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EPIDEMIOLOGY

Early postoperative outcomes in implant, pedicled, and free flap reconstruction for breast cancer: an analysis of 23,834 patients from the ACS-NSQIP datasets

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Abstract

Introduction Many patients seek breast reconstruction following mastectomy. Debate exists regarding the best reconstructive option. The authors evaluate outcomes comparing implant, free flap, and pedicled flap reconstruction.

Methods Patients undergoing implant, pedicled flap, and free flap reconstruction were identified in the 2011–2016 NSQIP database. Demographics were analyzed and covariates were balanced using overlap propensity score. Logistic regression was used for binary outcomes and Gamma GLM for length of stay (LOS).

Results Of 23,834 patients, 87.7% underwent implant, 8.1% free flap, and 4.2% pedicled flap reconstruction. The implant group had the lowest mean operative time (206 min, SD 85.6). Implant patients had less pneumonia (OR 0.09, CI 0.02–0.36, $p < 0.01$), return to operating room (OR 0.62, CI 0.50–0.75, $p < 0.01$), venous thromboembolism (VTE) (OR 0.33, CI 0.14–0.79, $p = 0.01$), postoperative bleeding (OR 0.10, CI 0.06–0.15, $p < 0.01$), and urinary tract infections (UTI) (OR 0.21, CI 0.07–0.58, $p < 0.01$) than free flap patients. Pedicled flap patients had less postoperative bleeding (OR 0.69, CI 0.49–0.96, $p = 0.03$) than free flap patients. Pedicled flap patients had more superficial surgical site infections ($p = 0.03$), pneumonia ($p = 0.02$), postoperative bleeding ($p < 0.01$), VTE ($p = 0.04$), sepsis ($p = 0.05$), and unplanned reintubation ($p = 0.01$) than implant patients. Implant patients had the lowest LOS (1.6 days, $p < 0.01$).

Conclusion Implant reconstruction has less short-term postoperative complications than free flaps and pedicled flap reconstructions. The overall complication rate among all reconstructive modalities remains acceptably low and patients should be informed of all surgical options.

Keywords Breast reconstruction · Free flaps · Implants · Breast cancer · NSQIP

Introduction

Breast cancer is one of the most common cancer diagnoses in the United States [1]. While breast-conserving surgery and simple mastectomy remain suitable options, many patients seek mastectomy with reconstruction [2, 3]. The psychosocial, emotional, and functional benefits of breast reconstruction have been well documented [4, 5]. Additionally, improvements in patients body image and general well-being continue to manifest at 2 years following reconstruction [4].

Options for breast reconstruction include autologous or implant-based reconstruction. Autologous reconstruction involves moving flaps using patients own tissue to the breast and may be further categorized into pedicled flap or

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free flap reconstruction. Pedicled flap breast reconstruction involves transposition of tissue to the breast while keeping the primary blood supply to the flap intact, such as the transverse rectus abdominis myocutaneous (TRAM) flap and latissimus dorsi (LD) flap. Free flap breast reconstruction involves transferring tissue from one part of the body to the breast where the blood vessels to the flap are divided then reconnected at the recipient site using microsurgical techniques. Most commonly used free flaps for breast reconstruction are the deep inferior epigastric perforator (DIEP) flap or the superficial epigastric artery (SIEA) flap. Other donor sites such as the buttock, thighs, or hips may be used but are less common [6]. Breast implants have been widely used for breast reconstruction and are the leading reconstructive modality [5]. Implant-based reconstruction is often a staged procedure. A temporary tissue expander may be placed at the time of mastectomy, which is followed by a series of outpatient percutaneous saline injections. Once the desired size is achieved, the tissue expander is exchanged for permanent implants [6]. Breast reconstruction may be performed immediately following mastectomy or in delayed fashion depending on patient preference, physical characteristics, risk factors, and need for adjuvant radiation [7].

Recent studies demonstrated that while the rate of autologous breast reconstruction remained relatively stable, implant use increased at an average of 11% per year from 1998 to 2008, outnumbering autologous reconstruction by a ratio of 2:1 [5]. Breast implants continue to be a subject of debate given recent concerns of breast implant associated anaplastic large cell lymphoma (BIA-ALCL) and breast implant illness (BII) [8–10]. A previous study reported an overall incidence of 8.4% of major postoperative complications among all breast reconstruction modalities, with an increased risk of surgical and medical complications in autologous reconstruction compared to implant reconstruction [11]. However, these data do not specifically evaluate and compare outcomes between various techniques. In this study, we evaluate 30-day outcomes in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database comparing implant reconstruction with free flap and pedicled flap reconstruction.

Methods

Data source

We conducted a retrospective analysis of the ACS-NSQIP databases from years 2011 to 2016. ACS-NSQIP data including patient demographics, preoperative risk factors, baseline comorbidities, intraoperative risk factors, and 30-day postoperative morbidity and mortality were collected by trained research nurses at each institution using systematic sampling of general and vascular operations at each participating institution. Results of the audits completed to date reveal an overall disagreement rate of 2.3% for all assessed program variables. Datasets contain between 252 and 323 Health Insurance Portability and Accountability Act (HIPAA) compliant variables. The list of variables collected and definitions can be found at the NSQIP Website (http://www.acsnsqip.org/). The ACS-NSQIP is not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

In order to include patients who underwent breast reconstruction after mastectomy for breast cancer, we first identified the International Classification of Diseases (ICD) codes related to breast cancer: "174," "174.0," "174.1," "174.2," "174.3," "174.4," "174.5," "174.6," "174.8," "174.9," "217," "233.0," and "238.3." A subset of mastectomy patients was identified by the American Medical Association Current Procedural Terminology (CPT) codes for mastectomy: 19180, 19303, 19182, 19304, 19305, 19306, 19307, 19200, 19220, and 19240. From this cohort, breast reconstruction patients were identified and divided into three groups based on type of reconstruction: implant-based reconstruction (CPT Codes: 19340, 19357, 19342), free flap reconstruction (CPT codes: 19364), and pedicled flap reconstruction (CPT codes: 19361, 19367, 19369). Patients who did not have a mastectomy, those who underwent more than one reconstructive procedure, males, and those with missing demographic information (height, weight, gender, operation time) were excluded from the analysis. Additionally, patients with ventilator dependency, congestive heart failure, preoperative renal failure, $> 10\%$ preoperative weight loss, preoperative transfusion requirements, systemic sepsis, and patients with contaminated and infected wounds were excluded.

The patients' baseline demographics and comorbid conditions were analyzed between the three groups. Variables used for adjustment included patient demographics such as age, race, and ethnicity, and comorbid conditions such as body mass index (BMI), diabetes, smoking, dyspnea, preoperative functional status, chronic obstructive pulmonary disease (COPD), presence of malignant or disseminated cancer, open wound or wound infections, steroid use, bleeding disorder, wound class, and ASA classification.

Outcomes

Primary outcomes within 30 days included wound-related, infectious, and overall medical or surgical complications. Wound-related complications included wound dehiscence, superficial surgical site infection (SSI), and deep SSI

(fascia or muscle). Infectious complications included pneumonia, urinary tract infection (UTI), organ space infection, sepsis and/or septic shock. Additionally, overall complications included bleeding occurrences, return to the operating room, pulmonary embolism, deep venous thrombosis, postoperative renal insufficiency, stroke or cerebrovascular accidents (CVA), and myocardial infections. Results were considered significant if the observed p-value was < 0.05.

Statistical analysis

Sample characteristics were summarized using means, standard deviations, and proportions. Logistic regression models were used for binary outcomes and a generalized linear model (GLM) assuming a Gamma family and log link for the continuous LOS variable. Covariates were adjusted using propensity score-based overlap weighting [12]. Hypothesis testing was performed with bootstrap standard errors with fifty iterations. The bootstrap method accounted for the fact that the propensity score model was estimated and not known.

The free flap group was the reference category in models to compare to both implant and pedicled flap group. Additionally, the pedicled flap was compared to the implant group where the p-value is presented for a contrast test of the odds ratios of pedicled flap versus implant. The odds ratios for the pedicled flap versus implant comparisons can be obtained by division of their respective odds ratios with respect to free flap. The free flap was used as the reference category since the rates of free flap reconstruction have remained stable over the years, while pedicled flap rates decreased and implant rates increased [13]. Results were considered significant if the observed p-value was < 0.05. SAS (V9.4) and STATA (Statacorp, College Station, TX) were used for analyses.

Table 1 Socio-demographics

$N = 23,834$	Number	%
Mean age (SD)	51.7 (10.6)	
Mean BMI (SD)	27.5 (6.3)	
Race		
Asian	1065	4.5
Black	2099	8.8
White	18,342	77.0
Other	2328	9.8
Ethnicity		
Hispanic	1470	6.2
Non-Hispanic	20,505	86.0
Unknown	1859	7.8
Diabetes	1276	5.4
Smoking	2715	11.4
Reconstruction type		
Free flap	1924	8.1
Implant	20,909	87.7
Pedicled flap	1001	4.2

SD standard deviation

Table 2 Preoperative comorbidities

$N = 23,834$	Number	%
Malignant cancer	19,026	79.8
Dyspnea	522	2.2
Functional status		
Independent	23,713	99.5
Non-independent/unknown	121	0.5
History of COPD	195	0.8
Presence of disseminated cancer	298	1.3
Active wound infection	54	0.2
Current steroid use	455	1.9
Bleeding disorder	150	0.6

Results

Demographics and patient characteristics

A total of 23,834 patients were included in the study. There were 1924 (8.1%) in the free flap group, 20,909 (87.7%) in the implant group, and 1001 (4.2%) in the pedicled flap group (Table 1). The average age was 51.7 (SD: 10.64) and average BMI was 27.5 (SD: 6.34). The majority of patients were white and non-Hispanic. There were 1276 diabetics (5.4%) and 2715 smokers (11.4%). Cohort study characteristics and intraoperative comorbidities are summarized in Tables 2 and 3. Preoperative and intraoperative characteristics for each reconstructive modality are listed in Tables 4 and 5. There were no major differences in demographics with adjusted values. The majority of cases were clean and ASA class II.

Postoperative complications

Total complications across all cohorts are listed in Table 6. Most wound-related complications consisted of superficial SSIs (1.9%). Postoperative bleeding occurred in 2.1% of patients and return to the operating room in 7.5%. The readmission rate was 5.3%. Medical complications included all infectious complications (3.7%), sepsis (0.4%), all venous thromboembolism events (VTE) (0.5%), UTI

Table 3 Intraoperative characteristics

$N = 23,836$	Number	%
Wound class		
Clean	23,542	98.8
Clean/contaminated	292	1.2
ASA class		
1	1804	7.6
2	16,309	68.4
3	5643	23.7
4	78	0.3
Mean operative time (min) (SD)	236.0 (130.4)	
Probability of mortality (SD)	− 2.6 (15.9)	
Probability of morbidity (SD)	− 2.6 (16.0)	

SD standard deviation

(0.2%), and pneumonia (0.1%). Mean LOS for all cohorts was about 1.9 days.

Postoperative complications across reconstructive modalities are listed in Table 7. The pedicled flap group had slightly higher superficial SSIs (4.5%, $p < 0.01$, adjusted = 3.2%). Organ space infection was higher in the implant group (0.9%, $p < 0.01$, adjusted = 0.9%) and wound dehiscence was higher in the free flap group (1.4%, $p < 0.01$, adjusted = 1.2%). Pneumonia was also slightly higher in the free flap group (0.5%, $p < 0.01$, adjusted = 0.5%). Pulmonary embolism (PE) was slightly more frequent in the pedicled flap group (0.9%, $p < 0.01$, adjusted = 0.9%). The free flap group showed higher postoperative bleeding events or transfusion events (13.5%, $p < 0.01$, adjusted = 12.3%). Overall infection rates were higher in the pedicled flap group (6.6%, $p < 0.01$, adjus-

Table 4 Preoperative characteristics of each type of breast reconstruction

	Free flap			Implant			Pedicled flap			*p*-value*
	$N = 1924$			$N = 20,909$			$N = 1001$			
	Number	%	% (a)	Number	%	% (a)	Number	%	% (a)	
Average age (SD)	51.6 (9.0)		53.1 (9.5)	51.6 (10.8)		53.4 (9.4)	54.4 (9.6)		53.1 (9.3)	< 0.01
BMI (SD)	29.3 (5.8)		29.2 (6.3)	27.3 (6.4)		29.4 (6.1)	29.5 (6.4)		29.1 (5.9)	< 0.01
Race										< 0.01
Asian	89	4.6	4.1	936	4.5	4.1	40	4.0	5.0	
Black	281	14.6	14.0	1675	8.0	16.0	143	14.3	15.3	
White	1366	71.0	72.7	16,271	77.8	71.2	705	70.4	72.5	
Other	188	9.8	9.2	2027	9.7	8.7	113	11.3	7.2	
Ethnicity										< 0.01
Hispanic	148	7.7	7.1	1257	6.0	7.4	66	6.6	7.8	
Non-Hispanic	1579	82.1	86.3	18,088	86.5	85.9	838	83.7	85.8	
Unknown	197	10.2	6.6	1565	7.5	6.7	97	9.7	6.5	
Diabetes	100	5.2	5.7	1103	5.3	6.7	73	7.3	6.3	< 0.01
Smoking	178	9.3	10.1	2425	11.6	10.2	112	11.2	9.7	< 0.01
Malignant cancer	1490	77.4	79.3	16,747	80.1	79.3	789	78.8	78.7	0.02
Dyspnea	22	1.1	1.8	463	2.2	2.2	37	3.7	1.5	< 0.01
Functional status										< 0.01
Independent	1889	98.2	99.5	20,828	99.6	99.4	996	99.5	99.6	
Non-independent/unknown	35	1.8	0.5	81	0.4	0.6	5	0.5	0.4	
History of COPD	9	0.5	0.9	171	0.8	0.7	15	1.5	0.4	0.01
Disseminated cancer	21	1.1	1.8	254	1.2	1.6	23	2.3	1.4	< 0.01
Active wound infection	6	0.3	0.5	33	0.2	0.6	15	1.5	0.5	< 0.01
Active steroid use	34	1.8	1.5	399	1.9	1.7	22	2.2	1.5	0.72
Bleeding disorder	9	0.5	0.4	137	0.7	0.6	4	0.4	0.6	0.4

a adjusted value, *SD* standard deviation

**p*-value is before adjustment

Table 5 Intraoperative characteristics associated with each type of breast reconstruction

	Free flap			Implant			Pedicled flap			*p*-value*
	N = 1924			*N* = 20,909			*N* = 1001			
	Number	%	% (a)	Number	%	% (a)	Number	%	% (a)	
Wound class										0.67
Clean	1904	99.0	98.6	20,651	98.8	98.6	987	98.6	99.2	
Clean/contaminated	20	1.0	1.4	258	1.2	1.4	14	1.4	0.8	
ASA class										< 0.01
1	93	4.8	5.5	1659	7.9	5.2	52	5.2	5.1	
2	1245	64.7	69.8	14,400	68.9	68.1	664	66.3	68.7	
3	581	30.2	24.4	4782	22.9	26.4	280	28.0	25.9	
4	5	0.3	0.3	68	0.3	0.3	5	0.5	0.4	
Mean operative time (min) (SD)	506.2 (183.0)		507.8 (193.2)	206.5 (85.6)		215.3 (95.7)	334.6 (149.9)		352.3 (150.0)	< 0.01
Probability of mortality (SD)	− 3.2 (17.6)		− 7.7 (26.4)	− 2.4 (15.2)		− 7.1 (25.5)	− 6.4 (24.4)		− 6.3 (24.1)	< 0.01
Probability of morbidity (SD)	− 3.2 (17.6)		− 7.6 (26.5)	− 2.4 (15.2)		− 7.0 (25.5)	− 6.4 (24.4)		− 6.2 (24.1)	< 0.01

a adjusted value, *SD* standard deviation

**p*-value is before adjustment

Table 6 Total postoperative complications

N = 23,834	Number	%
Superficial surgical site infection	446	1.9
Deep surgical site infection	231	1.0
Wound dehiscence	189	0.8
Organ space infection	198	0.8
Pneumonia	24	0.1
Unplanned reintubation	10	< 0.1
Pulmonary embolism (PE)	61	0.3
Failure to wean off ventilation > 48 h	8	< 0.1
Renal insufficiency	5	< 0.1
Urinary tract infections (UTI)	54	0.2
Cerebrovascular accident (CVA)	5	< 0.1
Cardiac arrest	4	< 0.1
Myocardial infarction (MI)	4	< 0.1
Postoperative bleeding/transfusion	505	2.1
Deep vein thrombosis (DVT)	62	0.3
Sepsis	92	0.4
Septic shock	7	< 0.1
Any venous thromboembolism (VTE)	112	0.5
Any cardiac event	12	0.1
Any infection	878	3.7
Return to OR within 30 days	1799	7.5
Readmission within 30 days	1235	5.3
Mean length of stay (LOS) (d) (SD)	1.93 (3.3)	

d days, *SD* standard deviation

ted = 5.2%). Return to operating room events were higher in the free flap group (13.3%, $p < 0.01$, adjusted = 12.0%), while readmission rates were higher in the pedicled flap group (7.9%, $p < 0.01$, adjusted = 7.2%).

Outcome analysis

Table 8 represents the propensity score overlap weight-adjusted analysis of outcomes. The implant group demonstrated significantly less postoperative pneumonia than the free flap group ($p < 0.01$, CI 0.02–0.36) or the pedicled flap group ($p = 0.02$). PE was also less common in the implant group than in the free flap group ($p = 0.01$, CI 0.07–0.74) or the pedicled flap group ($p < 0.01$). UTI, postoperative bleeding, septic shock, VTE, and return to the operating room were also lower in the implant group compared to the free flap group. VTE, sepsis, postoperative bleeding, pneumonia, unplanned reintubation, and superficial SSIs were higher in the pedicled flap group compared to the implant group.

Length of stay

Gamma GLM was used for analysis of LOS, with the free flap group as the reference level. The average LOS was highest among the free flap group at 4.5 days ($p < 0.01$, adjusted = 4.6 days) followed by the pedicled flap group at 3.8 days ($p < 0.01$, adjusted = 3.8 days). The implant group demonstrated the lowest LOS at 1.6 days ($p < 0.01$,

Table 7 Postoperative complications associated with each type of breast reconstruction

	Free flap			Implant			Pedicled flap			*p*-value*
	N = 1924			*N* = 20,909			*N* = 1001			
	Number	%	% (a)	Number	%	% (a)	Number	Percent	% (a)	
Superficial surgical site infection	52	2.7	2.3	349	1.7	2.0	45	4.5	3.2	< 0.01
Deep surgical site infection	26	1.4	1.3	191	0.9	1.2	14	1.4	1.4	0.6
Wound dehiscence	27	1.4	1.2	152	0.7	0.8	10	1.0	0.8	< 0.01
Organ space infection	5	0.3	0.3	187	0.9	0.	6	0.6	0.5	0.01
Pneumonia	9	0.5	0.5	14	0.1	0.0	1	0.1	0.2	< 0.01
Unplanned reintubation	5	0.3	0.3	4	< 0.1	0.0	1	0.1	0.2	< 0.01
Pulmonary embolism (PE)	11	0.6	0.8	41	0.2	0.2	9	0.9	0.9	< 0.01
Failure to wean off ventilation > 48 h	5	0.3	0.1	3	< 0.1	0.0	0	0.0	0.0	< 0.01
Renal insufficiency	2	0.1	0.2	3	< 0.1	0.0	0	0.0	0.0	0.03
Urinary tract infections (UTI)	12	0.6	0.8	35	0.2	0.2	7	0.7	0.5	< 0.01
Cerebrovascular accident (CVA)	1	0.1	0.0	1	< 0.1	0.0	3	0.3	0.0	< 0.01
Cardiac arrest	2	0.1	0.1	2	< 0.1	0.0	0	0.0	0.0	0.01
Myocardial infarction (MI)	2	0.1	0.1	1	< 0.1	0.0	1	0.1	0.0	< 0.01
Postoperative bleeding/transfusion	259	13.5	12.3	154	0.7	1.4	92	9.2	8.8	< 0.01
Deep vein thrombosis (DVT)	18	0.9	0.5	37	0.2	0.2	7	0.7	0.6	< 0.01
Sepsis	14	0.7	0.8	67	0.3	0.4	11	1.1	0.9	< 0.01
Septic shock	2	0.1	0.1	4	< 0.1	0.0	1	0.1	0.0	0.05
Any venous thromboembolism (VTE)	27	1.4	1.2	73	0.3	0.4	12	1.2	1.2	< 0.01
Any cardiac event	4	0.2	0.2	4	< 0.1	0.0	4	0.4	0.3	< 0.01
Any infection	85	4.4	4.1	727	3.5	4.2	66	6.6	5.2	< 0.01
Return to OR within 30 days	256	13.3	12.0	1455	7.0	7.7	88	8.8	9.0	< 0.01
Readmission within 30 days	124	6.5	7.4	1033	5.0	6.0	78	7.9	7.2	< 0.01
Mean length of stay (LOS) (d) (SD)	4.5 (3.2)		4.6 (3.6)	1.6 (3.2)		1.8 (3.3)	3.8 (3.2)		3.8 (3.3)	< 0.01

a adjusted value, *d* days, *SD* standard deviation

**p*-value is before adjustment

adjusted = 1.8 days)). LOS of implant was 40% of the free flap group, while LOS of the pedicled flap was 84% of the free flap group.

Discussion

This study explores 30-day outcomes of different reconstructive modalities for patients with breast cancer using the ACS-NSQIP dataset and identifies encounters for implant, free flap, and pedicled flap-based reconstruction. While prior studies compared implant-based reconstruction with autologous reconstruction, this study further analyzes both techniques of autologous breast reconstruction—free flap and pedicled flap-based reconstruction—separately.

The majority of patients in this study (88%) underwent implant-based reconstruction, consistent with the current trend of increasing rates of implant-based reconstruction over autologous reconstruction [5]. Of the autologous group, most patients underwent free flap reconstruction (8.1%) compared to pedicled flap reconstruction (4.2%). Current literature suggests the increased morbidity of autologous breast reconstruction, such as donor site complications and prolonged operative times, may contribute to the increasing trend in implant-based reconstruction [5]. For example, while the TRAM flap may be relatively easy to perform, it sacrifices the entire rectus muscle, which increases the risk of abdominal hernias and bulges [6]. Additionally, it was previously reported that free flap-based reconstruction is associated with higher rates of wound-related complications [11, 14, 15]. Our study demonstrated a 3.7% total rate of wound-related complications among all reconstructive modalities. On further analysis, the pedicled flap demonstrated the highest rate of superficial SSIs (4.5%, adjusted = 3.2%). The implant-based group demonstrated the lowest rate of superficial SSIs (1.7%, adjusted = 2.0%), significantly lower than the pedicled flap group. There was no significant difference in the rate of

Table 8 Weighted logistic regression analysis

Variable	Free flap OR = 1	Implant		Implant vs free flap *p*-value	Pedicled flap		Pedicled flap vs free flap *p*-value	Pedicled flap vs implant *p*-value
		OR	CI		OR	CI		
Superficial surgical site infection		0.90	0.54–1.50	0.67	1.45	0.78–2.71	0.24	0.03
Deep surgical site infection		0.94	0.45–1.94	0.87	1.09	0.52–2.26	0.82	0.69
Organ space infection		2.81	0.12–65.44	0.52	1.34	0.03–56.91	0.88	0.46
Wound dehiscence		0.61	0.35–1.08	0.09	0.65	0.21–2.06	0.47	0.91
Pneumonia		0.09	0.02–0.36	0.00	0.38	0.12–1.26	0.11	0.02
Unplanned reintubation		0.04	0.002–1.15	0.06	0.59	0.03–12.92	0.74	0.01
Pulmonary embolism (PE)		0.23	0.07–0.74	0.01	1.14	0.35–3.68	0.83	0.00
Failure to wean off ventilation > 48 h		0.06	0.002–0.95	0.05	n/a	n/a	n/a	n/a
Renal insufficiency		0.06	0.008–1.29	0.08	n/a	n/a	n/a	n/a
Urinary tract infections (UTI)		0.21	0.07–0.58	0.00	0.58	0.14–2.35	0.45	0.08
Cardiac arrest		0.06	0.00–15.41	0.27	n/a	n/a	n/a	n/a
Postoperative bleeding/transfusion		0.10	0.06–0.15	0.00	0.69	0.49–0.96	0.03	0.00
Deep vein thrombosis (DVT)		0.51	0.16–1.67	0.27	1.20	0.14–10.31	0.87	0.39
Sepsis		0.44	0.16–1.22	0.11	1.09	0.30–3.95	0.90	0.05
Any venous thromboembolism (VTE)		0.33	0.14–0.79	0.01	0.97	0.37–2.56	0.95	0.04
Any cardiac event		0.07	0.00–4.78	0.21	1.58	0.05–51.92	0.80	0.01
Any infection		1.02	0.73–1.42	0.93	1.26	0.85–1.87	0.24	0.24
Return to OR within 30 days		0.62	0.50–0.75	0.00	0.73	0.52–1.02	0.06	0.30
Readmission within 30 days		0.81	0.61–1.08	0.14	0.97	0.66–1.44	0.90	0.16
Length of stay (LOS)[a]		0.40[b]	0.35–0.37	< 0.01	0.84[b]	0.79–0.91	< 0.01	

[a]Gamma GLM used for analysis

[b]Relative change value

wound-related complications in the free flap group as compared to the implant or pedicled flap groups. However, this study does not delineate immediate versus delayed reconstruction, and prior studies have demonstrated that immediate reconstruction has been associated higher wound-related complications [15]. Moreover, prior studies have suggested that the LD flap is more often used for delayed reconstruction, particularly for patients who underwent radiation or as a salvage procedure for those who failed prior reconstruction [16].

When considering reconstructive modalities, factors such as total operative time and length of stay should be considered. Prolonged operative times have been reported as predictors of morbidity following breast reconstruction [2, 11]. This study demonstrates that free flap reconstruction and pedicled flap reconstruction take approximately 294 min and 136 min longer than implant-based reconstruction, respectively. This is expected given the nature of autologous breast reconstruction procedures. Longer operative times certainly may contribute to the increase in morbidity associated with autologous reconstruction. While rates of major surgical and medical complications remain exceptionally low among all three modalities, this study shows that the implant group had lower rates of medical complications such as pneumonia, VTE, UTI, and postoperative bleeding. While our study does not directly evaluate the association between longer operative times and morbidity, it does reinforce previous results in the literature that prolonged operative times are related to increased morbidity. Increased morbidity seen with free flap and pedicled flap-based reconstruction may also be reflected in increased LOS associated with autologous reconstruction. The free flap and pedicle flap groups, on average, stayed 2.88 and 2.2 days longer, respectively, than the implant group.

Other considerations to be taken into account when evaluating morbidity of reconstruction include patient factors and comorbid conditions. Patient characteristics

such as obesity, diabetes, smoking, and higher ASA class may contribute to complications and to increased morbidity. A higher incidence of surgical complications in the obese is well documented [17]. Additionally, multiple studies have reported that obese patients undergoing both autologous and implant-based reconstruction have increased complication rates [2, 14, 18, 19]. ASA $\geq$ 3 was also found to be associated with higher rates of complications among all reconstructive modalities [14].

There has been a clear increase in the frequency and likelihood of performing implant-based reconstruction. Between 1998 and 2008, there was a 2.26-fold increase in the likelihood for implant reconstruction over other options [5]. Implant-based reconstruction likely gained more widespread acceptance after approval for cosmetic breast reconstruction in 2006 by the US Food and Drug Administration [5]. Current data suggest that Medicare patients are more likely than private insurance carriers to undergo reconstruction using implant than autologous tissue, and professional reimbursement may indirectly incentivize implant reconstruction. Moreover, there is surgeon compensation favoring implants for patients with private insurances which may be an additional factor contributing to a rise in implant use [5]. Additionally, implant reconstruction was previously avoided in patients undergoing adjuvant radiation therapy. However, current literature demonstrates acceptable outcomes with implants in the setting of radiation therapy [19, 20]. With current concerns over ALCL and BII, it is unclear whether there will be a change in these trends. However, the outcomes of breast reconstruction remain important across all reconstructive modalities.

There are some limitations to this study. While prior studies have demonstrated that flap-based reconstruction is associated with increased complications, it is important to note that national databases may not completely capture implant reconstruction complications such as wound dehiscence and infections [21, 22]. Additionally, this study also does not evaluate immediate versus delayed reconstruction. Outcomes may vary between these two groups. While the large sample size of this study minimizes selection bias, the effect of radiation exposure on postoperative outcomes was not available for adjustment. Radiation therapy has been associated with an increased rate of complications among all reconstructive modalities. These rates are higher in implant-based than autologous reconstruction as the rates of implant extrusion and capsular contracture are increased in the irradiated breast [23, 24]. For such reasons, autologous breast reconstruction is generally preferred in the irradiated breast.

Additionally, while the study is generalizable since the ASC-NSQIP database provides data from over 600 hospitals, it may not represent a complete cross section average of US hospitals as many non-tertiary centers do not report into this database. It is possible that smaller institutions may be less equipped to perform free flap breast reconstruction and, therefore, may perform more pedicled reconstruction. However, this is difficult to determine since the national databases do not differentiate between the types of autologous reconstruction [5].

A final limitation is that the ACS-NSQIP database includes only 30-day outcomes and does not capture more long-term data. While implant reconstruction was shown to have a more favorable short-term adverse effect profile in this study, this effect has not been demonstrated in long-term follow-up in prior studies. No significant differences in complication rates were seen at 2 years of follow-up between implant and autologous reconstruction techniques in a 2002 study by Alderman et al. [24]. Fischer et al. suggested that free flap reconstruction resulted in stable reconstruction significantly faster, resulted in fewer procedure, and less clinic visits than with implant-based reconstruction [14]. In one meta-analysis, autologous breast reconstruction was associated with less reconstructive failures and SSI than implant reconstruction at a mean follow-up period between 6 and 60 months [25]. Moreover, patients reported improved long-term satisfaction with all reconstructive techniques. However, patients reported greater satisfaction with their breasts and their psychosocial and sexual well-being with autologous reconstruction than with implants at 1 and 2 years in prior studies [26, 27]. Further studies should be performed to evaluate long-term outcomes across all reconstructive modalities.

Conclusion

Short-term analysis of the ACS-NSQIP data demonstrates that implant-based reconstruction has lower postoperative complication rates and shorter LOS than free flap and pedicled flap-based reconstruction. Factors contributing to the increased short-term complications seen with autologous reconstruction may be related to longer operative times and donor site morbidity associated with the procedures. While short-term complications among implant-based reconstruction are lower compared to autologous reconstruction, the overall complication rates among all reconstructive modalities remains acceptably low with well-documented long-term psychosocial and functional benefits. Patients should be informed of all surgical

options, and the appropriate procedure should be tailored to patients individually.

Compliance with ethical standards

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

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