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ORIGINAL ARTICLE

Breast

Improved Operative Efficiency and Surgical Times in Autologous Breast Reconstruction: A 15-year Single-center Retrospective Review

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Background: Autologous breast reconstruction using a free deep inferior epigastric perforator (DIEP) flap is a complex procedure that requires a dedicated approach to achieve operative efficiency. We analyzed data for DIEP flaps at a single center over 15 years to identify factors contributing to operative efficiency.

Methods: A single-center, retrospective cohort analysis was performed of consecutive patients undergoing autologous breast reconstruction using DIEP free flaps between January 1, 2005, and December 31, 2019. Data were abstracted a priori from electronic medical records. Analysis was conducted by a medical statistician.

Results: Analysis of 416 unilateral and 320 bilateral cases (1056 flaps) demonstrated reduction in operative times from 2005 to 2019 (11.7–8.2 hours for bilateral and 8.4–6.2 hours for unilateral, $P < 0.000$). On regression analysis, factors significantly correlating with reduced operative times include the use of venous couplers ($P < 0.000$), and the internal mammary versus the thoracodorsal recipient vessels ($P < 0.000$). Individual surgeon experience correlated with reduced OR times. Post-operative length of stay decreased significantly, without an increase in 30-day readmission or emergency presentations. Flap failure occurred in two cases. Flap take-back rate was 2% (n = 23) with no change between 2005 and 2019.

Conclusions: Operative times for breast reconstruction have decreased significantly at this center over 15 years. The introduction of venous couplers, use of the internal mammary system, and year of surgery significantly correlated with decreased operative times. Surgeon experience and a shift in surgical workflow for DIEP flap reconstruction likely contributed to the latter finding. *(Plast Reconstr Surg Glob Open 2023; 11:e5231; doi: 10.1097/GOX.0000000000005231; Published online 15 September 2023.)*

INTRODUCTION

Breast reconstruction has become a gold standard treatment for women who undergo either mastectomy or breast conserving surgery to restore patients' body image and quality of life.[1] The deep inferior epigastric perforator (DIEP) free flap is the workhorse for autologous breast reconstruction, providing a natural breast shape, minimal donor morbidity, and managing the challenges of previous radiation.[2]

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It is well documented that due to its complexity, autologous free flap breast reconstruction has a longer operative duration than alloplastic reconstruction and requires microsurgical expertise. Over the last 20 years, the DIEP flap has become an increasingly common operation for breast reconstruction that is considered safe and reliable, and is performed at a high volume by many surgeons. There has a been a strong focus in the literature and in clinical practice on optimizing operative times and surgical efficiency.[3,4]

Individual factors influencing free flap operative times have been previously investigated, including surgeon experience, dedicated nursing teams, and specific surgical approaches.[4,5] Perforator number,[6] the use of CT angiogram (CTA),[4,7] involvement of trainees,[8] and a systematic two-team approach[9,10] have also been identified as important factors influencing operating room (OR) times. Despite time-based remuneration for free flap surgery at our center, improved operative efficiency has

Disclosure statements are at the end of this article, following the correspondence information.

emerged by implementing many of these developments over time, while maintaining safety. The present study was undertaken to reflect on the developments in surgical approaches over the past 15 years at a single center with the aim of illustrating their impact on operative efficiency. We hypothesized the following factors would influence OR times and incorporated these in our analysis, including the introduction of dedicated nursing teams, use of the internal mammary vessels (IMV) instead of the thoracodorsal (TD) system as recipient vessels, introduction of new technology (venous couplers), involvement of dedicated microvascular fellows, and surgeon experience. A less tangible factor has been a shift in surgical process and practices, with workflow strategies to increase efficiency.

Takeaways

Question: We investigated free DIEP flap cases at our center over 15 years to provide a thorough look at the main contributing factors in our improved operative efficiency.

Findings: Our study demonstrated that improved operative efficiency in DIEP free flap surgery is dependent on many factors, including surgeon's experience and volume, use of couplers, and use of the internal mammary recipient vessels.

Meaning: Operative efficiency in autologous breast surgery has many contributing factors, including surgeon's experience, volume, technical advances, and the continued evolution of workflow processes, which are important factors to continued improvements in this field.

METHODS

A retrospective cohort analysis was performed of consecutive adult patients at a single center undergoing free autologous breast reconstruction using abdominal tissue between January 1, 2005, and December 31, 2019. Data was abstracted in an a priori fashion from electronic medical records [Sunrise Clinical Manager, OR Manager (ORIS), and Synoptec]. In some instances, there were missing data points, such as reference to the use of coupler, perforator number, or specific recipient vessel. These cases were omitted from comparative and regression analysis. Similarly, if recipient vessels were selected outside of the IMV and TD, these cases were excluded from analysis (eg, lateral thoracic). Analysis was conducted by a medical statistician. Comparison of groups was done with an independent *t* test analysis for normally distributed data or Mann–Whitney *U* test for nonnormally distributed data. The Kolmogorov–Smirnov test was used to check for normality assumption, in addition to assessment of histograms. Simple linear regression analysis was conducted to test for the changes in operative times from 2005 to 2019. The adjusted r^2 value was 0.701 to reflect goodness of fit for our model.

Multiple linear regression analysis was additionally completed to assess the relative contributions of significant factors on operative times. All data analysis was done using Python (Version 3.7). Flap failure rate, patient length of stay (LOS), 30-day emergency department visit and readmission rates were analyzed as metrics to assess changes in postoperative complications over time. Readmission rates and emergency presentations were reported as rates, not absolute values, to account for differing patient volumes annually.

Developments in surgical workflow hypothesized to effect operative efficiency in free autologous breast reconstruction at our center included:

1. Operative year: since 2005, there has been a significant increase in annual DIEP flap reconstructions, compounding surgeon exposure and opportunity to hone workflow.
2. Standardized nursing teams: since May 2009, an effort has been made to staff all autologous breast reconstruction cases with nurses from a dedicated group knowledgeable about the flow and needs of microsurgical cases.
3. Venous couplers: venous couplers provide a safe and efficient method of completing the venous anastomoses in autologous breast reconstruction. Our center began regularly using venous couplers in 2010.
4. Recipient vessel selection: our center exclusively used TD vessels as the recipient vessels until 2010 when a shift to using the IMV occurred. At present, nearly all cases use the IMV as recipient vessels.
5. Microsurgery fellow: a dedicated microsurgery fellowship was established at our center in 2015. This surgeon would be present at the vast majority of autologous breast reconstruction cases.
6. Workflow modifications: at our center, two staff surgeons (a primary surgeon and a microsurgical assistant) are remunerated hourly for autologous breast reconstruction cases, which has been consistent over the course of the study period. Therefore, a two-team approach has consistently been employed, without fiscal motivation to reduce OR times. Recognizing the importance of shorter OR times on patient outcomes, use of hospital resources and impact on surgeon lifestyle has, however, translated to a focus on improved operative efficiency and reduced OR times. In addition, the DIEP flap has proven to be a very reliable flap; historically, perfusion breaks would occur after the flaps were elevated but before ischemia time started. The surgery would pause for 15–20 minutes to allow surgeons to break and ensure the flaps were healthy. We have shifted toward maximally utilizing all the skill in the OR, with flap elevation, vessel exposure, microsurgery, or donor site closure occurring simultaneously if deemed safe. Breaks are rotated such that the surgery is always progressing.

RESULTS

Between 2005 and 2019, we retrieved data from 416 unilateral and 320 bilateral autologous reconstructive cases (1056 flaps). The number of cases per year has significantly increased, from six cases in 2005, to 65 in 2019 (Table 1). These data demonstrated a marked and

Table 1. Cases per Year

	Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Bilateral	Delayed	0	1	3	3	11	6	5	12	10	14	13	14	13	11	6
	Immediate	0	6	10	7	10	7	9	7	8	9	19	3	13	30	27
Unilateral	Delayed	6	6	6	8	22	22	25	20	34	30	22	18	22	24	23
	Immediate	0	5	8	1	0	4	0	3	1	1	1	1	11	9	9

progressive reduction in operative times from 2005 to 2019 (11.7±1.1 to 8.2±1.1 hours for bilateral and 8.4±0.9 to 6.2±0.9 hours for unilateral, $P < 0.000$) (Fig. 1). This reduction was observed in both immediate and delayed reconstruction.

In univariate analysis, the use of venous couplers, IMV recipient, and presence of a microsurgical fellow were associated with a significant reduction in operative time. The use of venous couplers significantly correlated with decreased operative times (11.3±1.2 hours without versus 9.3±1.3 hours with coupler for bilateral, $P < 0.000$; 7.7±1.0 hours without versus 6.5±1.0 hours with coupler for unilateral, $P < 0.000$) (Table 2). Recipient vessel anastomosis to the IMV system correlated with improved operative times as compared to the TD vessels (8.4±1.1 hours IMV versus 10.6±1.4 hours TD for bilateral, $P < 0.001$, and 6.2±1.1 hours IMV versus 7.5±1.1 hours TD for unilateral, $P < 0.000$) (Table 3). The presence of a dedicated microsurgical fellow correlated with decreased operative times (9.0±1.2 hours with fellow versus 10.5±1.5 hours without for bilateral, 6.4±1.2 hours with fellow versus 7.5±1.1 hours without for unilateral, $P < 0.000$) (Table 4). There was not a significant reduction in operative time with the presence of a dedicated microsurgical nursing team. (Table 5) Additionally, resident involvement was ubiquitous, and therefore, the contribution of this variable could not be assessed. The perforator number was also assessed and not found to have a significant contribution (Spearman correlation coefficient for unilateral = 0.284, bilateral = 0.170).

Multiple linear regression analysis was then used to evaluate the relative importance of each factor impacting OR time independent of the other factors. The use of the IMV (55-minute reduction, $P < 0.000$) and venous couplers (44 minute reduction, $P < 0.000$) (Table 6) had the greatest impact on operative time. Regression analysis did not find that a dedicated OR team or the presence of a fellow were significant independent predictors influencing OR time (Table 6).

Postoperative LOS was also found to have decreased significantly between 2005 and 2019, with patients now admitted on average 4.3 days following free flap reconstruction, as compared to 6.8 days in 2005 [mean 2.2% (±0.245%) reduction per year]. (Fig. 2) Flap failure occurred in two

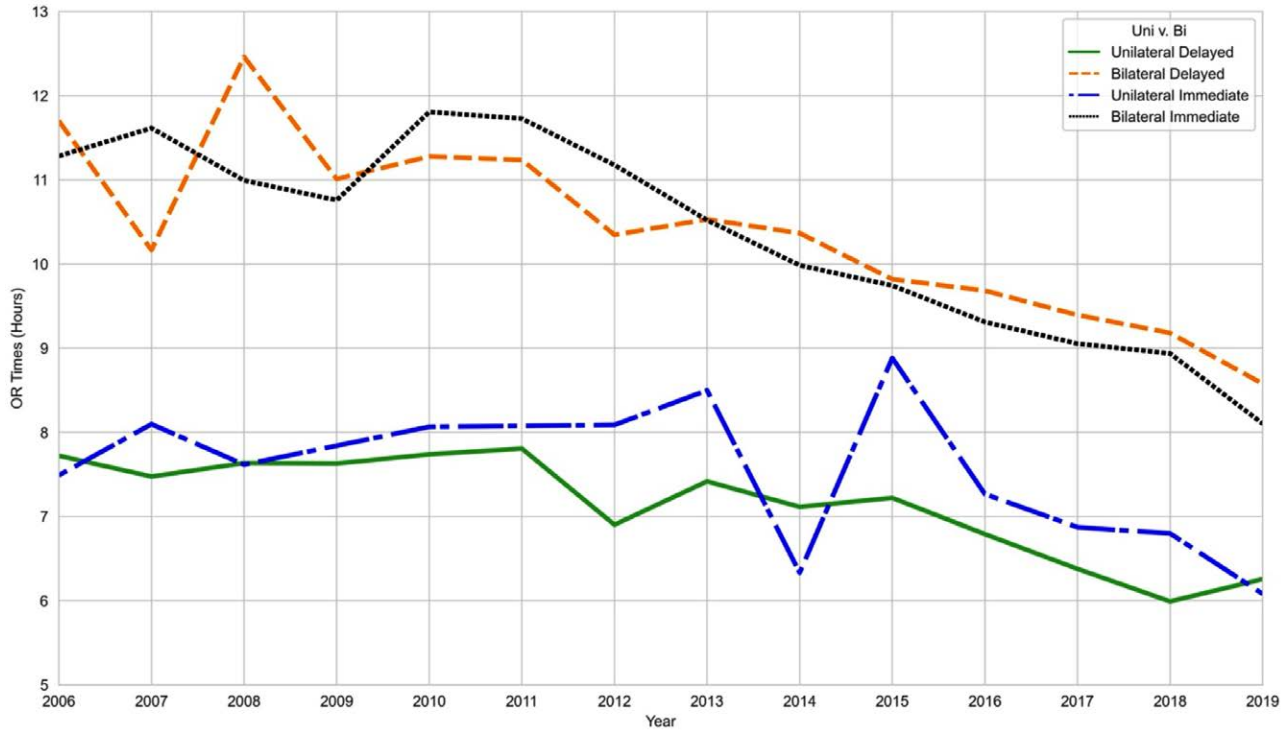

Fig. 1. A graph showing the reduction in operative times over 15 years for unilateral (delayed and immediate), and bilateral (delayed and immediate).

Table 2. Operative Time and Use of Venous Couplers (Univariate Analysis)

	No Coupler		Coupler		Mean Difference in OR Time (h)	*P*
	N	Mean OR Time, h (SD)	N	Mean OR Time, h (SD)		
Unilateral	235	7.74 (1.01)	167	6.54 (0.97)	1.2	<0.0001
Bilateral	125	11.23 (1.25)	185	9.30 (1.29)	1.93	<0.0001

Table 3. Operative Time and Use of IMV or TD Vessels (Univariate Analysis)

	TD		IM		Mean Difference in OR Time (h)	*P*
	N	Mean OR time, hours (SD)	N	Mean OR time, hours (SD)		
Unilateral	346	7.46 (1.07)	68	6.17 (1.12)	1.29	<0.0001
Bilateral	255	10.56 (1.35)	64	8.35 (1.11)	2.21	<0.0001

Table 4. Operative Time and Presence of a Microsurgery Fellow (Univariate Analysis)

	No Fellow		Fellow		Mean Difference in OR Time (h)	*P*
	N	Mean OR Time, h (SD)	N	Mean OR Time, h (SD)		
Unilateral	333	7.46 (1.08)	83	6.40 (1.16)	1.06	<0.0001
Bilateral	236	10.50 (1.51)	84	9.01 (1.19)	1.49	<0.0001

Table 5. Operative Time and Presence of a Dedicated Nursing Team (Univariate Analysis)

	No Dedicated Nursing Team		Dedicated Nursing Team		Mean Difference in OR Time (h)	*P*
	N	Mean OR time, hours (SD)	N	Mean OR time, hours (SD)		
Unilateral	55	7.43 (1.31)	361	7.22 (1.15)	0.21	0.2205
Bilateral	34	9.77 (1.52)	286	10.15 (1.58)	0.38	0.1837

Table 6. Multivariate Regression Analysis

Predictor	Coefficient	Change in OR Time (Min)	CI (95%)	*P*
Intercept	11.2526		10.894–11.611	**<0.000**
Coupler use	−0.7373	−44	−1.011 to −0.463	**<0.000**
Recipient vessels*	−0.9174	−55	−1.170 to −0.665	**<0.000**
Delayed vs immediate	−0.2090	−13	−0.415 to −0.003	**0.047**
Unilateral vs bilateral	−2.9444	−177	−3.138 to −2.751	**<0.000**
Fellow participation	−0.0189	−1	−0.259 to 0.221	0.877
Dedicated nursing team	0.1421	+9	−0.126 to 0.410	0.299
Year	−0.9786	−59	−1.525 to −0.432	**<0.001**

*Recipient vessels as comparing IM to TD recipient vessels.
Values in boldface $P<0.001$.

cases during the study period. Flap take-back rate was 2% (n = 23; five hematoma evacuation, 18 vascular compromise), with no significant difference between 2005 and 2019. As a metric to reflect safety, there has not been an increase in the rate of 30-day readmission ($P = 0.9914$), or rate of return to the emergency department ($P = 0.5418$). (Fig. 3) On analysis of the individual surgeon times, there were no outliers, and all surgeon OR times trended down over time, suggesting that surgeon experience is a contributing factor to the reduction in OR times.

DISCUSSION

Prolonged operative time has been associated with increased risk of postoperative complications, including septic shock, thromboembolic events, free flap failure and microvascular compromise, fat necrosis, and wound healing complications.[11–14] In a single-center analysis of operative times for autologous breast reconstruction, we found significant decreases in total surgical time over 15 years for both immediate and delayed reconstruction. Our study aimed to identify the independent contributions of various factors to reductions in operative time. Multivariate regression analysis demonstrated that the use of venous couplers and recipient IMV led to significant reductions in operative time. While we unable to assess the individual contribution of changes to workflow on operative time, surgeon experience and a multiteam approach were undoubtedly important contributors to the progressive decrease in OR times.

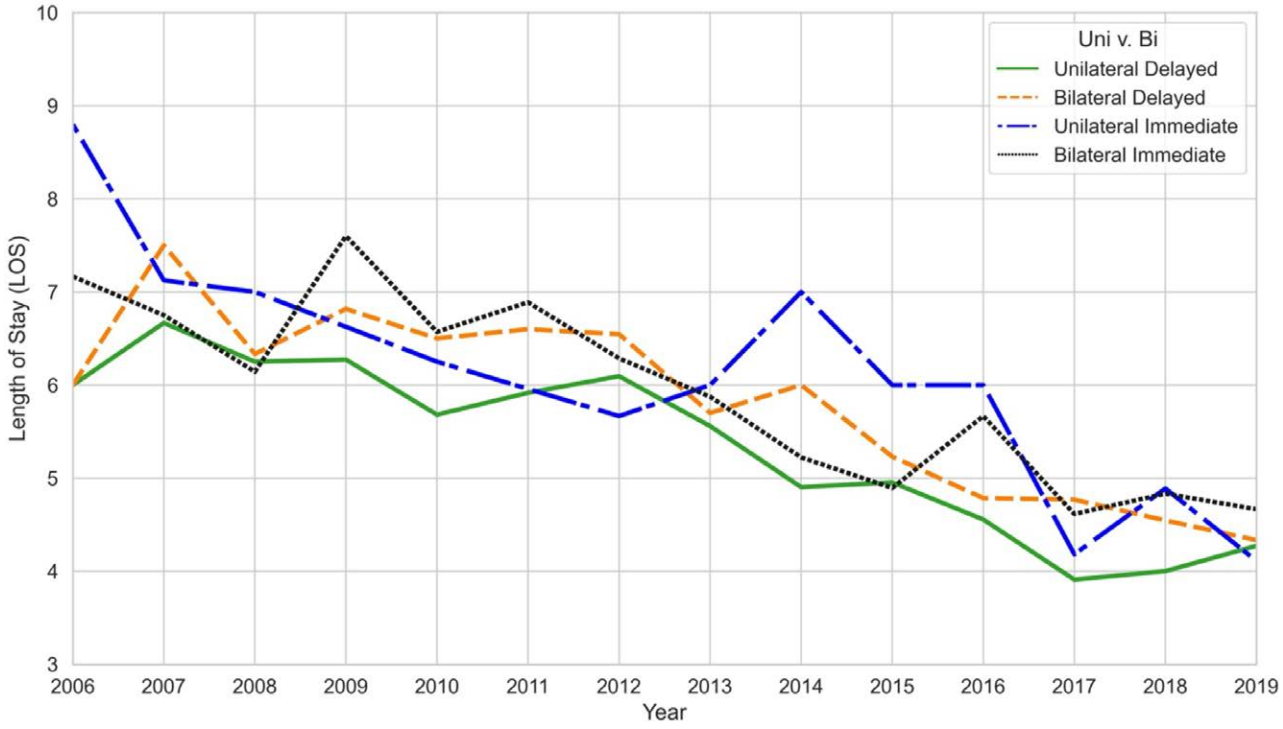

Fig. 2. A graph that shows the progressive reduction in post-operative LOS over 15 years.

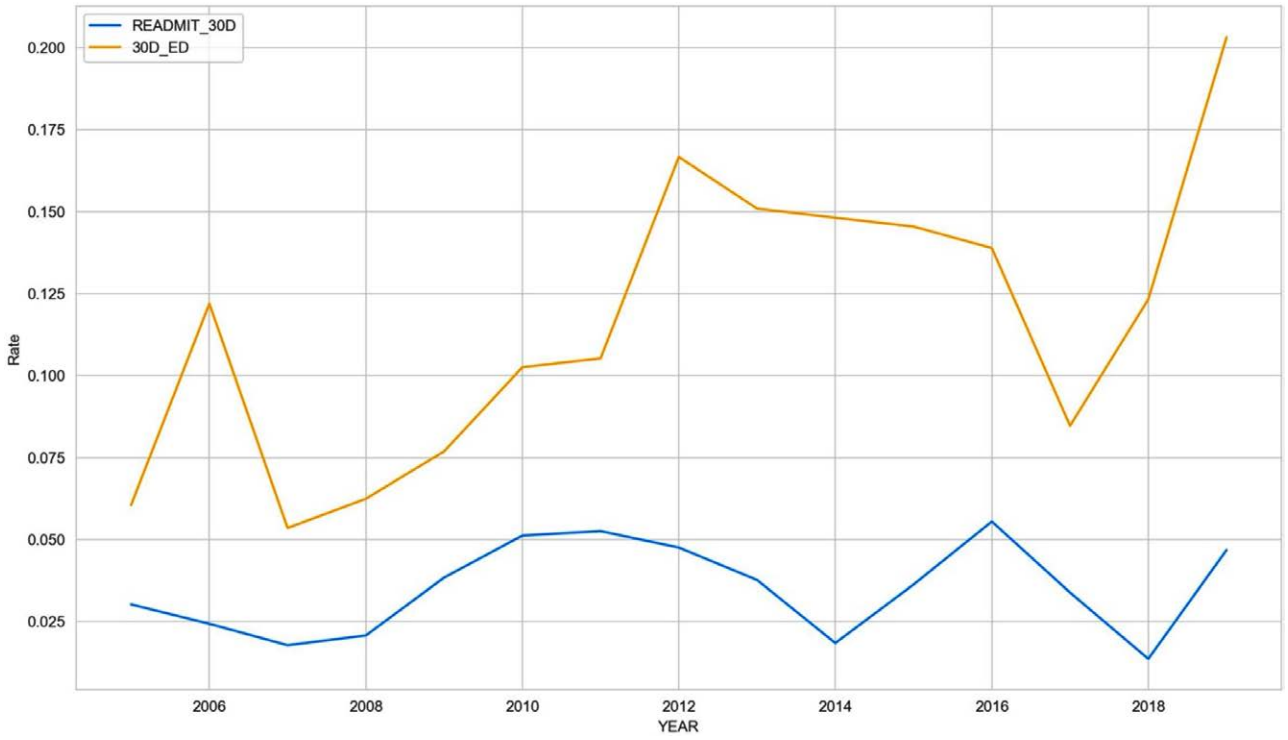

Fig. 3. A graph showing the rate of 30-day readmission and emergency department presentations, as a surrogate of postoperative complications.

Venous Couplers

Venous couplers have been widely adopted due to the associated time savings compared to hand sewn veins.[15,16] They have also been shown to have a decreased rate of venous thrombosis in breast reconstruction.[17] Our analysis found that couplers were an independent predictor of reduced operative time, with a 44 minute reduction ($P < 0.000$) (Table 2).

IM Recipient Vessels

Using the IMV as microvascular recipient vessels was associated with shorter OR times compared to the TD system (55-minute reduction, $P < 0.000$). Other studies have outlined the advantages of the IMV, including improved positioning for ease of microvascular anastomosis, medial positioning of the flap on the chest wall, and avoidance of axillary scarring.[18,19] In the setting of radiation, both have been found to have similar outcomes.[20] We have also noted improved compatibility with multisite surgery and positioning (eg, flap dissection simultaneous to microvascular anastomosis).

Presence of Learners

Studies assessing the impact of learners in the OR have had mixed outcomes, with some demonstrating prolonged operative times,[21] whereas other studies have demonstrated improvements.[8,22] Specifically in breast reconstruction, the involvement of trainees has not previously been shown to negatively impact surgical outcomes.[8,22] In our regression analysis, the presence of a fellow was not a significant independent predictor of reduced OR time. In a month-by-month analysis of OR times since the introduction of fellows, we only found a nonstatistically significant increase in operative times in the first month of the fellowship program (September). Although the precise degree of resident involvement in the specific operative proceedings is not known, resident presence was noted in almost all cases. Therefore, without a comparative value, it was not able to be assessed as a contributing variable.

Dedicated Nursing Team

Although dedicated nursing teams have been associated with improved operative efficiency for microsurgical cases in other studies,[5] an association did not persist on regression analysis in our study.

Workflow Shift

Our analysis found that operative times consistently trended lower from 2005 to 2019. Year of surgery presents a surrogate of the multifactorial changes that we assessed, such as the use of couplers and IMV, in addition to changes in workflow. There was low staff turnover over the course of the study period, allowing for longitudinal analysis without the impact of initial learning curves. Other studies have also shown that surgeons with increased experience tend to have shorter operative times owing to the initial learning curve of performing autologous breast reconstruction.[23,24] We found that at our center, individual surgeon operative times trended downward over time, indicating that surgeon experience contributes to a reduction in OR time. The reduction in OR time may also be related to the increasing case volume each year, and therefore, opportunity to improve efficiency. Similar findings have been shown in the digital replant literature, where surgeons at high-volume centers tend to have increased success and decreased operative times.[25]

Intraoperative workflow and efficiency have been increasingly studied topics in the era of optimizing operative times.[3,9,26,27] We hypothesize that the trend in reduced operative times at our center mirror a shift in the surgical workflow in autologous breast reconstruction. Multiple studies have shown the advantages in operative efficiency and outcomes when utilizing a team-based approach with two microsurgeons operating simultaneously for free flap reconstruction.[9,10,28,29] Similarly, we have adopted a continuous multiteam approach, and strategies to improve efficiency. These include (1) flap elevation at time of mastectomy in immediate reconstruction cases; (2) simultaneous abdominal flap elevation and recipient vessel preparation; (3) microvascular anastomosis concurrent with contralateral flap harvest or abdominal closure; (4) role assignment for learners in an appropriate and staged fashion; and (5) structured perioperative workflow measures with the nursing and anesthesia teams.

To ensure that expedience did not portend poorer outcomes, we also reported on variables reflective of surgical outcomes. The outcomes data from this study showed a very low complication rate, with total flap failure occurring in only two cases during the study period. The flap "take-back" rate—requiring return to the OR during the initial post-operative admission—was only 2% (n = 23; five cases for hematoma evacuation, 18 cases for vascular compromise), with no significant difference between 2005 and 2019. LOS data steadily decreased (2.2% per year), from 6.8 days in 2005 to an average 4.3 days in 2019. Dedicated preoperative teaching sessions to manage patient expectations, and the adoption of the enhance recovery after surgery protocol likely both influenced this reduction. Despite the reduction in both operative times and postoperative LOS, we did not have a significant increase in 30-day readmission rates or rate of emergency department visits, both used as a proxy for late complications.

Overall, our data demonstrated that operative times had a significant decrease from year to year, which is reflective of the dedicated changes to improve workflow in addition to the use of the IMV and venous couplers. Haddock and Teotia recently published an article titled "The Efficient DIEP Flap," demonstrating their approach to bilateral reconstruction with a completion time under four hours.[3] Although we have not demonstrated results as dramatic as these, we have similarly found that a key component in our operative time reduction is having various portions of the operation occurring simultaneously within a cohesive microsurgical team.

Limitations

The cases included in our retrospective analysis included only those flaps with information accessible on our electronic records. Cases were omitted from analysis if there was insufficient data. Although we feel the results are reflective of our case profiles overall, this is a limitation of the retrospective review. There are other factors that have been shown to reduce OR times that we did not evaluate in the current study, including the use of CTA and intraoperative laser-assisted indocyanine green fluorescent-dye angiography (SPY imaging, Novadaq Technologies, Inc., Toronto, Ontario, Canada). CTA has been shown to decrease operative time by aiding in perforator selection, is cost-effective compared to intraoperative Doppler

use,[7,30] and may have reduced rates of return to the OR.[31] SPY imaging has had increased utilization across many centers in assessing free flap perfusion as well as mastectomy flap perfusion.[32–35] CTA and SPY imaging are not routinely employed at our center for pre- or intraoperative planning and, therefore, are not powered for inclusion in the study. Previous studies have also found that a greater number of perforators included in the flap dissection is associated with longer operative times.[6,8] We did not find a significant correlation with perforator number and operative time; however, we did not have data on perforator number from 2005 to 2007.

CONCLUSIONS

The findings of this study shine a light on many surgical processes that are now largely the standard of care at major breast reconstruction programs, including the use of venous couplers and the IMV recipient vessels. Additionally, our case volumes have increased each year, and individual surgeon times have decreased, suggesting that surgical volume and experience are valuable contributing factors. Reflection on the continued adoption of new strategies and an ongoing focus on optimizing surgical efficiency, while maintaining patient safety, is an important part of influencing clinical care.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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