JAMA Surgery | Original Investigation

Comparison of 2-Year Complication Rates Among Common Techniques for Postmastectomy Breast Reconstruction

Katelyn G. Bennett, MD; Ji Qi, MS; Hyungjin M. Kim, ScD; Jennifer B. Hamill, MPH; Andrea L. Pusic, MD; Edwin G. Wilkins, MD, MS

IMPORTANCE In breast reconstruction, it is critical for patients and surgeons to have comprehensive information on the relative risks of the available options. However, previous studies that evaluated complications were limited by single-center designs, inadequate follow-up, and confounding.

OBJECTIVE To assess 2-year complication rates across common techniques for postmastectomy reconstruction in a multicenter patient population.

DESIGN, SETTING, AND PARTICIPANTS This longitudinal, multicenter, prospective cohort study conducted from February 1, 2012, through July 31, 2015, took place at the 11 study sites associated with the Mastectomy Reconstruction Outcomes Consortium study. Eligible patients included women 18 years and older presenting for first-time breast reconstruction with at least 2 years of follow-up. Procedures evaluated included direct-to-implant (DTI) technique, expander-implant (EI) technique, latissimus dorsi (LD) flap, pedicled transverse rectus abdominis myocutaneous (pTRAM) flap, free transverse rectus abdominis myocutaneous (fTRAM) flap, deep inferior epigastric perforator (DIEP) flap, and superficial inferior epigastric artery (SIEA) flap.

INTERVENTIONS Postmastectomy breast reconstruction.

MAIN OUTCOMES AND MEASURES Development of complications, reoperative complications, and wound infections during 2-year follow-up. Mixed-effects logistic regression analysis controlled for variability among centers and for demographic and clinical variables.

RESULTS A total of 2343 patients (mean [SD] age, 49.5 [10.1] years; mean [SD] body mass index, 26.6 [5.7]) met the inclusion criteria. A total of 1525 patients (65.1%) underwent EI reconstruction, with 112 (4.8%) receiving DTI reconstruction, 85 (3.6%) pTRAM flaps, 95 (4.1%) fTRAM flaps, 390 (16.6%) DIEP flaps, 71 (3.0%) LD flaps, and 65 (2.8%) SIEA flaps. Overall, complications were noted in 771 (32.9%), with reoperative complications in 453 (19.3%) and wound infections in 230 (9.8%). Two years postoperatively, patients undergoing any autologous reconstruction type had significantly higher odds of developing any complication compared with those undergoing EI reconstruction (pTRAM flap: odds ratio [OR], 1.91; 95% CI, 1.10-3.31; $P = .02$; fTRAM flap: OR, 2.05; 95% CI, 1.24-3.40; $P = .005$; DIEP flap: OR, 1.97; 95% CI, 1.41-2.76; $P < .001$; LD flaps: OR, 1.87; 95% CI, 1.03-3.40; $P = .04$; SIEA flap: OR, 4.71; 95% CI, 2.32-9.54; $P < .001$). With the exception of LD flap reconstructions, all flap procedures were associated with higher odds of reoperative complications (pTRAM flap: OR, 2.48; 95% CI, 1.33-4.64; $P = .005$; fTRAM flap: OR, 3.02; 95% CI, 1.73-5.29; $P < .001$; DIEP flap: OR, 2.76; 95% CI, 1.87-4.07; $P < .001$; SIEA flap: OR, 2.62; 95% CI, 1.24-5.53; $P = .01$) compared with EI techniques. Of the autologous reconstructions, only patients undergoing DIEP flaps had significantly lower odds of infection compared with those undergoing EI procedures (OR, 0.45; 95% CI, 0.25-0.29; $P = .006$). However, DTI and EI procedures had higher failure rates (EI and DTI techniques, 7.1%; pTRAM flap, 1.2%; fTRAM flap, 2.1%; DIEP flap, 1.3%; LD flap, 2.8%; and SIEA flap, 0%; $P < .001$).

CONCLUSIONS AND RELEVANCE Significant differences were noted across reconstructive procedure types for overall and reoperative complications, which is critically important information for women and surgeons making breast reconstruction decisions.

JAMA Surg. 2018;153(10):901-908. doi:10.1001/jamasurg.2018.1687
Published online June 20, 2018.

Invited Commentary page 899

Author Audio Interview

Related article page 891

Author Affiliations: Section of Plastic Surgery, Department of Surgery, University of Michigan, Ann Arbor (Bennett, Qi, Hamill, Wilkins); Center for Statistical Consultation and Research, University of Michigan, Ann Arbor (Kim); Department of Biostatistics, University of Michigan, Ann Arbor (Kim); Plastic and Reconstructive Surgery, Brigham and Women's Hospital, Boston, Massachusetts (Pusic).

Corresponding Author: Edwin G. Wilkins, MD, MS, Section of Plastic Surgery, Department of Surgery, University of Michigan Health System, 1500 E Medical Center Dr, 2130 Taubman Center, Ann Arbor, MI 48109 (ewilkins@med.umich.edu).

Despite the equivalence of breast conservation therapy as primary treatment for early-stage breast cancer, mastectomy is still widely practiced for breast cancer treatment and prophylaxis. In many cases, patients' choice of mastectomy over breast conservation may be most influenced by the desire for contralateral prophylactic mastectomy, usually performed to reduce anxiety about recurrence.[1] Although breast reconstruction after mastectomy is now commonplace, many physicians before the 1980s argued that breast reconstruction was medically unnecessary and of little value.[2] However, it has become clear that quality of life, body image, and psychosocial well-being are critically important to women after mastectomy.[3] A variety of techniques for breast reconstruction have been developed during the past 50 years to lessen the negative influence of mastectomy on quality of life. With the increasing number of available options, patients and surgeons must now not only evaluate differences between implant-based and autologous techniques but also consider technical variations within these categories: implant type, shape, and texture; 1- or 2-stage implant-based procedures; and the various donor sites available for autologous reconstruction. Reliable information on associated risks is essential for effective decision making, but previous studies[4-7] of complications have been limited by single-center designs, small patient populations, and inadequate follow-up.

Patient-specific estimates of surgical risk for the available reconstructive options are essential to inform decision making and minimize complications. Previously, a 1-year complications analysis using the Mastectomy Reconstruction Outcomes Consortium (MROC) data demonstrated that autologous procedures were associated with significantly higher odds of complications and that women undergoing pedicled transverse rectus abdominis musculocutaneous (pTRAM) and deep inferior epigastric perforator (DIEP) flap procedures had significantly higher odds of developing major complications compared with women undergoing implant-based techniques.[8] Although these analyses evaluated complication rates within the first 12 months after the initial reconstruction, longer-term follow-up was still needed because many patients had not completed their reconstructions at 1 year, particularly in the expander-implant (EI) cohort. Using multicenter, prospective data, we sought to compare complications among reconstructive procedure types at 2 years to provide longer-term information on surgical risks and to better facilitate decision making between surgeons and patients.

Key Points

Question How do long-term complications compare across procedure types in postmastectomy breast reconstruction?

Findings In this multicenter cohort study of 2343 patients, the overall complication rate was 32.9%. Patients undergoing all autologous reconstruction types had significantly higher odds of developing any complication compared with patients undergoing expander-implant techniques.

Meaning Rates of complications after breast reconstruction are high and tend to be higher after autologous procedure types.

Methods

Study Population

The MROC was a multicenter, prospective cohort study funded by the National Cancer Institute to compare long-term outcomes among common techniques of breast reconstruction. Eligible patients included all women 18 years and older presenting for first-time breast reconstruction after mastectomy for cancer treatment or prophylaxis at 1 of the 11 participating institutions across the United States and Canada. After institutional review board approval was obtained from all participating sites, patients were recruited from February 1, 2012, to July 31, 2015. Written informed consent was obtained from all patients. Data were deidentified at the completion of the study, but data were not deidentified during the collection and analysis phases.

This analysis included women undergoing direct-to-implant (DTI) or EI procedures, as well as latissimus dorsi (LD) flap, pedicled transverse rectus abdominis myocutaneous (pTRAM) flap, free transverse rectus abdominis myocutaneous (fTRAM) flap, DIEP flap, or superficial inferior epigastric artery (SIEA) flap procedures. Patients with mixed reconstructive timing (1 side immediate, 1 side delayed), mixed procedure types (1 side implant based, 1 side autologous), or crossover reconstructions (delayed-immediate reconstructions beginning with implant techniques with a planned autologous second stage or implant techniques converted to autologous for other reasons) were excluded. Patients who failed to complete the study's initial preoperative questionnaire were withdrawn from the entire MROC database; therefore, loss to follow-up was not a consideration.

Dependent Variables

Two-year postreconstruction complication rates were subsequently compared across procedure types. For 2-stage EI cases, postreconstruction follow-up time was defined as the interval from the initial tissue expander placement. The primary outcomes of interest were any (all) complications, reoperative complications, and wound infections. A complication was defined as an adverse, postoperative, surgery-related event that required additional treatment. We identified postoperative wound infections based on the Centers for Disease Control and Prevention criteria: (1) presence of purulent drainage, (2) positive aseptically obtained culture result, (3) peri-incisional erythema and incision opened by the surgeon, or (4) physician diagnosis of infection, such as cellulitis, for which antibiotics were prescribed.[9]

Primary Independent Variable and Covariates

The primary independent variable was procedure type. Demographic and clinical variables included age, body mass index (BMI; calculated as weight in kilograms divided by height in meters squared), race, ethnicity, income, educational level, marital status, employment status, diabetes status, smoking status, timing of reconstruction (immediate vs delayed), laterality (unilateral vs bilateral), lymph node management, indication for mastectomy (cancer treatment vs prophylaxis), radiotherapy, and chemotherapy. Lymph node management was classified as none (no lymph node removal), sentinel lymph node

biopsy, or axillary lymph node dissection. Radiotherapy was categorized as before reconstruction, during or after reconstruction, or none. Chemotherapy was recorded as none, neoadjuvant, adjuvant, or neoadjuvant and adjuvant. Diabetes and smoking were also included as covariates because both have been associated with higher surgical risk. Patients were categorized as never smokers, previous smokers, or current smokers.

Statistical Analysis

Patient characteristics were compared across the 7 reconstructive procedure cohorts using 1-way analysis of variance for continuous variables and Pearson χ^2 test for categorical variables. Two-year complication rates by procedure type were summarized through frequencies and percentages. To further compare 2-year complications across the different techniques, we used separate mixed-effects logistic regression models for any type of complication, reoperative complications, and wound infection. Each model included indicators for each reconstructive procedure type as the primary independent variable, with EI technique as the reference procedure type. All models also included demographic and clinical characteristics as covariates and random intercepts for centers (hospitals) to account for variability among centers. We reported adjusted odds ratios (ORs) with 95% CIs based on the models. Statistical analyses were performed with SAS statistical software, version 9.4 (SAS Institute Inc, NC), and statistical significance was set at $P < .05$.

Results

Summary of Demographic Data

A total of 2343 patients (mean [SD] age, 49.5 [10.1] years; mean [SD] BMI, 26.6 [5.7]) met the inclusion criteria for the study analyses. Procedure types included 112 DTI technique (4.8%), 1525 EI technique (65.1%), 85 pTRAM flap (3.6%), 95 fTRAM flap (4.1%), 390 DIEP flap (16.6%), 71 LD flap (3.0%), and 65 SIEA flap reconstructions (2.8%). A total of 2184 reconstructions (93.2%) were performed at the time of mastectomy, and 1266 (54.0%) were bilateral. A total of 2095 patients (89.4%) underwent mastectomies for cancer treatment, and 1093 patients (46.6%) underwent sentinel lymph node biopsy. As summarized in **Table 1**, bivariate analyses found significant differences across procedure types for all the demographic and clinical covariates, with the exception of marital and employment statuses. Consequently, all the patient characteristics in Table 1 were controlled for in our regression.

Summary of Complication Data

Two-year complication rates are summarized in **Table 2**. Among all study patients, 771 (32.9%) experienced a complication. A total of 453 patients (19.3%) had a reoperative complication, and 126 reconstructions (5.4%) failed. The overall complication rate was highest among patients with SIEA flaps (48 [73.9%]), whereas reoperative complications occurred more frequently in non-LD flap autologous reconstructions compared with implant-based techniques (Table 3). By contrast, patients undergoing DTI or EI procedures had the highest failure rates (DTI failure rate, 8 [7.1%]; EI failure rate, 108 [7.1%]) (Table 2).

Mixed-Effects Regression Model Results

Results from the mixed-effects logistic regression model are reported in **Table 3**. Compared with EI procedures, all flap-based procedure types were associated with significantly higher odds of any complication (pTRAM flap: OR, 1.91; 95% CI, 1.10-3.31; $P = .02$; fTRAM flap: OR, 2.05; 95% CI, 1.24-3.40; $P = .005$; DIEP flap: OR, 1.97; 95% CI, 1.41-2.76; $P < .001$; LD flap: OR, 1.87; 95% CI, 1.03-3.40; $P = .04$; and SIEA flap: OR, 4.71; 95% CI, 2.32-9.54; $P < .001$). In addition, compared with EI procedures, pTRAM (OR, 2.48; 95% CI, 1.33-4.64; $P = .005$), fTRAM (OR, 3.02; 95% CI, 1.73-5.29; $P < .001$), DIEP (OR, 2.76; 95% CI, 1.87-4.07; $P < .001$), and SIEA (OR, 2.62; 95% CI, 1.24-5.53; $P = .01$) flaps were associated with significantly higher odds of reoperative complications. Finally, DIEP flaps were associated with significantly lower odds of infection compared with EI reconstructions (OR, 0.44; 95% CI, 0.25-0.78; $P = .005$).

From our regression analysis, demographic and clinical covariates with significant associations with complication outcomes included age, where the odds of developing any complication or a reoperative complication were higher for older women (OR, 1.02; 95% CI, 1.01-1.03; $P = .004$). Higher BMI was also associated with greater odds of any complication (OR, 1.05; 95% CI, 1.05-1.10; $P < .001$), reoperative complications (OR, 1.04; 95% CI, 1.02-1.07; $P < .001$), and wound infection (OR, 1.07; 95% CI, 1.05-1.10; $P < .001$).

Patients undergoing delayed reconstructions were significantly less likely to develop any complication compared with women receiving immediate reconstructions (OR, 0.55; 95% CI, 0.34-0.89; $P = .02$). Patients who had bilateral reconstructions were at greater risk for any complications (OR, 1.50; 95% CI, 1.20-1.86; $P < .001$) and reoperative complications (OR, 1.52; 95% CI, 1.17-1.97; $P = .002$). Compared with nonsmokers, current smokers were more likely to develop any complication (OR, 1.92; 95% CI, 1.09-3.40; $P = .02$) and reoperative complications (OR, 2.06; 95% CI, 1.10-3.86; $P = .02$). Patients undergoing radiotherapy during or after reconstruction had significantly higher odds of developing any complication (OR, 1.99, 95% CI, 1.46-2.69; $P < .001$), reoperative complications (OR, 1.96; 95% CI, 1.38-2.78; $P < .001$), and wound infections (OR, 2.77; 95% CI, 1.78-4.31; $P < .001$) compared with those not receiving radiotherapy. Patients who received neoadjuvant and adjuvant chemotherapy had significantly higher odds of developing reoperative complications (OR, 2.41; 95% CI, 1.28-4.51; $P = .006$). No significant associations with complications were observed for race, ethnicity, income, marital status, educational level, or employment status.

Discussion

Breast reconstruction offers significant quality-of-life benefits in many patients undergoing mastectomy.[10-14] Women who opt for breast reconstruction often do so to "regain femininity" or to "feel whole again."[15] In acknowledgment of the tremendous health benefits and quality-of-life gains that reconstruction provides, the Women's Health and Cancer Rights Act was passed in 1998, requiring US health care payers to provide coverage for all stages of reconstruction,

Table 1. Clinical and Demographic Characteristics of Patients by Procedure Type[a]

Characteristic	DTI Technique (n = 112)	EI Technique (n = 1525)	pTRAM Flap (n = 85)	fTRAM Flap (n = 95)	DIEP Flap (n = 390)	LD Flap (n = 71)	SIEA Flap (n = 65)	*P* Value
Age, mean (SD), y	48.2 (12.1)	48.4 (10.3)	53.5 (8.4)	51.8 (8.7)	51.0 (8.8)	53.5 (9.7)	52.8 (8.1)	<.001
BMI, mean (SD)	25.1 (6.2)	25.7 (5.3)	28.7 (5.8)	30.9 (5.2)	28.6 (5.1)	26.1 (7.0)	30.6 (7.3)	<.001
Timing								
Immediate	110 (98.2)	1495 (98.0)	76 (89.4)	71 (74.7)	325 (83.3)	48 (67.6)	59 (90.8)	<.001
Delayed	2 (1.8)	30 (2.0)	9 (10.6)	24 (25.3)	65 (16.7)	23 (32.4)	6 (9.2)	
Laterality								
Unilateral	36 (32.1)	583 (38.2)	70 (82.4)	63 (66.3)	228 (58.5)	55 (77.5)	42 (64.6)	<.001
Bilateral	76 (67.9)	942 (61.8)	15 (17.6)	32 (33.7)	162 (41.5)	16 (22.5)	23 (35.4)	
Indication								
Therapeutic	84 (75.0)	1367 (89.6)	81 (95.3)	87 (91.6)	349 (89.5)	68 (95.8)	59 (90.8)	<.001
Prophylactic	28 (25.0)	158 (10.4)	4 (4.7)	8 (8.4)	41 (10.5)	3 (4.2)	6 (9.2)	
Lymph node management								
None	43 (38.4)	311 (20.4)	31 (36.5)	34 (35.8)	153 (39.2)	32 (45.1)	18 (27.7)	<.001
SLNB	55 (49.1)	727 (47.7)	40 (47.1)	48 (50.5)	166 (42.6)	25 (35.2)	32 (49.2)	
ALND	14 (12.5)	487 (31.9)	14 (16.5)	13 (13.7)	71 (18.2)	14 (19.7)	15 (23.1)	
Diabetes								
Yes	3 (2.7)	46 (3.0)	6 (7.1)	4 (4.2)	26 (6.7)	6 (8.5)	8 (12.3)	<.001
No	109 (97.3)	1479 (97.0)	79 (92.9)	91 (95.8)	364 (93.3)	65 (91.5)	57 (87.7)	
Smoking status								
Never	80 (72.7)	1004 (66.7)	51 (60.7)	58 (61.1)	221 (57.0)	45 (63.4)	38 (58.5)	.02
Previous	30 (27.3)	462 (30.7)	32 (38.1)	35 (36.8)	151 (38.9)	25 (35.2)	26 (40.0)	
Current		40 (2.7)	1 (1.2)	2 (2.1)	16 (4.1)	1 (1.4)	1 (1.5)	
Radiotherapy								
Before reconstruction	9 (8.0)	76 (5.0)	28 (32.9)	37 (38.9)	87 (22.3)	40 (56.3)	11 (16.9)	<.001
During or after reconstruction	14 (12.5)	322 (21.1)	14 (16.5)	1 (1.1)	79 (20.3)	5 (7.0)	25 (38.5)	
None	89 (79.5)	1127 (73.9)	43 (50.6)	57 (60.0)	224 (57.4)	26 (36.6)	29 (44.6)	
Chemotherapy								
During or after reconstruction	13 (11.6)	518 (34.0)	21 (24.7)	10 (10.5)	112 (28.7)	16 (22.5)	32 (49.2)	<.001
None	99 (88.4)	1007 (66.0)	64 (75.3)	85 (89.5)	278 (71.3)	55 (77.5)	33 (50.8)	
Race								
White	103 (92.8)	1329 (88.0)	71 (83.5)	76 (80.9)	340 (88.8)	60 (85.7)	60 (93.8)	.001
Black	1 (0.9)	107 (7.1)	5 (5.9)	14 (14.9)	17 (4.4)	4 (5.7)	-	
Other	7 (6.3)	75 (5.0)	9 (10.6)	4 (4.3)	26 (6.8)	6 (8.6)	4 (6.3)	
Ethnicity								
Hispanic or Latina	3 (2.8)	86 (5.7)	1 (1.2)	14 (14.9)	18 (4.7)	3 (4.4)	0	<.001
Non-Hispanic or Latina	105 (97.2)	1412 (94.3)	84 (98.8)	80 (85.1)	367 (95.3)	65 (95.6)	60 (100)	
Income, $								
<50 000	15 (14.4)	211 (14.2)	26 (31.3)	26 (28.0)	81 (21.4)	24 (34.8)	25 (40.3)	<.001
50 000-99 000	28 (26.9)	442 (29.8)	30 (36.1)	22 (23.7)	176 (46.6)	29 (42.0)	17 (27.4)	
≥100 000	61 (58.7)	832 (56.0)	27 (32.5)	45 (48.4)	121 (32.0)	16 (23.2)	20 (32.3)	
Educational level								
High school or less	11 (9.9)	107 (7.0)	13 (15.3)	7 (7.4)	70 (18.1)	13 (18.3)	19 (29.2)	<.001
Some college	18 (16.2)	219 (14.4)	16 (18.8)	19 (20.0)	80 (20.7)	21 (29.6)	15 (23.1)	
College degree	41 (36.9)	675 (44.5)	38 (44.7)	37 (38.9)	171 (44.2)	25 (35.2)	28 (43.1)	
Master's or doctoral degree	41 (36.9)	517 (34.1)	18 (21.2)	32 (33.7)	66 (17.1)	12 (16.9)	3 (4.6)	
Marital status								
Married or partnered	81 (73.0)	1191 (78.8)	64 (75.3)	74 (77.9)	312 (80.2)	46 (65.7)	52 (80.0)	.13
Not married or partnered	30 (27.0)	321 (21.2)	21 (24.7)	21 (22.1)	77 (19.8)	24 (34.3)	13 (20.0)	
Employment status								
Full time (including student)	64 (59.8)	864 (57.2)	46 (54.8)	62 (66.7)	232 (60.4)	33 (47.1)	36 (55.4)	.20
Part time	14 (13.1)	213 (14.1)	8 (9.5)	6 (6.5)	51 (13.3)	11 (15.7)	5 (7.7)	
Unemployed	29 (27.1)	433 (28.7)	30 (35.7)	25 (26.9)	101 (26.3)	26 (37.1)	24 (36.9)	

Abbreviations: ALND, axillary lymph node dissection; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); DIEP, deep inferior epigastric artery perforator; DTI, direct to implant; EI, expander implant; fTRAM, free transverse rectus abdominis myocutaneous; LD latissimus dorsi; pTRAM, pedicled transverse rectus abdominis myocutaneous; SIEA, superficial inferior epigastric artery perforator; SLNB, sentinel lymph node biopsy.

[a] Data are expressed as number (percentage) unless otherwise indicated.

Table 2. Two-Year Postoperative Complication Rates Overall and by Procedure Type

Complication	No. (%) of Complications								P Value
	Overall (n = 2343)	DTI Technique (n = 112)	EI Technique (n = 1525)	pTRAM Flap (n = 85)	fTRAM Flap (n = 95)	DIEP Flap (n = 390)	LD Flap (n = 71)	SIEA Flap (n = 65)	
Any complication	771 (32.9)	35 (31.3)	406 (26.6)	35 (41.2)	34 (35.8)	185 (47.4)	28 (39.4)	48 (73.9)	<.001
Reoperative complication	453 (19.3)	21 (18.8)	237 (15.5)	25 (29.4)	26 (27.4)	114 (29.2)	10 (14.1)	20 (30.8)	<.001
Reconstructive failure	126 (5.4)	8 (7.1)	108 (7.1)	1 (1.2)	2 (2.1)	5 (1.3)	2 (2.8)	0	<.001
Wound infection	230 (9.8)	17 (15.2)	159 (10.4)	8 (9.4)	5 (5.3)	27 (6.9)	6 (8.5)	8 (12.3)	.13

Abbreviations: DIEP, deep inferior epigastric artery perforator; DTI, direct to implant; EI, expander implant; fTRAM, free transverse rectus abdominis myocutaneous; LD, latissimus dorsi; pTRAM, pedicled transverse rectus abdominis myocutaneous; SIEA, superficial inferior epigastric artery perforator.

procedures on the contralateral breast to achieve symmetry, and treatment of complications. Since passage of the act, the number of breast reconstructions performed in the United States has increased by almost 40%.[16]

When referred to a plastic surgeon for breast reconstruction after mastectomy, women are faced with a complex, multilayered decision as they choose between a multitude of surgical options. Although body habitus, age, medical comorbidities, prior radiotherapy, or availability of donor sites may limit these choices, most women are reasonable candidates for a variety of options. Thus, choosing the right operation usually involves careful weighing of the potential benefits against the risks of the various procedure types. To make these choices, surgeons and patients need reliable, comprehensive complication data on implant-based and autologous reconstruction techniques. For example, patients electing to undergo implant-based procedures must consider the potential for subsequent rupture and capsular contracture.[17] Alternatively, women who prefer using their own tissue (autologous reconstruction) must take into account the possibilities of donor site complications[18] and a 1% to 5% chance of total flap loss with microsurgical reconstructions.[19]

As with the 1-year analysis previously reported from MROC,[8] the 2-year complication rates in our study were impressively high. Overall rates ranged from 26.6% for EI reconstruction to 73.9% for SIEA flaps. Because overall complications included relatively minor issues, such as small wound dehiscences and seromas treated in the clinic or office setting, we also examined reoperative complications, which have a greater influence on patients' lives and well-being after reconstruction. Although adverse postoperative events that required additional surgery were less likely, they were still common, with rates ranging from 15.5% for EI procedures to 30.8% among SIEA reconstructions.

Furthermore, we noted significant differences in odds of overall complications and reoperative complications between the EI and autologous procedures, controlling for demographic and clinical covariates. The odds of developing complications were significantly higher in autologous reconstructions, despite the risk of infection, capsular contracture, and rupture in implant-based procedures. These differences may be attributable to the 2-year follow-up period of this study. Because implant-based procedures are still subject to potential capsular contracture and leakage throughout the life of the reconstruction, it seems likely that complication rates for these devices would increase with additional years of follow-up. Longitudinal studies capable of measuring long-term, implant-related complications are needed to facilitate informed decision making.

Despite the high rates of overall complications and reoperative complications, failure rates were low, ranging from 0% for SIEA flaps to 7.1% for DTI and EI techniques. Interestingly, the procedure types with the highest complications rates also had the lowest likelihoods of failure. This finding may be attributable (in part) to the higher infection rates among implant-based reconstructions compared with autologous procedures. In addition, although a postoperative wound infection in an implant-based reconstruction often necessitates explantation, an infection in an autologous reconstruction rarely requires debridement or flap removal.

The findings of previous studies[4,20,21] evaluating complication rates among reconstructive techniques are difficult to compare with those of the current analysis because of variations in the methods by which complications were defined and counted as well as other fundamental differences in study designs. Lagares-Borrego et al[4] compared complications between DIEP flaps and EI procedures, and although overall complications were higher for EI procedures (40.3% vs 32.8%), the minimal follow-up interval for the patients in the EI cohort was 3 years longer than that of the patients in the DIEP cohort. Given these variations in lengths of follow-up among procedure types, these findings are difficult to interpret. An additional study by Sacotte et al[20] that evaluated complications in patients undergoing immediate reconstruction and postmastectomy radiotherapy demonstrated a high rate of major complications (44%), although major complications in EI and autologous procedures were not significantly different. In a systematic review published in 2014, Tsoi et al[21] reviewed studies that compared complications between EI and autologous techniques. Of the 14 included studies, only 6 involved more than 100 breasts, and follow-up varied from 6 to 60 months. Pooled data revealed that patients who underwent autologous reconstruction were less likely to experience reconstructive failure (relative risk, 0.14; 95% CI, 0.25-0.55), but there was no difference in risk for additional operations for infection or skin necrosis between the 2 techniques. In this analysis, there was no comparison of overall complications between EI and autologous procedures.

In our study, several baseline patient characteristics were associated with higher odds of complications. Of note, radiotherapy during or after reconstruction and chemotherapy

Table 3. Mixed-Effects Logistic Regression Model for 2-Year Postoperative Complications

	Any Complication		Reoperative Complication		Wound Infection	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age	1.02 (1.01-1.03)	.004	1.02 (1.01-1.03)	.003	1.01 (1.00-1.03)	.10
BMI	1.05 (1.03-1.07)	<.001	1.04 (1.02-1.07)	<.001	1.07 (1.05-1.10)	<.001
Procedure type						
EI technique	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
DTI technique	1.08 (0.65-1.77)	.78	1.06 (0.56-1.99)	.87	1.70 (0.91-3.18)	.10
pTRAM flap	1.91 (1.10-3.31)	.02	2.48 (1.33-4.64)	.005	0.73 (0.31-1.70)	.46
fTRAM flap	2.05 (1.24-3.40)	.005	3.02 (1.73-5.29)	<.001	0.45 (0.17-1.18)	.10
DIEP flap	1.97 (1.41-2.76)	<.001	2.76 (1.87-4.07)	<.001	0.44 (0.25-0.78)	.005
LD flap	1.87 (1.03-3.40)	.04	1.03 (0.46-2.29)	.94	0.50 (0.16-1.56)	.23
SIEA flap	4.71 (2.32-9.54)	<.001	2.62 (1.24-5.53)	.01	0.67 (0.25-1.82)	.43
Timing						
Immediate	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Delayed	0.55 (0.34-0.89)	.02	0.71 (0.40-1.25)	.23	0.76 (0.33-1.71)	.50
Laterality						
Unilateral	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Bilateral	1.50 (1.20-1.86)	<.001	1.52 (1.17-1.97)	.002	1.27 (0.91-1.76)	.16
Indication						
Therapeutic	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Prophylactic	0.89 (0.59-1.32)	.55	1.18 (0.73-1.90)	.50	0.66 (0.35-1.27)	.22
Lymph node management						
None	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
SLNB	0.82 (0.60-1.12)	.21	1.04 (0.71-1.53)	.83	0.79 (0.49-1.28)	.34
ALND	0.84 (0.58-1.22)	.36	1.10 (0.71-1.71)	.68	0.58 (0.33-1.01)	.056
Diabetes	1.08 (0.66-1.78)	.75	1.40 (0.81-2.42)	.22	1.09 (0.53-2.23)	.81
Smoking status						
None	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Previous	1.12 (0.91-1.38)	.29	1.23 (0.96-1.57)	.11	0.94 (0.68-1.30)	.71
Current	1.92 (1.09-3.40)	.02	2.06 (1.10-3.86)	.02	0.79 (0.30-2.12)	.64
Radiotherapy						
None	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Before reconstruction	1.05 (0.73-1.50)	.80	0.78 (0.50-1.20)	.26	1.67 (0.96-2.89)	.07
During or after reconstruction	1.99 (1.46-2.69)	<.001	1.96 (1.38-2.78)	<.001	2.77 (1.78-4.31)	<.001
Chemotherapy						
None	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Neoadjuvant	0.88 (0.63-1.21)	.42	1.03 (0.70-1.51)	.90	0.77 (0.47-1.27)	.31
Adjuvant	1.05 (0.80-1.37)	.74	1.36 (0.98-1.87)	.06	1.03 (0.68-1.55)	.89
Neoadjuvant and adjuvant	1.50 (0.83-2.72)	.18	2.41 (1.28-4.51)	.006	0.80 (0.31-2.06)	.64
Race						
White	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Black	0.77 (0.50-1.18)	.23	0.73 (0.44-1.22)	.23	0.74 (0.37-1.48)	.40
Other	1.07 (0.69-1.66)	.77	0.58 (0.31-1.08)	.09	1.14 (0.58-2.25)	.70
Ethnicity						
Non-Hispanic or Latino	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Hispanic or Latino	0.66 (0.40-1.10)	.11	0.62 (0.32-1.19)	.15	0.72 (0.32-1.63)	.43
Income, $						
≥100 000	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
<50 000	1.06 (0.77-1.46)	.71	1.17 (0.80-1.69)	.42	0.70 (0.42-1.16)	.17
50 000-99 000	1.10 (0.87-1.39)	.42	1.25 (0.95-1.65)	.12	0.97 (0.68-1.39)	.88
Educational level						
High school or less	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Some college	0.97 (0.66-1.41)	.86	1.42 (0.91-2.21)	.12	1.16 (0.62-2.16)	.64
College degree	0.89 (0.63-1.26)	.51	1.22 (0.80-1.84)	.35	1.28 (0.73-2.25)	.39
Master's or doctoral degree	0.88 (0.60-1.29)	.51	1.06 (0.67-1.68)	.81	1.10 (0.60-2.03)	.76

(continued)

Table 3. Mixed-Effects Logistic Regression Model for 2-Year Postoperative Complications (continued)

	Any Complication		Reoperative Complication		Wound Infection	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Marital status						
Not married or partnered	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Married or partnered	0.98 (0.76-1.27)	.90	1.03 (0.76-1.39)	.86	1.09 (0.73-1.64)	.67
Employment status						
Unemployed	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
Full time (including student)	1.01 (0.80-1.28)	.94	1.08 (0.82-1.43)	.58	1.09 (0.75-1.57)	.66
Part time	1.10 (0.80-1.51)	.56	1.04 (0.71-1.52)	.84	1.64 (1.03-2.60)	.04

Abbreviations: ALND, axillary lymph node dissection; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); DIEP, deep inferior epigastric perforator; DTI, direct to implant; EI, expander implant; fTRAM, free transverse rectus abdominis myocutaneous; LD, latissimus dorsi; NA, not applicable; OR, odds ratio; pTRAM, pedicled transverse rectus abdominis myocutaneous; SIEA, superficial inferior epigastric artery perforator; SLNB, sentinel lymph node biopsy.

during or after reconstruction were associated with increased odds of complications. Bilateral reconstructions were also associated with higher odds of complications compared with unilateral reconstructions, consistent with the 1-year analysis.[9] This is critical information for women who are considering contralateral prophylactic mastectomy because increased odds of reconstructive complications may outweigh the psychological benefit conferred by prophylactic mastectomy. In addition, the odds of any complication were significantly lower in delayed reconstructions than in immediate cases, which is consistent with prior results from the MROC study.[22] These results may influence surgical decision making regarding radiotherapy timing and prophylactic mastectomy. Although BMI was associated with increased odds of complications, diabetes had no independent association with the odds of any complication, reoperative complication, or infection. Age was also associated with increased odds of complications, which was consistent with the results from the 1-year analysis.[9]

Limitations

Although our study's strengths lie in its multicenter, multisurgeon, prospective design and large patient population, it is not without limitations. Patients were not randomized to procedure types; consequently, our results may have been subject to confounding by unrecognized demographic or clinical covariates. We were also limited by small numbers of certain types of reconstructions (eg, transverse upper gracilis flaps); therefore, we could not include them in our analysis. In addition, we could not control for individual surgeons, which may have had a significant association with complication rates. It is also possible that our complication rates are conservative estimates because some patients may have sought care at other hospitals for complications. Finally, our results may not be generalizable to all patients in all settings because most participating study sites were academic medical centers in the United States and Canada.

Conclusions

Comprehensive data from prospective, multicenter studies are vital for promoting informed decision making in breast reconstruction. This 2-year, multicenter, prospective analysis revealed high rates of overall complications and reoperative complications, with significantly higher odds of complications associated with autologous reconstruction compared with implant techniques. However, failure rates were low across procedure types. Reconstruction may be associated with a high risk for complications, but successful reconstruction may still be achieved in most patients. Women electing to undergo reconstruction after mastectomy should demonstrate a firm understanding of the risks and benefits during the consent process. Finally, studies with longer follow-up are needed to adequately assess the association between procedure choice and complication rates.

ARTICLE INFORMATION

Accepted for Publication: May 24, 2018.

Published Online: June 20, 2018. doi:10.1001/jamasurg.2018.1687

Author Contributions: Dr Wilkins had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Bennett, Kim, Hamill, Pusic, Wilkins.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Bennett, Qi, Pusic, Wilkins.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Qi, Kim, Wilkins.
Obtained funding: Kim, Wilkins.
Administrative, technical, or material support: Hamill, Wilkins.
Supervision: Pusic, Wilkins.

Conflict of Interest Disclosures: None reported.

Funding/Support: This study was supported by grant R01CA152192 from the National Cancer Institute of the National Institutes of Health (Drs Pusic and Wilkins). Dr Bennett is currently supported by grant 1F32DE027604-01 from the National Institute for Dental and Craniofacial Research.

Role of the Funder/Sponsor: The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily reflect the official views of the National Institutes of Health.

Additional Contributions: We acknowledge the Mastectomy Reconstruction Outcomes Consortium site principal investigators for their contributions: Yoon S. Chun, MD (Brigham and Women's Hospital), Richard Greco, MD (Georgia Institute of Plastic Surgery), Troy A. Pittman, MD (Georgetown University), Mark W. Clemens, MD (MD Anderson

Cancer Center), John Kim, MD (Northwestern University), Daniel Sherick, MD (Saint Joseph Mercy Hospital), Gayle Gordillo, MD, Ed (The Ohio State University), Ed Buchel, MD (University of Manitoba), and Nancy Van Laeken, MD (University of British Columbia). We also thank all the patients who participated in the Mastectomy Reconstruction Outcomes Consortium study and made this work possible.

REFERENCES

1. Kummerow KL, Du L, Penson DF, Shyr Y, Hooks MA. Nationwide trends in mastectomy for early-stage breast cancer. *JAMA Surg*. 2015;150(1):9-16.

2. Goldwyn RM. Breast reconstruction after mastectomy. *N Engl J Med*. 1987;317(27):1711-1714.

3. Kincaid SB. Breast reconstruction: a review. *Ann Plast Surg*. 1984;12(5):431-448.

4. Lagares-Borrego A, Gacto-Sanchez P, Infante-Cossio P, Barrera-Pulido F, Sicilia-Castro D, Gomez-Cia T. A comparison of long-term cost and clinical outcomes between the two-stage sequence expander/prosthesis and autologous deep inferior epigastric flap methods for breast reconstruction in a public hospital. *J Plast Reconstr Aesthet Surg*. 2016;69(2):196-205.

5. Chun YS, Sinha I, Turko A, et al. Comparison of morbidity, functional outcome, and satisfaction following bilateral TRAM versus bilateral DIEP flap breast reconstruction. *Plast Reconstr Surg*. 2010;126(4):1133-1141.

6. Cordeiro PG, McCarthy CM. A single surgeon's 12-year experience with tissue expander/implant breast reconstruction, part I: a prospective analysis of early complications. *Plast Reconstr Surg*. 2006;118(4):825-831.

7. 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(3):713-721.

8. Wilkins E, Hamill J, Kim H, et al. Complications in postmastectomy breast reconstruction: one-year outcomes of the Mastectomy Reconstruction Outcomes Consortium (MROC) study. *Ann Surg*. 2018;267(1):164-170.

9. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR; Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Guideline for prevention of surgical site infection, 1999. *Am J Infect Control*. 1999;27(2):97-132.

10. Dauplat J, Kwiatkowski F, Rouanet P, et al; STIC-RMI working group. Quality of life after mastectomy with or without immediate breast reconstruction. *Br J Surg*. 2017;104(9):1197-1206.

11. Wilkins EG, Cederna PS, Lowery JC, et al. Prospective analysis of psychosocial outcomes in breast reconstruction: one-year postoperative results from the Michigan Breast Reconstruction Outcome Study. *Plast Reconstr Surg*. 2000;106(5):1014-1025.

12. Brandberg Y, Malm M, Blomqvist L. A prospective and randomized study, "SVEA," comparing effects of three methods for delayed breast reconstruction on quality of life, patient-defined problem areas of life, and cosmetic result. *Plast Reconstr Surg*. 2000;105(1):66-74.

13. Elder EE, Brandberg Y, Björklund T, et al. Quality of life and patient satisfaction in breast cancer patients after immediate breast reconstruction: a prospective study. *Breast*. 2005;14(3):201-208.

14. Girotto JA, Schreiber J, Nahabedian MY. Breast reconstruction in the elderly: preserving excellent quality of life. *Ann Plast Surg*. 2003;50(6):572-578.

15. Reaby LL. Reasons why women who have mastectomy decide to have or not to have breast reconstruction. *Plast Reconstr Surg*. 1998;101(7):1810-1818.

16. Plastic Surgery Statistics. Plastic surgery procedural statistics from the American Society of Plastic Surgeons. https://www.plasticsurgery.org/news/plastic-surgery-statistics/. Accessed November 7, 2017.

17. Handel N, Jensen JA, Black Q, Waisman JR, Silverstein MJ. The fate of breast implants: a critical analysis of complications and outcomes. *Plast Reconstr Surg*. 1995;96(7):1521-1533.

18. Knox AD, Ho AL, Leung L, et al. Comparison of outcomes following autologous breast reconstruction using the DIEP and pedicled TRAM flaps: a 12-year clinical retrospective study and literature review. *Plast Reconstr Surg*. 2016;138(1):16-28.

19. Wade RG, Razzano S, Sassoon EM, Haywood RM, Ali RS, Figus A. Complications in DIEP flap breast reconstruction after mastectomy for breast cancer: a prospective cohort study comparing unilateral versus bilateral reconstructions. *Ann Surg Oncol*. 2017;24(6):1465-1474.

20. Sacotte R, Fine N, Kim JY, et al. Assessing long-term complications in patients undergoing immediate postmastectomy breast reconstruction and adjuvant radiation. *Pract Radiat Oncol*. 2017;7(2):e91-e97.

21. Tsoi B, Ziolkowski NI, Thoma A, Campbell K, O'Reilly D, Goeree R. Safety of tissue expander/implant versus autologous abdominal tissue breast reconstruction in postmastectomy breast cancer patients: a systematic review and meta-analysis. *Plast Reconstr Surg*. 2014;133(2):234-249.

22. Yoon AP, Qi J, Brown DL, et al. Outcomes of immediate versus delayed breast reconstruction: results of a multicenter prospective study. *Breast*. 2018;37:72-79.