mass index impacts infection rates in immediate autogenous breast reconstruction

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Abstract

Purpose Risk of postoperative infection following breast cancer reconstruction warrants consideration of both classic and procedure-specific risk factors. We performed a retrospective chart review of patients with breast cancer over a 10-year period that underwent reconstructive surgery to identify factors that increase risk of postoperative infection.

Methods Rates of postoperative infection were assessed in primary (immediate or delayed, alloplastic or autogenous) and secondary reconstructive procedures. Patient characteristics, surgical details, and cancer features were analyzed using two-sample *t* test and Fisher's exact test for continuous and categorical data, respectively.

Results 456 procedures were performed on 264 patients with 29 cases of postoperative infection (6%). Infection was more likely to occur in earlier reconstructive procedures ($p < 0.03$). Overall, primary reconstructive procedures were associated with a higher infection rate ($p = 0.005$). Other associated risk factors included: autogenous reconstruction ($p < 0.018$), length of admission ($p < 0.001$) and immediate reconstruction ($p = 0.01$). Subgroup analysis revealed increased risk of infection with immediate autogenous reconstruction ($p < 0.03$). Furthermore, patients with greater body mass index (BMI) receiving immediate autogenous reconstruction had a greater risk of infection ($p < 0.003$). Factors unrelated to risk of infection included history of irradiation, smoking, cancer stage, tumor type and tumor size.

Conclusions Our findings suggest that risk of infection is higher in immediate autogenous reconstructions particularly when patients are overweight (BMI > 30). Our data do not support a relationship between infection and irradiation, features of cancer, or repeated reconstructive procedures. Prospective studies may be required to further validate these findings.

Keywords Breast cancer · Breast reconstruction · Infection · Body mass index

Background

In Canada, approximately 7.9% of patients receiving mastectomy for breast cancer will seek breast reconstructive surgery [1], with rates as low as 3.8% in Nova Scotia [2]. Despite no apparent differences in recurrence [3] and possible survival benefit among patients pursuing breast reconstruction compared to mastectomy alone, the procedure remains underutilized [4]. Some established negative predictors of reconstruction include lower socioeconomic status, geographic access to health care, non-white ethnic background, increased age, major comorbidities and chemotherapy/radiotherapy [5, 6]. Specifically in Ontario, patients with limited access to a plastic surgeon had lower rates of breast reconstruction [7]. Compared to those seeking purely cosmetic surgery, patients receiving breast reconstruction are more likely to have postoperative complications [8]. Therefore, it is important for surgeons to assess individual risk factors in this patient population for surgical complications.

Postoperative infection after breast reconstruction, in particular, causes significant morbidity and a burden on health care expenditure [9]. In order to minimize the frequency of postoperative complications, particularly infection, surgeons must be equipped with resources to assess risk factors and better counsel their patients preoperatively. Previous studies have identified several factors that are correlated with

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increased risk of postoperative infection in breast cancer patients following reconstruction. Some of these mirror classic risk factors for infection and delayed wound healing, such as obesity [4, 5], smoking [4], hypertension [10, 11], irradiation [4, 12] and increased preoperative hospital stay [13]. In addition, risk factors specific to this population, including repeated implant-based reconstruction, delayed reconstruction [12] and bilateral reconstruction [13], have been identified by various authors.

The aim of this current study is to identify patient characteristics, surgical details, and oncologic features that may increase the risk of postoperative infection following postmastectomy breast reconstruction in a tertiary center.

Methods

We performed a retrospective chart review of patients with breast cancer who underwent reconstructive surgery over a 10-year period (January 2001 to April 2011) at St. Michael's Hospital in Toronto, Ontario, Canada. Infection was defined by a positive wound culture or the surgeon's clinical assessment, where infection consisted of at least two of: erythema, purulent discharge, fluctuant area suggestive of abscess, or wound breakdown. Cases of prophylactic mastectomy and surgical complications (flap failure, re-do vessel grafts, irrigation and debridement for hematoma) were excluded.

Patient characteristics, surgical details and features of the oncologic diagnosis and treatment were collected for comparison between the infection and non-infection groups. Patient characteristics included age, body mass index (BMI) and history of smoking. BMI was calculated from height and weight recorded on the day of surgery, and smoking history was obtained from a combination of consult notes and anesthesiology records. For surgical details, we studied length of postoperative hospital stay, immediate versus delayed reconstruction, autogenous versus alloplastic reconstruction, flap type used for autogenous reconstructions, and time elapsed since previous reconstructive surgery. These details were obtained from hospital e-records and chart hard copies. Finally, we collected information on cancer stage, histological grade, tumor type, tumor size and history of irradiation using a combination of all available surgical, oncology and pathology reports.

For data analysis, procedures were divided into primary and secondary reconstructive procedures. Primary reconstructions included all first reconstructive procedures, all autogenous flap reconstructions and all alloplastic procedures with tissue expander insertion and first implant exchange. Secondary reconstructions included mound revisions, implant exchange, capsulotomy, flap revision, contralateral balancing, nipple–areolar complex reconstruction or a combination of these. To gain an understanding of the typical number of reconstructions performed per patient, we also recorded the total number of procedures and the total number of surgeries (operating room visits) for all patients. For example, if a patient had a left-sided autogenous reconstruction and a right-sided balancing reduction during the same operation, it was recorded as one surgery and two procedures.

Subgroup analysis within the primary reconstruction group was performed to compare infection cases within the immediate reconstruction group and the delayed reconstruction group. Immediate and delayed groups were then further divided for analysis looking at autogenous and alloplastic reconstructions individually. In a similar fashion, subgroup analysis within the secondary reconstructive procedure group was performed to compare infection cases seen in mound revisions, contralateral balancing, nipple–areolar complex procedures or a combination of two or more.

Continuous data (age, BMI and length of hospital stay) were analyzed using two-sample t test. Categorical data (smoking, autogenous vs. alloplastic reconstruction, type of autogenous reconstruction, cancer stage, histologic grade, invasive versus noninvasive cancer type, tumor size < 5 cm or greater than 5 cm, history of irradiation) were analyzed using Fisher's exact test. We categorized tumor size as either less than 5 cm or greater-than-or-equal-to 5 cm which corresponds, respectively, with a T1–T2 or T3–T4 diagnosis in the TMN staging system of the American Joint Committee on Cancer. For analysis of cancer stage, stages 0, I and II were compared to stages III and IV. Statistical significance was designated as $p < 0.05$.

Results

A total of 456 procedures were performed on 264 patients. The average age of all patients at the time of surgery was 50.66 ± 8.97. The mean number of procedures was 2.73 per patient, and the average number of surgeries was 2.06 per patient. There were 283 primary reconstructions and 173 secondary reconstructive procedures (Fig. 1). A total of 115 of 212 documented patients (54.2%) received radiation. There were very few cases of alloplastic reconstruction involving the use of acellular dermal matrix ($n = 3$ immediate, 2 delayed).

Cases of postoperative infection

Overall, there were only 29 cases of postoperative infection (Table 1). Subjective symptoms described by patients included fever, pain, feeling unwell, redness, discharge/drainage and odor. Twenty-five cases of postoperative infection occurred after primary reconstruction and four after

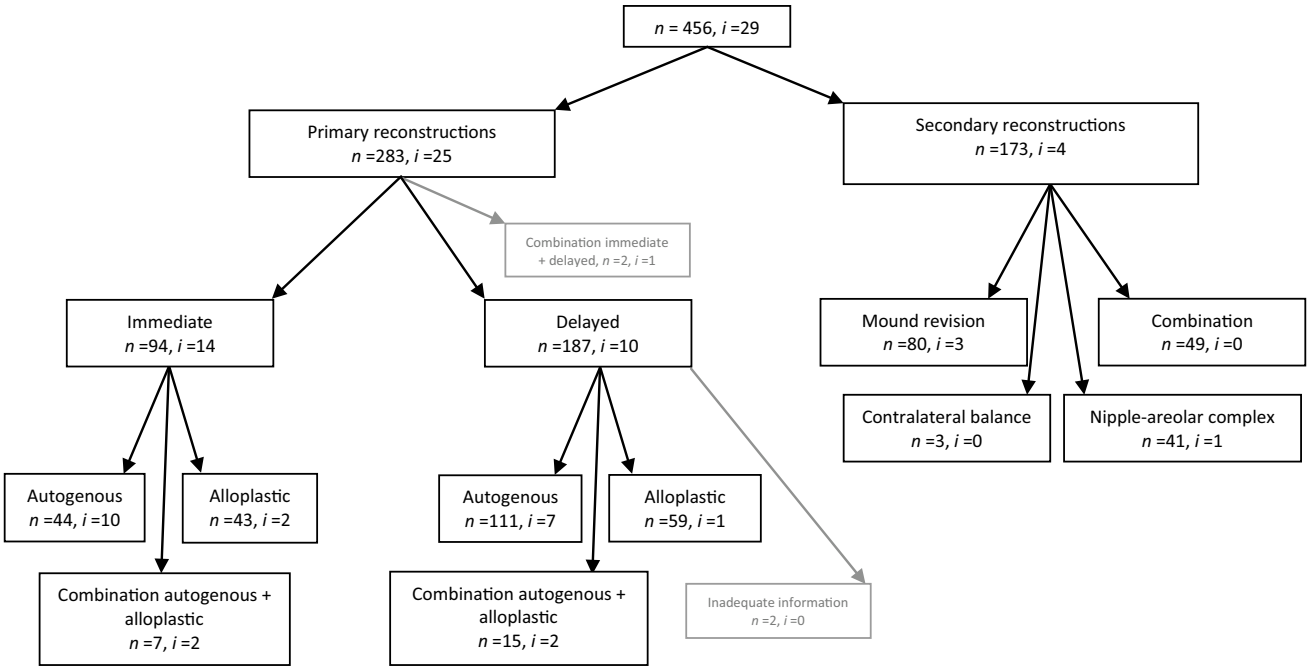

Fig. 1 Summary of cases included in study (n = total number of cases, i = number of infections)

Table 1 Postoperative infection: patient characteristics, etiology and treatment, $n = 29$

Average age	Average BMI	Average hospital stay post-op (# nights)	Wound culture (%) (24/29 cases cultured)		Treatment (%)	
48.9	31.6	3.0	Polymicrobial	12 (50.0)	WC	7 (24.1)
			S. aureus	8 (33.3)	ABX	5 (17.2)
			Pseudomonas	2 (8.3)	WC + ABX	14 (48.3)
			E. coli	2 (8.3)	Operative	3 (10.3)

ABX antibiotics, *WC* wound care

secondary reconstructive procedures; this was statistically significant ($p = 0.005$).

A majority of cases were treated successfully with conservative management using a combination of antibiotics and wound care (dressing changes, debridement or aspiration in clinic) ($n = 14$, 48.3%; see Fig. 2). Seven cases (24.1%) were treated by wound care alone, five (17.2%) by antibiotics alone and three (10.3%) required surgery for irrigation and debridement or to remove a prosthesis. Overall, two implants were lost. Wound cultures were performed in 24 cases and the causative microorganism was most often polymicrobial (50%). The most common individually isolated microorganisms were *Staphylococcus aureus* (33.3%), *Pseudomonas* (8.3%) and *E. coli* (8.3%).

Infection was diagnosed at a mean of 49.7 days postoperatively, with a considerable range of 8-200 days (Table 2). The mean number of procedures performed in cases of postoperative infection was 1.85, and 2.61 in the non-infection

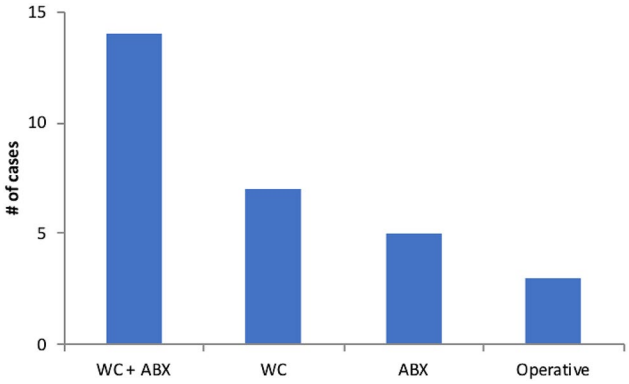

Fig. 2 Treatment of postoperative infection ($n = 29$, WC = wound culture, ABX = antibiotics)

Table 2 Timing of infection and surgical details, $n=29$

Average # days post-op for diagnosis	Total # of operations to date (%)		Total# of procedures to date (%) (information available for 27/29 cases)		For primary procedures ($n=25$): immediate versus delayed reconstruction (%)		For primary procedures ($n=25$): autogenous versus alloplastic (%)	
49.7	1st surgery	23 (79.3)	1st procedure	11 (40.7)	Immediate	14 (56.0)	Autogenous	17 (68.0)
	2nd surgery	5 (17.2)	2nd procedure	12 (44.4)	Delayed	10 (40.0)	Alloplastic	3 (12.0)
	3rd surgery	1 (3.4)	3rd procedure	1 (3.7)	Mixed	1 (4.0)	Both	4 (16.0)
			4th procedure	3 (11.1)				

Table 3 Patient characteristics for primary procedures, $n=283$

Factor	Average	Number cases/ total cases (%)
Age (years)	50.0	–
Body mass index	30.2	–
Tobacco*	–	97/257 (37.7)
Case length	3 h 51 m	–
No. nights overnight stay post-op	1.6	–
Immediate reconstructions	–	94/283 (33.2)
Autogenous	–	44/94 (46.8)
Alloplastic	–	43/94 (45.7)
Mixed autogenous and alloplastic	–	7/94 (7.4)
No. infections	–	14/94 (14.9)
Delayed reconstructions	–	187/283 (66.1)
Autogenous	–	111/187 (59.4)
Alloplastic	–	59/187 (31.6)
Mixed autogenous and alloplastic	–	15/187 (8.0)
No. infections	–	10/187 (5.3)
Combination immediate + delayed	–	2/283 (0.7)

*Total less than 283 as smoking history unavailable in some cases

group, which is statistically significant ($p=0.027$). The mean number of surgeries performed when comparing the infection to the non-infection group was also statistically significant (mean 1.24 surgeries in infection group vs. 1.94 in non-infection group; $p<0.001$).

Primary reconstructions

Patient characteristics are outlined in Table 3. There were a total of 283 primary reconstruction cases, which included 94 immediate reconstructions, 187 delayed reconstructions and 2 cases of combined immediate and delayed reconstruction. Fourteen of the 25 postoperative infections occurred in the immediate group (14.8%), ten in the delayed group (5.3%), and one in the combined immediate/delayed group. Comparison of infection rates in the immediate versus delayed reconstruction groups was statistically significant ($p=0.011$).

Multivariate analysis of all primary reconstruction cases comparing the infection group and the non-infection group revealed a significantly longer hospital stay in the infection group (2.76 nights vs. 1.28 nights, $p<0.0001$), a higher rate of infection in immediate reconstructions compared to delayed ($p=0.0114$), and a higher rate of infection in autogenous reconstructions compared to alloplastic reconstructions ($p=0.0181$) (Table 4). There were no significant differences in age, BMI, smoking history, type of autogenous reconstruction, cancer stage, cancer type, tumor size or history of irradiation.

Unfortunately, there were not enough histological reports available for a satisfactory analysis of histological grade.

Immediate reconstructions

When all cases of immediate reconstruction were isolated ($n=94$), there was no difference in the infection and non-infection groups with any of the variables analyzed, which included age, BMI, smoking history, history of irradiation, cancer stage, cancer type or tumor size (Table 5).

However, subgroup analysis with immediate autogenous procedures ($n=44$) revealed a statistically significant increase in BMI in the infection group compared with the non-infection group (35.3 vs. 27.3, $p=0.0026$). There was no difference in infection rate with age, smoking history, history of irradiation, cancer stage, cancer type or tumor size in this subgroup.

Unfortunately, an insufficient number of cases of infection ($n=2$) in the immediate-alloplastic reconstruction group did not allow for meaningful statistical analysis.

Delayed reconstructions

Multivariate analysis in the delayed reconstruction group ($n=187$) did not reveal a difference in infection rate in any of the parameters studied (age, BMI, smoking history,

Table 4 Analysis of potential risk factors in primary reconstructions

	Infection group average	Non-infection group average	*p* (two-sample *t* test)
Patient characteristics			
Age (years)	49.24	50.03	0.69
BMI	31.28	30.06	0.88
Features of surgery			
# overnights in hospital post-op	2.76	1.38	<0.001
	No. infection group	No. non-infection group	*p* (Fischer's test)
Patient characteristics			
Tobacco			
Yes	9	88	1.00
No	14	146	
Features of surgery			
Immediate versus delayed reconstruction			
Immediate	14	80	0.0114[a]
Delayed	10	177	
Combination immediate + delayed	1	1	
Autogenous versus alloplastic			
Autogenous	18	139	0.0181[b]
Alloplastic	3	99	
Both	4	18	
Type of autogenous reconstruction			
Abdominal based flap	17	106	1.00[c]
Latissimus dorsi flap	5	31	
Other	0	20	
Features of cancer			
Stage			
Zero	1	41	0.212[d]
I	5	49	
II	4	56	
III	5	35	
IV	1	6	
Cancer-type			
Noninvasive	1	44	0.306
Invasive	12	137	
Size of largest tumour			
< 5 cm (T2 or less)	13	135	0.310
≥ 5 cm (T3 or T4)	1	35	

Any one row may not add up to case total of 283 as several cases did not have complete information

[a]For immediate versus delayed reconstruction

[b]For autogenous versus alloplastic reconstruction

[c]For pedicled TRAM flap versus latissimus dorsi flap

[d]For stage 0, I, or II versus stage III or IV

history of irradiation, cancer, stage, cancer type or tumor size) (Table 5). Subgroup analysis examining delayed autogenous reconstructions ($n = 111$) also did not produce statistically significant results. There were not enough cases of infection ($n = 1$) in the delayed alloplastic group for meaningful statistical analysis.

Table 5 Summary of statistical analysis in subgroup analysis of immediate and delayed reconstruction

	Immediate reconstruction (*p* values)			Delayed reconstruction (*p* values)		
	All cases immediate reconstruction	Immediate-autogenous	Immediate-alloplastic	All cases delayed reconstruction	Delayed-autogenous	Delayed-alloplastic
Age	0.63	0.80	Insufficient data (2 infections)	0.70	0.88	Insufficient data (1 infection)
BMI	0.72	0.0030		0.99	0.91	
Tobacco	0.77	0.46		0.50	0.17	
History of irradiation	0.75	1.00		0.30	0.66	
Cancer stage (0–II vs. III–IV)	0.45	0.61		0.16	0.47	
Cancer type (noninvasive vs. invasive)	0.28	0.40		1.00	1.00	
Tumor size (< 5 cm vs. ≥ 5 cm)	0.20	0.30		0.58	1.00	

Table 6 Patient characteristics for secondary procedures, $n = 173$

Factor	Average	Number cases/total cases (%)
Age (years)	51.1	–
BMI	31.6	–
Tobacco*	–	55/159 (34.6)
Case length	2 h 57 m	–
No. nights overnight stay post-op	0.39	–
Elapsed time since previous surgery (months)	9.88	–
Type of revision		
Mound revision	–	80/173 (46.2)
Contralateral balancing	–	3/173 (1.7)
Nipple–areolar complex	–	41/173 (23.7)
Combination	–	49/173 (28.3)

*Total less than 258 cases as data unavailable for some cases

Secondary reconstructive procedures

There were a total of 173 cases of secondary reconstruction including four cases of postoperative infection (Table 6). There were 80 mound revisions, 3 contralateral balancing procedures, 41 nipple–areolar reconstructions, and 49 cases with a combination of these procedures. For all secondary reconstructive procedures, the mean elapsed time from the previous surgery was 9.88 months.

Three of the postoperative infections occurred in the mound revision group and one in the nipple–areolar reconstruction group. Due to the small number of infection cases, multivariate analysis of the secondary reconstruction group comparing the infection and non-infection group was not feasible. A summary of all statistically significant findings can be found in Table 7.

Discussion

Review of all breast reconstructive procedures in our cancer patients over a 10-year period revealed 29 cases of postoperative infection in 456 cases, corresponding to an overall rate of 6.4%. Although this rate is quite low, it is essential that surgeons are equipped with tools to identify the patients in their practice that are at a higher risk of developing infection and to be aware that these infections may be outside the boundaries of the surgical site infection timeline (within 30 days of a procedure). This permits better counselling of

Table 7 Summary of significant risk factors in the development of postoperative wound infection

Risk factor	Odds ratio	95% CI	*p*
Primary versus secondary reconstructive procedure	4.09	1.32–14.14	0.005
Fewer total # surgeries	–	–	< 0.0001
Fewer total # procedures	–	–	0.032
Length of stay following primary reconstruction	–	–	< 0.0001
Immediate versus delayed reconstruction	3.10	1.11–7.90	0.011
Autogenous versus alloplastic reconstruction	4.27	1.15–18.78	0.018
Immediate-autogenous versus immediate-alloplastic	6.03	1.12–42.97	0.026
BMI in immediate-autogenous reconstruction	–	–	0.003

patients preoperatively and can encourage interventions to tackle modifiable risk factors. Postoperatively, these patients may benefit from increased postoperative support in the home and/or postoperative surveillance to identify early signs of infection. Such measures may help alleviate some of the morbidity and costs associated with postoperative infection after breast reconstruction.

It is well known that patients with more time spent in hospital have increased risk of acquiring infection, and this was reflected in our statistical analysis [13–15]. Not surprisingly, our findings are supported by other studies in this population [7]. With respect to microorganism etiology, results from our patients' wound cultures echo findings from other studies that demonstrate *Staphylococcus* is the most common organism isolated with infections of the breast [13], although in a large majority of our cases (50%), the etiology was polymicrobial. It is unclear whether this disparity is a reflection of different patient populations or a shift occurring as a result of two further decades of antimicrobial use.

When considering risk factors for infection in our patients, it is essential to consider risk factors specific to the patient, such as age and BMI, as well as features of the surgical intervention itself that may carry inherent risk. In our analysis of 456 cases, our data suggests primary reconstructive procedures are associated with more infections than secondary procedures ($p = 0.005$), with an odds ratio of four. This is not difficult to conceive as primary reconstructions are typically more invasive, require longer operating time and are associated with larger incisions. However, length of incision was not measured in this study. This is particularly true of immediate reconstructions and autogenous reconstructions, where operating time may double due to concurrent mastectomy. Musculocutaneous flaps also create additional tissue trauma and more incisions due to donor sites. Indeed, our data reflect a threefold higher risk of postoperative infection with immediate reconstruction compared to delayed, and fourfold with autogenous versus alloplastic reconstruction. However, infections in autogenous reconstructions tend to be trivial, easy to treat, and rarely result in reconstructive failure, whereas infections in implant-based reconstructions tend to be more serious, more difficult to treat and often result in reconstructive failure [16].

These findings are generally supported by other studies, although there are some discrepancies. Three studies cite higher rates of infection with immediate reconstruction [13–15] while another showed a propensity for infection with delayed reconstruction [12]. Pinsolle et al. reported a higher complication rate for immediate reconstruction with latissimus dorsi flap compared to implant alone, although this was not statistically significant [4]; Armstrong et al. reported a higher rate of infection in alloplastic reconstructions with immediate reconstruction [13]; Costa et al. demonstrated that after correction for confounding factors, all methods of immediate reconstruction were equally viable options with respect to infection risk [17]. A 10-year analysis of trends in breast reconstruction demonstrated that there were significantly more complications after autogenous reconstruction compared to any other type of reconstruction [18]. This was also shown in the NSQIP database study by Hanwright et al. that exhibited higher morbidity in autologous reconstruction in patients with elevated BMI, with the latissimus dorsi flap as the lowest. Our study adds further support to the increased potential for complications (particularly infection) in immediate, autogenous reconstruction. This is true in cases where increased abdominal tissue in a patient with a higher BMI may predispose a surgeon to choose an autogenous option.

Our subgroup analysis revealed a significant relationship between increased BMI and infection in immediate autogenous reconstructions ($p = 0.003$). This has also been shown in numerous studies as a significant risk factor for infection [9, 18–21]. Obesity was associated with higher complication-related and total healthcare costs due to post-reconstruction infections and perfusion complications [11]. As our data already revealed an association between infection and both immediate and autogenous reconstructions independently, encountering a patient with high BMI should warrant careful consideration and thorough counselling to address risks and benefits of proceeding with an immediate autogenous reconstruction rather than a delayed or alloplastic procedure. Additionally, patients with elevated BMI may also carry underlying comorbidities that can further impact postoperative recovery. In this patient population, oncoplastic rather than immediate breast reconstruction may be the best option, as it was 10 times less likely to require reoperation due to complications, and 20 times less likely to have a delay in adjuvant therapy [22].

Our data do not support increased risk of infection with repeated reconstruction. Interestingly, our infection group had a significantly lower total number of reconstructive procedures than the non-infection group ($p = 0.03$), and this finding held true when we analyzed the total number of surgeries ($p < 0.001$). A possible explanation for our findings is that patients who had infection complications avoided further surgery or had these additional procedures with another surgeon. Moreover, given that the infections were diagnosed at a mean time of 49.7 days postoperatively suggests that infections may be in connection with delayed reporting or poor wound care management after discharge.

In breast reconstruction, it is interesting to also consider whether features of the cancer such as histologic grade, stage and tumor size have an effect on postoperative infection. Previous studies have pointed to increased postoperative infection when there is a history of chemotherapy [14] and irradiation [12, 23] due to possible fibrosis and decreased vascularity in treated tissues. Our study does not support a significantly increased risk of infection with

history of irradiation, or in those with a history of smoking. However, we did not control for surgical judgment exerted by choice and timing of operation, which is an important factor in patients with risk factors. For example, smokers may have been more routinely subjected to delayed rather than immediate primary reconstructions. Additionally, smokers may have been advised to undergo non-skin sparing mastectomies that were delayed after mastectomy flaps healed due to high risk of skin necrosis. Patients with radiation also may have undergone non-skin sparing procedures and, instead, may have chosen autologous tissue for a more satisfactory reconstruction. We were unable to find any studies that explore the relationship between infection and cancer stage, cancer type (invasive vs. noninvasive) or tumor size. We did not find a correlation of cancer stage or tumor size to postoperative infection, and unfortunately, we did not have enough data for meaningful statistical analysis with histological grade.

In summary, in our population we found that primary reconstructive surgery, immediate reconstruction, autogenous reconstruction, increased hospital stay and high BMI in immediate autogenous reconstruction may place patients at a higher risk of postoperative infection. Our data did not support a relationship between infection and history of irradiation, smoking, cancer type, cancer stage, or tumor size. Further research is needed to understand whether a relationship exists between features of patients' cancer and infection risk.

This study demonstrates that good surgical judgment involving timing and choice of operations may reduce infection rates by employing appropriate surgical technologies. Identifying patients at increased risk of infection is the first step to reducing the morbidity and cost of this complication. All surgeons should be cognisant of patient risk factors and strategies to address them, particularly those that are modifiable, which includes the choice of surgical intervention. Discharging patients from hospital at the earliest time that is safe, considering delayed reconstruction rather than immediate reconstruction, and alloplastic rather than autogenous reconstruction may be steps to consider in a high-risk patient to minimize the risk of complications.

Compliance with ethical standards

Conflict of interest Lauren I. Whilloughby, MD, FRCS(C), Josephine A. D'Abbondanza, MD, MSc declares , Heather L. Baltzer, MD, MSc, FRCS(C), James L. Mahoney, MD, FRCS(C), and Melinda A. Musgrave, MD, PhD, FRCS(C) declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, informed consent is not required.

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