Enhanced Recovery Pathway in Microvascular Autologous Tissue-Based Breast Reconstruction: Should It Become the Standard of Care?

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Background: Enhanced recovery pathway programs have demonstrated improved perioperative care and shorter length of hospital stay in several surgical disciplines. The purpose of this study was to compare outcomes of patients undergoing autologous tissue–based breast reconstruction before and after the implementation of an enhanced recovery pathway program.

Methods: The authors retrospectively reviewed consecutive patients who underwent autologous tissue–based breast reconstruction performed by two surgeons before and after the implementation of the enhanced recovery pathway at a university center over a 3-year period. Patient demographics, perioperative data, and 45-day postoperative outcomes were compared between the traditional standard of care (pre–enhanced recovery pathway) and enhanced recovery pathway patients. Multivariate logistic regression was performed to identify risk factors for length of hospital stay. Cost analysis was performed.

Results: Between April of 2014 and January of 2017, 100 consecutive women were identified, with 50 women in each group. Both groups had similar demographics, comorbidities, and reconstruction types. Postoperatively, the enhanced recovery pathway cohort used significantly less opiate and more acetaminophen compared with the traditional standard of care cohort. Median length of stay was shorter in the enhanced recovery pathway cohort, which resulted in an extrapolated $279,258 savings from freeing up inpatient beds and increase in overall contribution margins of $189,342. Participation in an enhanced recovery pathway program and lower total morphine-equivalent use were independent predictors for decreased length of hospital stay. Overall 45-day major complication rates, partial flap loss rates, emergency room visits, hospital readmissions, and unplanned reoperations were similar between the two groups.

Conclusion: Enhanced recovery pathway program implementation should be considered as the standard approach for perioperative care in autologous tissue–based breast reconstruction because it does not affect morbidity and is associated with accelerated recovery with reduced postoperative opiate use and decreased length of hospital stay, leading to downstream health care cost savings. (*Plast. Reconstr. Surg.* 141: 841, 2018.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

There has been a steady growth in breast reconstructive procedures, with a 39 percent increase in procedural volume since 2000.[1] Although microvascular autologous breast reconstruction accounts for a small overall portion of these procedures, it has remained steady over the years, which implies that the actual number of procedures continues to increase. Excellent perioperative care for this patient population is essential for expediting recovery and optimizing resource use. Implementation of enhanced recovery pathways has been proposed as one way of accomplishing these goals; however, this has not been universally adopted.[2–5]

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Received for publication July 23, 2017; accepted October 20, 2017.
Presented at the 2018 American Society of Reconstructive Microsurgery Annual Meeting, in Phoenix, Arizona, January 13 through 16, 2018.

DOI: 10.1097/PRS.0000000000004197

Disclosure: *None of the authors has a financial interest in any of the products, devices or drugs mentioned in this article.*

Enhanced recovery pathways are collective standardized evidence-based preoperative, intraoperative, and postoperative multidisciplinary protocols involving collaboration of several specialties, including surgeons, anesthesiologists, nurses, dieticians, pharmacists, and home care specialists.[6] These programs challenge and reevaluate traditional practices to improve quality of care. Their success is attributed to the attenuation of the neurohormonal stress response to surgery, thereby limiting physiologic stress and consequently diminishing complications and organ dysfunction.[6] The benefits of enhanced recovery pathway programs have been well established in several surgical disciplines, including general, colorectal, bariatric, neurologic, orthopedic, and gynecologic surgery.[6–16] Although these programs have not yet been widely implemented in plastic surgery, emphasis on cost-effective quality initiatives has driven several institutions around the country to consider this quality measure. However, current literature on an enhanced recovery pathway for microvascular breast reconstruction is scarce. Some of the limitations of previous studies include small number of subjects, inequalities between the study groups, and use of expensive medications (e.g., liposomal bupivacaine) as part of the multimodal analgesic regimens.[2–5] Continued critical evaluation of enhanced recovery pathway programs in plastic surgery is necessary, not only to demonstrate that the previously observed positive impact on length of hospital stay and other patient outcomes is replicable, but also to further optimize existing enhanced recovery pathway protocols. This study compared perioperative outcomes of patients who underwent microvascular breast reconstruction before and after the implementation of our institution's enhanced recovery pathway, examined risk factors for length of hospital stay, and performed a cost analysis.

PATIENTS AND METHODS

Study Design and Data Collection

This is a single-center retrospective cohort study comparing perioperative outcomes following microvascular breast reconstruction, immediate or delayed, among consecutive patients who were managed with the traditional standard of care (pre–enhanced recovery pathway group) and after implementation of an enhanced recovery pathway program. The enhanced recovery pathway for women undergoing microvascular breast reconstruction was designed through collaboration of health care professionals from plastic surgery, anesthesia, nursing, and pharmacy at our institution (Table 1). After implementation in August of 2015, all patients undergoing microvascular breast reconstruction performed by the two surgeons participating in the study were subjected to the enhanced recovery pathway. Exclusion criteria included allergies or adverse reactions to any of the medications used, pregnancy, prisoners, and age younger than 18 years. The study was approved by the institutional review board (study number 160806).

Patient demographics and clinical characteristics, intraoperative data, postoperative outcomes, and complications were recorded. Data were gathered by two unblinded investigators and entered into a Microsoft Excel (Microsoft Corp., Redmond, Wash.) spreadsheet using prepared deidentified codes. Unresolved data points or entry errors were reviewed and clarified by the principal investigators.

Microvascular Autologous Tissue–Based Breast Reconstruction Standard-of-Care Pathway (Pre–Enhanced Recovery Pathway)

In this pathway, patients were kept nil by mouth for 6 hours before surgery and continued until the morning of postoperative day 1. The patient's diet was then slowly advanced as tolerated over the following 24 hours. Maintenance intravenous fluids were used until the patient tolerated an unrestricted diet. Analgesic regimens, intraoperative management, and postoperative nausea and vomiting prophylaxis were not standardized, but were administered at the discretion of the attending anesthesiologists. No regional nerve blocks, such as transversus abdominis plane blocks, were performed. Prophylactic enoxaparin was started the evening of surgery, and 81-mg daily aspirin was started the following morning for 30 days. Antibiotic prophylaxis was similar to that in the enhanced recovery pathway. Postoperatively, the patient's hospital admission and flap monitoring were similar to those in the enhanced recovery pathway. Pain management was not standardized and included intravenous opiate analgesics or patient-controlled analgesia pump until at least postoperative day 1 when the patient's diet was advanced. Once the patient was tolerating a diet, acetaminophen and oral narcotics were used on an as-needed basis, with intravenous narcotics for breakthrough pain. Perioperative nausea and vomiting prophylaxis was used for symptomatic relief. Early ambulation was encouraged but not expected. Foley catheters were removed on

Table 1. Enhanced Recovery Pathway Program

Intervention Category	Intervention		
	Preoperative Holding Area	**Intraoperative**	**Postoperative**
Diet	Fasting: Solid food: 6 hr before surgery Clear liquids: 2 hr before surgery	Nil by mouth	Clear liquids immediately and unrestricted diet on POD 1 at 7 AM
Multimodal analgesia	1 hr before surgery: Acetaminophen 1000 mg PO with sip of water‡ Gabapentin 600 mg PO with sip of water¶ Celecoxib 400 mg PO with sip of water†† Bilateral TAP blocks by anesthesia team§§	Lidocaine 1.5 mg/kg bolus with induction, then 2 mg/min infusion until end of case* Ketamine 0.5 mg/kg bolus with induction, then 5 mg/min infusion until completion of vessel anastomosis§ IV methadone 10–20 mg with induction# Avoid opiate use Ketorolac 15–30 mg IV at the end of the case	Continue lidocaine infusion for first 24 hr after termination of anesthesia† Acetaminophen 1000 mg PO every 8 hr‖ Gabapentin 300–900 mg PO every 8 hr** Ketorolac 15–30 mg IV every 6 hr; switch to Celecoxib 200 mg PO every 12 hr when tolerating regular diet‡‡ Oxycodone 5–10 mg PO every 3 hr as needed for pain score >4/10 Hydromorphone 0.5 mg IV as needed for breakthrough pain‖‖
Antiemetics	Scopolamine patch¶¶ if >2 risk factors for PONV	Prophylactic use of at least 2 agents from different classes or more if >2 risk factors: Propofol drip or full TIVA for high risk PONV Dexamethasone 8 mg IV## Ondansetron 4 mg IV Scopolamine patch¶¶	Ondansetron 4 mg IV/PO every 6 hr as needed Haloperidol 0.5–1 mg IV as needed Promethazine 6.25–12.5 mg IV/PO as needed Scopolamine patch up to 72 hr postoperatively
Fluid administration	None	Goal-directed to achieve euvolemia with zero balance and maintain urine output higher than 0.5 ml/kg/hr***	Maintenance fluids until POD 1 at 7 AM
VTE prophylaxis	Sequential compression stockings	Sequential compression stockings Heparin 5000 IU SC	Sequential compression stockings Prophylactic dose enoxaparin to start at 10 PM the night of surgery
Antibiotic prophylaxis	30–60 min before incision: Cefazolin 1–3 g IV or clindamycin 600 mg IV if allergic to cefazolin	Readminister according to the specific antibiotic recommendations	Continue antibiotics for 24 hr

POD, postoperative day; PO, oral; IV, intravenous; TAP, transverse abdominis plane; PONV, postoperative nausea and vomiting; TIVA, total intravenous anesthesia; TAP, transversus abdominis plane; VTE, venous thromboembolism.
*Contraindications: unstable heart disease, recent myocardial infarction, heart block, heart failure, electrolyte disturbances, seizure disorder, and current antiarrhythmics such as amiodarone or sotalol.
†Dose is 1 mg/min IV if patient weighs <70 kg, 1.5 mg/min IV if patient weighs 70–100 kg, and 2 mg/min IV if patient weighs >100 kg.
‡Reduce dose to 650 mg if weight is less than 70 kg or patient is older than 65 yr. Do not use if history of liver disease.
§Consider reducing dose to 0.25 mg/kg or not using bolus in patients older than 65 yr.
‖Decrease dose to 650 mg every 6 to 8 hr if patient weighs <70 kg.
¶Reduce dose to 300 mg in patients older than 65 yr. Consider not giving or reducing to 100 mg in patients older than 75 yr. Consider reducing the dose in patients with obstructive sleep apnea.
#For patients with known preoperative chronic opiate use. May consider higher doses based on home opioid regimen. If opioids are required, consider methadone on emergence or in recovery room (5 mg IV boluses) every 5 to 10 minutes for a total of 20 mg before using other opioids.
**Use lower dose for patients older than 65 yr or if patient is having significant sedation/dizziness.
††Reduce dose to 200 mg if moderate hepatic impairment. Do not use if severe hepatic or renal impairment, or history of gastrointestinal bleeding.
‡‡Use ketorolac 15–30 mg IV every 6 hr for 3 days if unable to take oral celecoxib.
§§Contains bupivacaine 0.25% and dexamethasone 4 mg. Can also add clonidine to extend block duration. If unable to perform in preoperative holding area, can be completed in the operating room immediately after induction or postoperatively. If TAP blocks were not feasible, bilateral paravertebral blocks at T9–T10 level were considered.
‖‖Consider patient-controlled analgesia if pain is refractory to all other pain medications. If pain continues to be uncontrolled, consider local anesthetic cream or postoperative local anesthesia.
¶¶Do not use in patients older than 65 yr, and if there is concern for oversedation or anticholinergic use.
##If not in TAP blocks.
***Lactated Ringer or plasmalyte were the preferred IV fluids administered. Normal saline was not used. Vasopressors were used only if the mean arterial pressure dropped 20% below the patient's baseline and it was not volume responsive. The preferred agents were ephedrine and dobutamine. Phenylephrine was avoided, if possible.

postoperative day 1 or 2 depending on the progress of the patient. Discharge to home was at the discretion of the surgeon.

Microvascular Autologous Tissue–Based Breast Reconstruction Enhanced Recovery Pathway

The enhanced recovery pathway protocol was developed through a literature review followed by a multidisciplinary consensus (Table 1). Preadmission education and counseling were provided to all patients elected to proceed with microvascular autologous reconstruction and met the study inclusion criteria. Unlike the pre–enhanced recovery pathway cohort, bilateral transversus abdominis plane blocks (containing bupivacaine 0.25%, dexamethasone 4 mg, and possible clonidine to extend block duration) were performed by the anesthesia team, either in the preoperative holding area or in the operating room immediately after induction of anesthesia, as part of the multimodal analgesic regimen. Postoperatively, pain control was managed by the Anesthesia Perioperative Consult Service. Patients were encouraged to be up and walking the evening of surgery. Foley catheters were removed at 6 AM on the first postoperative day. Discharge planning was begun the day after surgery, along with education on drain management at home. Discharge criteria included sufficient oral intake without nausea and vomiting, adequate ambulation, good urine output, and satisfactory pain control with an oral analgesic regimen.

Surgical Technique

All operations were performed by two participating attending microvascular surgeons. The surgical technique was similar for all the flaps, without a learning curve for this procedure in either cohort. Standard flap harvest techniques were used. The internal mammary vessels were used as recipient vessels in all flaps.

Outcomes

The primary outcome was length of hospital stay, which was defined as the number of nights the patient spent in the hospital from admission until discharge. Postoperative day 0 was defined as the day of surgery.

Secondary endpoints included postoperative inpatient analgesic and antiemetic requirements, and minor and major complications within 45 days from the index operation. Analgesic requirements were divided into acetaminophen and opiate use. Opiate use was calculated by converting all forms of opioid intake, parenteral and oral, into oral morphine equivalents.[17] The need for a patient-controlled analgesia pump and duration of use was also recorded. Major complications were defined as complications that were related directly to the index admission and required hospital readmission or reoperation within 45 days from the index operation. Partial or complete flap loss was also included in the major complications. Partial flap loss was defined as less than 40 percent of the total flap volume secondary to vascular compromise of an area of the flap. Complete flap loss was defined as irreversible vascular compromise of the flap because of microvascular arterial or venous thrombosis requiring explantation. All other complications were considered as minor.

Our institution uses a cost accounting system that allows assignment of fixed and variable expenses at the charge level for both professional and technical services. For example, the system can assign nursing salary to inpatient room and board charges, actual medical supply costs to the individual charge items, and on the professional side the actual physician salary to Current Procedural Terminology codes and services. This allows for an accurate assessment of the cost of specific services for the organization. To understand the impact of the enhanced recovery pathway on autologous breast reconstruction, we examined all financial information (e.g., charges, payments, fixed and variable costs) associated with each study patient before and after the implementation of the program.

Statistical Analysis

Patient characteristics, operative details, and postoperative outcomes were compared between pre–enhanced recovery pathway and enhanced recovery pathway groups. Descriptive statistics were reported as mean ± SD or median with range, or as the number of patients or flaps with percentages. Categorical variables were compared using Pearson chi-square and Fisher's exact tests. Continuous variables were compared with the two-tailed t test. All group comparisons were unpaired and p values were two-tailed, with statistical significance set at $p < 0.05$. IBM SPSS Version 23.0 (IBM Corp., Armonk, N.Y.) was used for univariate analyses.

Multivariate analysis was performed to further analyze factors contributing to length of hospital stay using statistical software R version 3.3.0. Length of hospital stay was described as a median with interquartile ranges and compared between

pre–enhanced recovery pathway and enhanced recovery pathway groups using the Wilcoxon rank sum test. Because the distribution of length of hospital stay was highly skewed, a multivariable ordinal logistic regression was used to evaluate the difference between the two groups with adjustment for age, body mass index, bilateral reconstruction, operative time, total intraoperative fluid amount, total oral morphine equivalent use, and total acetaminophen use. Variables were examined for their distribution and transformations were made when needed. Results were presented as interquartile-range odds ratios for continuous predictors and simple odds ratios for categorical predictors.

RESULTS

Between April of 2014 and January of 2017, a cohort of 100 consecutive women, who underwent a total of 145 microsurgical autologous breast reconstructions (45 bilateral procedures), were identified; 50 women were managed with the pre–enhanced recovery pathway and 50 women were managed with the enhanced recovery pathway. Baseline patient demographics and clinical characteristics were not significantly different between the two groups (Table 2). There were no significant differences between the two groups with regard to surgical timing (immediate versus delayed), laterality, or type of reconstruction (Table 3).

Data related to the intraoperative course are listed in Table 4. Overall operative times were found to be higher in the pre–enhanced recovery pathway cohort. Unilateral reconstructions had a significantly longer operative time in the pre–enhanced recovery pathway cohort, but no difference was noted between the two groups for patients undergoing bilateral reconstructions. There were no differences between the two groups in terms of intraoperative transfusions, intraoperative vasopressor use, or the use of mesh for abdominal wall reinforcement. Reduction in intraoperative fluid administration was seen in the enhanced recovery pathway group.

A comparison of postoperative outcomes between the two groups is presented in Table 5. The enhanced recovery pathway cohort had a significantly shorter median length of hospital stay, and received less total oral morphine equivalents. The use of a patient-controlled analgesia pump was significantly less common for the enhanced recovery pathway group; however, when used, there was no difference in duration of use between groups. The enhanced recovery pathway group had significantly higher use of acetaminophen in the first 48 hours,

Table 2. Demographic and Clinical Characteristics

Characteristic	Patient Group		*p*
	Pre-ERP (%)	ERP (%)	
No. of patients	50	50	
Mean age at surgery ± SD, yr	51.0 ± 10.0	51.9 ± 8.9	0.36
Mean BMI ± SD, kg/m^2	28.8 ± 4.0	29.7 ± 5.5	0.62
Smoking history			0.51
Never	30 (60.0)	34 (68.0)	
Past user	19 (38.0)	14 (28.0)	
Current user	1 (2.0)	2 (4.0)	
Diabetes mellitus	2 (4.0)	6 (12.0)	0.27
Hormonal therapy			0.05
Never	21 (42.0)	20 (40.0)	
Prior use	1 (2.0)	8 (16.0)	
Current use	28 (56.0)	22 (44.0)	
Oral contraceptive pill	2 (4.0)	0 (0)	0.50
Immunosuppressive medication	1 (2.0)	2 (4.0)	1.00
Preoperative hypercoagulable state	0	0	—
History of chest wall irradiation	23 (46.0)	19 (38.0)	0.42
History of systemic chemotherapy	26 (52.0)	29 (58.0)	0.55
Chronic pain diagnosis	3 (6.0)	4 (8.0)	1.00
Fibromyalgia	3 (6.0)	4 (8.0)	1.00
Hypertension	14 (28.0)	18 (36.0)	0.39
Chronic kidney disease	0	0	—

ERP, enhanced recovery pathway; BMI, body mass index.

Table 3. Breast Reconstruction Data per Patient

Variable	Patient Group		*p*
	Pre-ERP (%)	ERP (%)	
No. of patients	50	50	
Reconstruction timing			0.11
Immediate	6 (12.0)	1 (2.0)	
Delayed	44 (88.0)	49 (98.0)	
Reconstruction laterality			0.84
Unilateral	27 (54.0)	28 (56.0)	
Bilateral	23 (46.0)	22 (44.0)	
Type of reconstruction			0.62
Unilateral DIEP flap	22 (44.0)	25 (50.0)	
Unilateral stacked DIEP flap	1 (2.0)	2 (4.0)	
Unilateral stacked DIEP flap with implant	0	1 (2.0)	
Unilateral free MS-TRAM flap	1 (2.0)	0	
Unilateral SIEA flap	1 (2.0)	0	
Unilateral PAP flap	1 (2.0)	0	
Bilateral DIEP flap	19 (38.0.)	17 (34.0)	
Bilateral DIEP flap and free MS-TRAM flap	3 (6.0)	5 (10.0)	
Bilateral DIEP flap and SIEA flap	1 (2.0)	0	
Bilateral free MS TRAM flap	1 (2.0)	0	

ERP, enhanced recovery pathway; DIEP, deep inferior epigastric artery perforator; MS, muscle-sparing; TRAM, transverse rectus abdominis myocutaneous; SIEA, superficial inferior epigastric artery; PAP, profunda artery perforator.

Table 4. Intraoperative Data

Variable	Patient Group		*p*
	Pre-ERP (%)	ERP (%)	
No. of patients	50	50	
Mean operative time ± SD, min*			
Total	464.1 ± 100.0	413.8 ± 107.1	0.02
Unilateral	418.0 ± 94.1	358.0 ± 89.8	0.02
Bilateral	518.2 ± 78.4	484.7 ± 83.4	0.17
Abdominal wall mesh use†	3 (6.0)	2 (4.0)	1.00
Mean total intraoperative intravenous fluids ± SD, liters	3.9 ± 1.2	3.2 ± 1.0	<0.01
Intraoperative transfusion	3 (6.0)	1 (2.0)	0.62
Intraoperative vasopressor use	16 (32.0)	18 (36.0)	0.67
Phenylephrine	16 (32.0)	14 (28.0)	0.66
Dobutamine	0 (0)	4 (8.0)	0.12

ERP, enhanced recovery pathway.
*Operative time is defined as skin incision to skin closure.
†Mesh used was polypropylene.

use equal to that of the pre–enhanced recovery pathway group on postoperative day 3, and less on subsequent days. In addition, the enhanced recovery pathway cohort used significantly less ondansetron during the overall hospitalization, and specifically on postoperative days 0, 1, and 5. Table 6 compares the two groups with regard to 45-day postoperative complications. There was no difference in frequency of minor or major complications, emergency room visits, hospital readmissions, or unplanned reoperations. However, there was a significant difference between the two groups in donor-site wound healing, with higher rates of delayed wound healing in the enhanced recovery pathway cohort. Of note, the majority of these cases were managed nonoperatively with local wound care in the outpatient setting, with complete resolution. Only three cases, two in the pre–enhanced recovery pathway and one in the enhanced recovery pathway cohort, required operative intervention.

Multivariate logistic regression analysis of risk factors for length of hospital stay is shown in Table 7. Participation in an enhanced recovery pathway program and lower total morphine equivalent use were independent predictors for decreased length of hospital stay.

Implementation of the enhanced recovery pathway decreased mean length of hospital stay by 1.7 days, resulting in a decrease of 108 inpatient days. This translated to a saving of $4400 per patient. Contribution margin is equivalent to the cost savings on a per-patient basis and driven by payer mix and the corresponding payer mix. For our study, we identified an extrapolated $279,258 savings from freeing up inpatient beds and increase in overall contribution margins of $189,342.

Table 5. Postoperative Outcomes

	Patient Group		*p*
	Pre-ERP (%)	ERP (%)	
No. of patients	50	50	
Mean total length of hospital stay ± SD, days	4.7 ± 2.3	3.0 ± 0.6	<0.01
Total length of hospital stay, days			<0.01
Median	4.0	3.0	
Range	3–17	2–5	
Use of PCA	50 (100)	3 (6.0)	<0.01
Mean PCA duration ± SD, hr	46.8 ± 16.0	40.8 ± 21.8	0.10
Oral morphine equivalent, mg			
Total			<0.01
Median	276.3	67.5	
Range	12.5–1015.0	0–432.5	
POD 0			<0.01
Median	28.75	7.50	
Range	0–291.0	0–88.0	
POD 1			<0.01
Median	91.3	26.3	
Range	5.0–546.0	0–100.0	
POD 2			<0.01
Median	70.0	22.5	
Range	0–365.0	0–90.0	
POD 3			<0.01
Median	40.0	7.5	
Range	0–210.0	0–145.0	
POD 4			<0.01
Median	20.0	0	
Range	0–70.0	0–97.5	
POD 5			<0.01
Median	0	0	
Range	0–90.0	0–60.0	
Total acetaminophen use, mg			
Total			<0.01
Median	5200	8000	
Range	0–14,000	0–16,000	
POD 0			<0.01
Median	325.0	1000	
Range	0–3000	0–2000	
POD 1			
Median	1000	3000	
Range	0–3650	0–5000	<0.01
POD 2			
Median	1300	3000	
Range	0–3900	1000–5000	<0.01
POD 3			
Median	1150	1000	
Range	0–3000	0–4000	0.25
POD 4			
Median	975	0	
Range	0–3000	0–3000	<0.01
POD 5			
Median	0	0	
Range	0–3000	0–1000	<0.01
Mean ondansetron ± SD, mg			
Total	5.92 ± 7.01	2.56 ± 5.28	0.01
POD 0	1.92 ± 2.83	0.80 ± 1.81	0.02
POD 1	1.36 ± 2.63	0.32 ± 1.36	0.02
POD 2	1.12 ± 2.14	0.56 ± 1.81	0.16
POD 3	0.88 ± 2.72	0.72 ± 2.38	0.76
POD 4	0.40 ± 1.46	0.08 ± 0.57	0.15
POD 5	0.24 ± 1.26	0.08 ± 0.57	<0.01

ERP, enhanced recovery pathway; PCA, patient-controlled analgesia; POD, postoperative day.

Table 6. Postoperative Complications at 45 Days per Patient

	Patient Group		
	Pre-ERP (%)	ERP (%)	*p*
No. of patients	50	50	
No. of complications			
None	23 (46.0)	20 (40.0)	0.55
One	17 (34.0)	20 (40.0)	0.53
Two	6 (12.0)	8 (16.0)	0.56
Three	3 (6.0)	2 (4.0)	1.00
Four	1 (2.0)	0	1.00
Minor complications	24 (48.0)	28 (56.0)	0.42
Major complications	8 (16.0)	3 (6.0)	0.20
Emergency room visits	4 (8.0)	5 (10.0)	1.00
Hospital readmissions	4 (8.0)	2 (4.0)	0.68
Unplanned reoperations, any	5 (10.0)	2 (4.0)	0.44
Breast recipient-site complications, any	32 (16.0)	9 (18.0)	0.11
Donor-site complications, any	18 (36.0)	25 (51.0)	0.13
Unplanned reoperations			
Deep SSI, recipient site	1 (2.0)	0	1.00
Deep SSI, donor site	0	0	—
Delayed wound healing, recipient site	0	0	—
Delayed wound healing, donor site	2 (4.0)	1 (2.0)	1.00
Hematoma, recipient site	0	0	—
Hematoma, donor site	1 (2.0)	0	1.00
Seroma, recipient site	0	0	—
Seroma, donor site	0	0	—
Flap vascular compromise	2 (4.0)	1 (2.0)	1.00
Breast recipient-site complications			
Superficial SSI requiring oral antibiotics	1 (2.0)	0	1.00
Superficial SSI requiring IV antibiotics	1 (2.0)	1 (2.0)	1.00
Deep SSI requiring oral antibiotics	0	0	—
Deep SSI requiring IV antibiotics	1 (2.0)	1 (2.0)	1.00
Wound dehiscence	0	0	—
Delayed wound healing	5 (10.0)	0	0.06
Fat necrosis	0	4 (8.0)	0.12
Hematoma managed nonoperatively	1 (2.0)	0	1.00
Hematoma requiring drainage in clinic	2 (4.0)	0	0.50
Seroma managed nonoperatively	0	0	—
Seroma requiring drainage in clinic	2 (4.0)	0	0.50
Flap vascular compromise, nonoperative	0	1 (2.0)	1.00
Flap loss, partial	3 (6.0)	0	0.24
Flap loss, total	0	0	—
Donor-site complications			
Superficial SSI requiring oral antibiotics	2 (4.0)	8 (16.0)	0.09
Superficial SSI requiring IV antibiotics	1 (2.0)	0	1.00
Deep SSI requiring oral antibiotics	1 (2.0)	0	1.00
Deep SSI requiring IV antibiotics	1 (2.0)	1 (2.0)	1.00
Wound dehiscence	0	0	—
Delayed wound healing	8 (16.0)	18 (36.0)	0.02
Fat necrosis	4 (8.0)	2 (4.0)	0.68
Hematoma managed nonoperatively	0	1 (2.0)	1.00
Seroma managed nonoperatively	0	0	—
Seroma requiring drainage in clinic	3 (6.0)	0	0.24
Neoumbilicus necrosis	2 (4.0)	1 (2.0)	1.00
Deep vein thrombosis	0	0	—
Pulmonary embolism	0	0	—
Pneumonia	0	1 (2.0)	1.00
Urinary tract infection	0	0	—
Cardiac complications	0	0	—
Gastrointestinal complications	0	0	—

ERP, enhanced recovery pathway; SSI, surgical-site infection; IV, intravenous.

DISCUSSION

The enhanced recovery pathway program used at our institution encompasses core features from the enhanced recovery pathway literature, including preoperative patient education, avoidance of prolonged preoperative fasting, goal-directed fluid management, standardized multimodal analgesic and anesthetic regimens, prevention of postoperative nausea and vomiting, venous thromboembolism prophylaxis, antibiotic

Table 7. Multivariable Logistic Regression Analysis of Risk Factors for Length of Hospital Stay

Risk Factor	OR	95% CI	*p**
Age	1.55	0.82–2.93	0.18
Body mass index	1.32	0.72–2.44	0.37
Bilateral breast reconstruction	0.81	0.28–2.34	0.70
Operative time	2.08	0.85–5.12	0.11
Intraoperative intravenous fluid amount	0.98	0.57–1.68	0.93
Total oral morphine equivalent use	6.56	2.64–16.30	<0.01
Total acetaminophen use	1.51	0.92–2.46	0.10
Enhanced recovery pathway	0.07	0.02–0.28	<0.01

*Statistical significance defined as $p < 0.05$.

prophylaxis, early ambulation, and early resumption of diet postoperatively.[18,19] To the best of our knowledge, currently, only four other studies have proposed a standardized care pathway in microvascular breast reconstruction and evaluated its efficacy by comparing outcomes after its implementation. Batdorf et al. examined the role of an enhanced recovery pathway in 100 consecutive patients (pre–enhanced recovery pathway, $n = 51$; enhanced recovery pathway, $n = 49$) undergoing microvascular breast reconstruction performed by two surgeons.[2] Afonso et al. retrospectively reviewed 91 patients (pre–enhanced recovery pathway, $n = 49$; enhanced recovery pathway, $n = 42$) undergoing deep inferior epigastric artery perforator or muscle-sparing transverse rectus abdominis myocutaneous flaps for breast reconstruction performed by multiple surgeons.[3] Bonde et al. presented their results before and after the establishment of a fast-track surgery protocol for unilateral microsurgical breast reconstruction (pre–enhanced recovery pathway, $n = 292$; enhanced recovery pathway, $n = 177$), and later revised their protocol and reexamined their outcomes on 16 consecutive patients.[4,5] Although all studies highlighted the conceivable success of an enhanced recovery pathway program in microvascular breast reconstruction, a few limitations were noted. The initial protocol of fast-track surgery that Bonde et al. used was not comprehensive because it did not include some key components of the current enhanced recovery pathways. When that protocol was revised, the results of only 16 patients were reported. The study by Batdorf et al. had patients with a significantly lower body mass index and less chronic pain diagnosis in the enhanced recovery pathway cohort. The enhanced recovery pathway cohort also had a higher number of patients who underwent deep inferior epigastric artery perforator flap surgery (compared to muscle-sparing transverse rectus abdominis musculocutaneous flaps), and fewer abdominal wall reconstructions with mesh compared to the non–enhanced recovery pathway group. These differences might have confounded their outcomes. Afonso et al. attempted to account for these differences and included multiple surgeons with different practice patterns for better generalizability of their results. However, intraoperative and postoperative ketorolac as an analgesic adjuvant was used inconsistently based on surgeon discretion, which might have introduced a selection bias. One significant difference between our multimodal analgesic regimen and that of the last two studies is the strict documented compliance with scheduled acetaminophen and the use of bupivacaine and dexamethasone for the transversus abdominis plane blocks, as opposed to liposomal bupivacaine. Our findings suggest that liposomal bupivacaine may not be necessary for transversus abdominis plane blocks, given its higher cost and absence of strong evidence to suggest superiority to bupivacaine hydrochloride.[20,21] It is possible that plain bupivacaine when administered in combination with a medication that prolongs the duration of the nerve block, such as dexamethasone, may be equally beneficial.

As in prior studies, our primary endpoint was length of hospital stay. Although a nonspecific variable, it is readily available, and can be used as a proxy for the clinical recovery trajectory. The studies by Batdorf et al. and Afonso et al. demonstrated a significant drop in length of hospital stay in the enhanced recovery pathway group, from 5.5 days to 3.9 days ($p < 0.001$) and from 5 days to 4 days ($p < 0.0001$), respectively.[2,3] Bonde et al. demonstrated a decrease in mean length of hospital stay from 7.4 days to 6.2 days with their initial fast-track protocol; however, after it was revised, a dramatic reduction in mean length of hospital stay to 3.1 days was reported.[4,5] Our study showed a significant decrease in the median length of hospital stay for the enhanced recovery pathway cohort from 4 days to 3 days, without any increase in major complications, hospital readmissions or unplanned reoperations. A recently presented study of 3666 patients examined the rates of free flap compromise requiring reoperation after autologous breast reconstruction, and identified a very low rate of reoperation after postoperative day 2.[22] The authors concluded that providers may consider discontinuing flap monitoring after the first 48 hours. In addition, it is possible that a procedure with a shorter anticipated length of hospital stay is perceived as less invasive by patients which,

when coupled with the high patient satisfaction rates observed in previous studies,[2] could make microvascular autologous breast reconstruction a more attractive option for appropriate candidates in the future. Our analysis went one step further to examine risk factors associated with length of hospital stay, and showed participation in an enhanced recovery pathway program and lower total morphine equivalent use to be predictors of a decreased length of hospital stay. Based on these data, we do believe that improvement of the enhanced recovery pathway programs has the potential to safely decrease the length of hospital stay further to 2 days, which could potentially generate tremendous savings for the health care system.

Consistent with findings by Batdorf et al., we demonstrated a significantly lower use of total and daily oral morphine equivalents in the enhanced recovery pathway cohort.[2] The analyses by Afonso et al. and Batdorf et al. showed no difference in antiemetic use between groups; however, our study revealed significantly lower total ondansetron use in the enhanced recovery pathway cohort.[2,3] This may be related to the lower use of patient-controlled analgesia in the enhanced recovery pathway cohort; only three of 50 patients in the enhanced recovery pathway group needed patient-controlled analgesia, as opposed to all patients in the pre–enhanced recovery pathway group. This may be related to the significantly higher intake of acetaminophen in the enhanced recovery pathway cohort in the first 2 postoperative days seen in our study.

Intraoperative multidisciplinary optimization has been shown to be a critical component of surgical enhanced recovery pathways. In our study, goal-directed fluid management by the anesthesia team for the enhanced recovery pathway cohort resulted in administration of a significantly lower volume of intravenous fluids. This might have improved our outcomes, because previous authors have investigated the implications of perioperative intravenous fluid management on microsurgical breast reconstruction and concluded that excessive intravenous fluid administration significantly predicted postoperative complications.[23,24] Furthermore, we observed a considerable decrease in the overall operative time for the enhanced recovery pathway cohort, which was more noticeable in the unilateral cases. This could be indirectly related to the enhanced recovery pathway program resulting in more standardized care that could increase the efficiency of the involved teams. It could have also contributed to some of the other positive outcomes noted in the enhanced recovery pathway cohort, such as lower intraoperative fluid administration. This is especially meaningful, as prior studies on breast reconstruction have demonstrated the risk of encountering any early postoperative complication increases by 5.2 percent for every 10 minutes' additional duration of surgery.[25] Moreover, shorter duration of surgery has important implications in cost savings and resource use for the operating room and, as a result, can make this operation a more viable option from a financial perspective for large institutions.

In 2010, health care expenditures in the United States approached $2.6 trillion, 10 times the amount spent in 1980.[26] It is thus not surprising that reduction in health care expenditures and more effective use of resources has become an overriding health policy priority. Although the cost savings resulting from enhanced recovery pathways have been documented across several surgical specialties, to the best of our knowledge, our study is the first in the plastic surgery literature to address this benefit.[27–33] There is a substantial effect of enhanced recovery pathway implementation on health care expenditure, with significant savings from freeing up inpatient beds and increased contribution margins, which warrants further evaluation.

This study has some limitations despite its overall contribution to the enhanced recovery pathway literature. It is not a randomized controlled trial and is therefore limited by the inherent drawbacks of a retrospective study design. Although we attempted to control for secular trends in our organization that may have occurred concurrently with our enhanced recovery pathway implementation, it is possible that we did not capture confounding factors that might have affected our outcomes irrespective of the enhanced recovery pathway. Also, our study is restricted by its single-center patient population and participation of only two surgeons, which may limit the generalizability of our results. We did not assess postoperative pain scores between the two groups, like prior studies, because opioid consumption is a more reliable and objective endpoint reflecting the patient's need for analgesics. It has been previously shown that pain scores are fundamentally subjective and interpreted differently among individuals, making them less reliable measures of pain control.[34]

This study examined the effects of implementing a comprehensive enhanced recovery pathway

for microvascular autologous breast reconstruction at a large academic institution. Multiple benefits were observed, including less postoperative narcotic and antiemetic requirements and decreased length of hospital stay without increasing patient morbidity. Of note, a higher rate of minor delayed wound healing problems that were managed with local wound care in the outpatient setting was observed in the enhanced recovery pathway cohort. The cause of this is unclear and has to be addressed with patients in the preoperative setting. Equally important, in an era governed by policies to lower health care expenditures, our results suggest that implementation of such a program can assist in optimizing resource use with substantial cost savings. As advocates for our patients and our practices, we should start questioning whether such programs for breast reconstruction should become standard of care and applied widely throughout the country. Even then, continued reassessment and research will be required to further refine and improve on the components of the program for better outcomes.

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ACKNOWLEDGMENTS

Financial support was provided by the Vanderbilt Institute for Clinical and Translational Research for assistance with the statistical analysis through the Department of Biostatistics at the Vanderbilt School of Medicine. The project was supported by the National Center of Research Resources (grant UL1 RR024975-01), and is now at the National Center for Advancing Translational Sciences (grant 2 UL1 TR000445-06). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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