



Early institutional adoption of robotic-assisted microsurgical reconstruction: A retrospective descriptive study

Yizhuo Shen ^a, Renee Gao ^b, Stav Brown ^a, Felix J. Klinitz ^{a,c},
Meera Nair ^a, Samira Glaeser-Khan ^a, Luccie Wo ^a,
Kamal Addagatla ^a, Bohdan Pomahac ^a, Siba Haykal ^{a,*}

^a Plastic and Reconstructive Surgery Division, Department of Surgery, Yale School of Medicine, New Haven, CT, USA

^b UMass Chen Medical School, Worcester, MA, USA

^c Department of Hand and Plastic Surgery, Burn Center, BG Trauma Center Berlin, Chair of Hand Surgery Charité - Universitätsmedizin Berlin, Germany

Received 12 December 2025; Accepted 27 June 2026

KEYWORDS

Microsurgical robot;
Microsurgery;
Surgical robot;
Anastomosis;
Lymphatic
reconstruction;
Autologous breast
reconstruction

Summary *Background:* Robotic microsurgery enables submillimetric precision and enhanced dexterity. However, early real-world clinical experience remains limited. This study describes early institutional adoption of robotic-assisted microsurgery across free flap and lymphatic reconstructive procedures, with a focus on utilization patterns and operative performance.

Methods: A single-center retrospective review was performed from September 2024 to September 2025. Patients who underwent free flap breast reconstruction, immediate lymphatic reconstruction (ILR), or lymphaticovenous bypass (LVB) were included. Robotic cases were performed using the Symani Surgical System for microvascular anastomosis, whereas manual cases were performed using conventional techniques. Demographics, operative characteristics, and postoperative outcomes were summarized descriptively.

Results: A total of 118 procedures were analyzed (36 robotic and 82 manual). Robotic use was most common in ILR (52.8%), followed by free flap breast reconstruction (33.3%) and LVB (13.9%), with variation across surgeons. Mean operative duration was longer in robotic cases for free flap (594.7 ± 109.6 vs. 532.1 ± 139.6 min) and ILR procedures (92.4 ± 23.6 vs. 49.4 ± 18.1 min), consistent with early-phase adoption. Postoperative complications and anastomotic revision occurred in robotic and manual groups without a consistent pattern favoring either

Presentations at Conferences: American Society for Reconstructive Microsurgery Annual Meeting, January 2026.

* Correspondence to: Department of Surgery, Yale School of Medicine, 330 Cedar St, 06519 New Haven, CT, USA.

E-mail address: siba.haykal@yale.edu (S. Haykal).

<https://doi.org/10.1016/j.bjps.2026.06.031>

1748-6815/© 2026 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

approach. Anastomosis time varied across sequential cases, with a general reduction observed over time.

Conclusions: This study describes early institutional experience with robotic-assisted microsurgery, demonstrating technical feasibility and variability in its utilization during initial adoption. Findings suggest improving operative efficiency with experience. Further prospective studies are needed to better define long-term outcomes and comparative effectiveness.

© 2026 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

Robotic assistance in reconstructive surgery has advanced considerably over the past decades. In 2007, the first robotic-assisted microvascular anastomosis of a muscle-sparing transverse rectus abdominis myocutaneous (MS-TRAM) flap was performed using the da Vinci Surgical System (Intuitive Surgical, Inc.).¹ However, the specialized need for greater magnification and fine instrument control in microsurgical procedures prompted the development of dedicated robotic platforms.² These systems, including the MUSA System (MicroSure) and Symani Surgical System (Medical Microinstruments, Inc.),³ replicate hand movements while filtering tremor and scaling motion for sub-millimetric precision.

Preclinical studies of the Symani system have demonstrated promising technical performance, with comparable vessel patency and reduced tissue trauma relative to manual technique, albeit with longer operative times.⁴ In the clinical setting, early descriptive reports have begun to emerge, particularly in lymphatic reconstruction, where it has demonstrated feasibility and potential clinical benefit.⁵ However, these studies often have small sample sizes, lack a manual cohort, and primarily offer anecdotal observations regarding the impact on operative workflow.

To date, structured clinical evaluation of robotic reconstructive microsurgery has been performed using the MUSA platform, comparing robotic and manual lymphovenous bypass (LVB) in 20 patients with breast cancer-related lymphedema.⁶ Although this study demonstrated comparable outcomes, there remains a lack of published data evaluating the Symani system within a real-world, multi-procedural reconstructive practice. Moreover, although prior studies have focused primarily on robotic-assisted lymphatic reconstruction for secondary lymphedema and free flap reconstruction,^{7,8} integration of its application in immediate lymphatic reconstruction (ILR) remains unexplored.

In April 2024, the United States Food and Drug Administration (FDA) granted its first clinical approval for a microsurgical robot, the Symani Surgical System, representing a crucial milestone in the adoption of robotic microsurgery.⁹ Despite this, real-world clinical data describing early institutional experience, adoption patterns, and operative performance remain limited. This study describes early institutional experience with robotic-assisted microsurgery across a heterogeneous cohort of reconstructive procedures, with a focus on variability in utilization and operative performance during initial adoption.

Methods

Study design and setting

A single-center retrospective cohort study was approved under the institutional review board (IRB) at Yale New Haven Hospital. The study was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.¹⁰ Patients were identified through prospectively maintained institutional repositories: the Lymphedema Repository (IRB# 2000038539) and Breast Reconstruction Repository (IRB# 2000038540). Patients who underwent microsurgical reconstruction, including free flap-based breast reconstruction (deep inferior epigastric perforator [DIEP] and MS-TRAM flaps), ILR to prevent lymphedema, and LVB to treat existing lymphedema of the upper and lower extremities, from September 2024 to September 2025 were included. ILR and LVB were performed according to their respective clinical indications and represent distinct procedures.

The Symani® Surgical System was introduced at our institution in March 2025. This study reflects the initial institutional experience with robotic-assisted microsurgery. All eligible patients during the study period were included consecutively without case selection. Robotic assistance was used when the system was available, reflecting real-world implementation during early adoption. Intraoperative conversion to manual technique was carried out at the discretion of the attending surgeon based on technical considerations and surgeon judgment. Patients with fewer than 30-day follow-up were excluded. Baseline demographic and clinical characteristics included age at surgery, race, ethnicity, body mass index (BMI) at surgery, smoking status, hypertension, diabetes, pre-reconstruction radiation, and receipt of neoadjuvant and adjuvant chemotherapy.

Surgical technique

The robotic-assisted cohort comprised patients in whom the Symani Surgical System was employed for the microvascular anastomosis. Anastomoses were classified as fully robotic or as involving crossover to manual technique for the purposes of analysis. Conversion from robotic to manual was defined as abandonment of the robotic platform at any point during the anastomosis, after which the remaining procedure was completed using a conventional manual technique. Conversion was recorded as a binary event, as partial or intermittent switching between techniques did not occur.

Indications for conversion were recorded when available. The manual cohort included those who underwent comparable procedures performed exclusively using standard microsurgical instruments under an operating microscope.

Procedures were performed by four attending plastic surgeons with formal training in microsurgery, three of whom used the robotic platform during the study period. Prior to clinical implementation, all microsurgeons had no prior clinical experience with robotic-assisted microsurgery and completed standardized training with Symani provided by the manufacturer Medical Microinstruments, Inc. The Symani system was used only for arterial anastomoses in free-flap breast reconstruction and lymphovenous anastomoses in ILR and LVB procedures. End-to-end anastomoses were performed for all arterial cases. For lymphovenous anastomosis, three surgeons used end-to-end anastomoses, whereas one surgeon employed a manual-only end-to-side technique. Arterial diameters ranged from 2 to 3 mm. Lymphatic diameters are summarized in the accompanying tables. All patients received standardized perioperative management, including flap monitoring, anticoagulation, and postoperative surveillance per institutional protocol.

Variables and outcomes

The primary outcome was postoperative safety, assessed through the occurrence of postoperative complications, including partial or complete flap failure, mastectomy skin flap necrosis, infection, hematoma, seroma, reoperation, wound dehiscence, and 30-day readmission. Outcomes were analyzed at the procedure level, with multiple anastomoses possible per case. Secondary outcomes included microsurgical feasibility and technical performance metrics. Intraoperative variables included laterality (unilateral vs. bilateral), total procedure length (documented start-to-end time of the primary plastic surgeon in the medical record), number of arterial or lymphatic anastomoses, and anastomosis revision with documented reason according to the operative note by the primary surgeon. Anastomosis revision was defined as any instance in which an arterial or lymphatic anastomosis was re-performed, using either robotic or manual technique at the discretion of the attending surgeon. Revisions were performed owing to technical (tear or leak) or clinical (venous congestion or arterial thrombosis requiring revision to optimize flap perfusion) reasons. In cases of flap compromise, including venous congestion, arterial and venous anastomoses were routinely evaluated, and could involve one or both anastomoses at the discretion of the attending surgeon. Therefore, venous congestion was recorded as the clinical indication prompting revision or re-exploration, even when the arterial anastomosis was also re-performed.

For the robotic subgroup, anastomosis time and stitch count were recorded by Symani, with anastomosis time defined as the interval from the first to the final suture placed. Times were recorded as categorical ranges in 10-minute intervals (e.g., 0-10, 10-20 min). For analysis, the midpoint of each interval was used, resulting in discretized time values.

Partial flap failure is defined as partial flap ischemia. Complete flap failure is defined as the complete loss of the

free flap. Postoperative complications were identified through chart review using standardized definitions applied across the robotic-assisted and manual cohorts. Readmission was defined as re-hospitalization within 30 days of surgery under the plastic surgery service.

Given that plastic surgeons often perform immediate breast reconstruction at the same time as ILR, a variable indicating whether a concurrent procedure was performed (yes/no) was included to better account for differences in operative length. Concurrent procedures for ILR were defined as any additional procedure performed by the plastic surgeon performing the ILR and was included in the total operating length reported, including vein graft, implant-based reconstruction, oncoplastic reconstruction, and esthetic flat closure.

Statistical analysis

Continuous variables are summarized as means with standard deviations or medians with interquartile ranges (IQR). Categorical variables are reported as counts and percentages. Analyses were primarily descriptive, with subgroup summaries reported by procedure type and operative approach. Baseline demographic and clinical characteristics were compared between the robotic-assisted and manual cohorts within each procedure type using the Wilcoxon rank-sum test for continuous variables and Fisher's exact test for categorical variables (Table 1). P-values are provided for reference but are not interpreted as confirmatory given the cohort heterogeneity and small sample sizes. All analyses were performed using R (Version 2025.09.2+418, R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 118 qualifying microsurgical reconstruction procedures performed between September 2024 and September 2025 were included in the study. Among these, 82 (69.5%) were performed manually, whereas 36 (30.5%) were performed using the microsurgical robot (Figure 1). Robotic assistance was most common for ILR (19, 52.8%), followed by autologous breast reconstruction (free flap) (12, 33.3%) and LVB (5, 13.9%). All five LVB cases were robotic.

Patient and operative characteristics

Across all procedure types, comorbidities, racial and ethnic distribution, and treatment history were comparable between the robotic and manual cohorts (Table 1). Robotic utilization varied among the four surgeons, with surgeon 1 performing 95% of all robotic ILR cases, surgeon 2 performing most robotic free flap cases (66.7%), and surgeon 3 contributing primarily to robotic LVB procedures (60.0%). Surgeon 4 did not perform any robotic-assisted procedures (Table 1). The procedure-specific distribution of robotic-assisted cases for each surgeon is detailed in Supplemental Table 1.

Follow-up duration was longer in the manual cohort across the procedure types ($p < 0.01$). Median follow-up was

Table 1 Baseline demographics and clinical characteristics by procedure type and surgical approach (robotic vs. manual).

	Free Flap		p-value*	ILR		p-value*	LVB
	Robotic (N = 12)	Manual (N = 64)		Robotic (N = 19)	Manual (N = 18)		Robotic (N = 5)
Age, years			0.83			0.64	
Mean $\pm$ SD	49.7 $\pm$ 11.8	47.6 $\pm$ 8.9		55.8 $\pm$ 11.2	52.7 $\pm$ 16.5		65.0 $\pm$ 6.8
Median (IQR)	47.5 (41.0-59.0)	48.0 (42.5-53.0)		55.0 (49.0-66.0)	53.5 (37.0-64.0)		67.0 (59.0-68.0)
BMI, kg/m ²			0.22			0.82	
Mean $\pm$ SD	27.5 $\pm$ 3.9	29.1 $\pm$ 4.1		27.5 $\pm$ 4.4	30.6 $\pm$ 9.7		30.9 $\pm$ 2.0
Median (IQR)	26.2 (24.6-30.4)	29.7 (25.8-32.3)		28.0 (23.3-30.6)	26.1 (24.6-32.3)		29.9 (29.5-33.0)
Race			> 0.90			0.13	
White	9 (75.0%)	43 (67.2%)		16 (84.2%)	10 (55.6%)		4 (80.0%)
Black	2 (16.7%)	7 (10.9%)		1 (5.3%)	5 (27.8%)		0 (0.0%)
Asian	0 (0.0%)	4 (6.3%)		0 (0.0%)	0 (0.0%)		0 (0.0%)
Latino	1 (8.3%)	6 (9.4%)		2 (10.5%)	3 (16.7%)		0 (0.0%)
Other	0 (0.0%)	5 (7.8%)		0 (0.0%)	0 (0.0%)		1 (20.0%)
Ethnicity			0.84			0.41	
Hispanic	2 (16.7%)	16 (25.0%)		3 (15.8%)	5 (27.8%)		0 (0.0%)
Non-Hispanic	10 (83.3%)	46 (71.9%)		16 (84.2%)	13 (72.2%)		5 (100.0%)
Unknown	0 (0.0%)	2 (3.2%)		0 (0.0%)	0 (0.0%)		0 (0.0%)
Hypertension	2 (16.7%)	13 (20.3%)	> 0.90	6 (31.6%)	5 (27.8%)	> 0.90	1 (20.0%)
Diabetes	0 (0.0%)	5 (7.8%)	> 0.90	3 (15.8%)	4 (22.2%)	0.72	0 (0.0%)
Smoking status			> 0.90			0.13	
Never	8 (66.7%)	42 (65.6%)		8 (42.1%)	13 (72.2%)		3 (60.0%)
Former	4 (33.3%)	20 (31.3%)		10 (52.6%)	5 (27.8%)		2 (40.0%)
Active	0 (0.0%)	2 (3.1%)		1 (5.3%)	0 (0.0%)		0 (0.0%)
Prior radiation	5 (41.7%)	24 (37.5%)	> 0.90	0 (0.0%)	1 (5.6%)	0.50	5 (100.0%)
Neoadjuvant chemotherapy	1 (8.3%)	23 (35.9%)	0.09	7 (36.8%)	10 (55.6%)	0.30	2 (40.0%)
Adjuvant chemotherapy	3 (25.0%)	16 (25.0%)	> 0.90	6 (31.6%)	8 (44.4%)	0.52	2 (40.0%)
Primary surgeon			0.01			0.005	
1	2 (16.7%)	34 (53.1%)		18 (94.7%)	11 (61.1%)		2 (40.0%)
2	8 (66.7%)	15 (23.4%)		1 (5.3%)	0 (0.0%)		0 (0.0%)
3	2 (16.7%)	7 (10.9%)		0 (0.0%)	2 (11.1%)		3 (60.0%)
4	0 (0.0%)	8 (12.5%)		0 (0.0%)	5 (27.8%)		0 (0.0%)
Hospital stay, hours			0.90			0.91	
Mean $\pm$ SD	66.7 $\pm$ 15.3	67.5 $\pm$ 22.4		34.8 $\pm$ 27.6	25.6 $\pm$ 13.1		21.6 $\pm$ 11.8
Median (IQR)	62.5 (53.5-76.5)	58.0 (53.0-77.0)		28.0 (24.0-50.0)	28.0 (11.0-33.0)		28.0 (9.0-28.0)
Follow-up, days			< 0.01			< 0.01	
Mean $\pm$ SD	54.5 $\pm$ 18.6	153.5 $\pm$ 85.8		68.9 $\pm$ 45.7	183.6 $\pm$ 111.3		49.0 $\pm$ 28.6
Median (IQR)	54.5 (40.5-58.5)	155.0 (76.5-223.5)		51.0 (37.0-84.0)	190.5 (73.0-260.0)		41.0 (32.0-44.0)

* Comparisons are performed between the robotic-assisted and manual cohorts within each procedure type.

155 days (IQR 77-224 days) for manual versus 55 days (IQR 41-59 days) for robotic free flaps, and 191 days (IQR 73-260 days) versus 51 days (IQR 37-84 days) for ILR (Table 1). LVB patients (robotic only) had a median follow-up of 41 days (IQR 32-44 days) (Supplemental Table 2).

Free flap outcomes

Among 76 free flap reconstructions (12 robotic and 64 manual), the distribution of reconstruction timing and

laterality was similar between the cohorts (Table 2). Median procedure length was 570.5 min (IQR 538.0-657.0 min) for robotic cases and 537.0 min (IQR 423.5-576.5 min) for manual cases. Median hospital stay was 62.5 and 58.0 h, respectively.

Postoperative complications were observed in both cohorts (Table 2). On a per-anastomosis basis, 22 robotic and 107 manual anastomoses were performed. Anastomosis revision occurred in 4 robotic and 6 manual anastomoses. In robotic cases, revisions were attributed to technical factors such as leaks (1/4) and tears (2/4), and clinical factors such as arterial thrombosis (1/4). In manual cases, revisions were

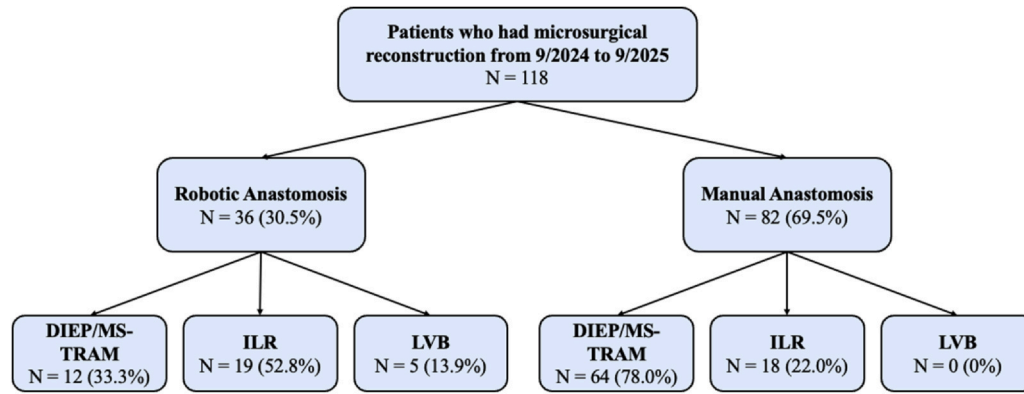


Figure 1 Flow diagram of study population and microsurgical procedure types (DIEP: deep inferior epigastric perforator flap; MS-TRAM: muscle sparing-transverse rectus abdominis myocutaneous flap; ILR: immediate lymphatic reconstruction to prevent lymphedema; LVB: lymphovenous bypass to treat existing lymphedema).

Table 2 Operative and postoperative characteristics (free flap).

	Robotic N = 12	Manual N = 64
Timing		
Immediate	5 (41.7%)	42 (65.6%)
Delayed	7 (58.3%)	20 (31.3%)
Combined	0 (0%)	2 (3.1%)
Bilateral procedure	10 (83.3%)	43 (67.2%)
Procedure length, minutes		
Mean $\pm$ SD	594.7 $\pm$ 109.6	532.1 $\pm$ 139.6
Median (IQR)	570.5 (538.0-657.0)	537.0 (423.5-576.5)
Hospital stay, hours		
Mean $\pm$ SD	66.7 $\pm$ 15.3	67.5 $\pm$ 22.4
Median (IQR)	62.5 (53.5-76.5)	58.0 (53.0-77.0)
Postoperative complications		
Partial flap failure	1 (8.3%)	0 (0.0%)
Complete flap failure	0 (0.0%)	1 (1.6%)
Mastectomy skin flap necrosis	1 (8.3%)	3 (4.7%)
Infection	0 (0.0%)	6 (9.4%)
Hematoma	1 (8.3%)	9 (14.1%)
Seroma	0 (0.0%)	10 (15.6%)
Reoperation	2 (16.7%)	7 (10.9%)
Dehiscence	0 (0.0%)	18 (28.1%)
Readmission	0 (0.0%)	8 (12.5%)
Anastomosis-level Data		
Total anastomoses (N)	22	107
Anastomosis revision	4 (18.2%)	6 (5.6%)
Reason for revision anastomosis^b	N=4	N=6
Leak	1/4	0/6
Tear	2/4	2/6
Venous congestion	0/4	3/6
Arterial thrombosis	1/4	4/6

^b Multiple contributing etiologies could be recorded for a single anastomosis revision; therefore, percentages may exceed 100%.

associated with arterial thrombosis (4/6), venous congestion (3/6), and tears (2/6) (Table 2).

Immediate Lymphatic Reconstruction (ILR)

Thirty-seven ILR procedures were performed (19 robotic and 18 manual). The proportion of cases performed with a concurrent procedure was similar between the groups (robotic vs. manual: 9/19 vs. 10/18). One robotic case was bilateral following bilateral groin lymph node dissection.

Median procedure length was 102.0 min (IQR 80.0-128.0 min) for robotic ILR and 79.5 min (IQR 52.0-228.0 min) for manual ILR. Hospital stay was comparable between the cohorts, with a median of 28.0 h in both groups (Table 3).

Postoperative complications were infrequent in both groups. In the robotic cohort, infection occurred in 3 cases, with additional instances of seroma (2/19), reoperation (1/19), and readmission (3/19). No hematomas or dehiscence were observed in either cohort. Anastomosis revision occurred in two manual anastomoses (2/18), both secondary to venous occlusion.

In ILR cases without concurrent procedures, median procedure length was 81.5 min (IQR 74.5-112.0 min) for robotic cases and 50.0 min (IQR 39.2-55.8 min) for manual cases (Table 3).

Lymphaticovenous Bypass (LVB)

Five robotic LVBs were performed, with a median operative time of 538 min and an average of 4.4 anastomoses per patient. There was 1 anastomotic revision (1/22) for venous occlusion (Supplemental Table 2) with no further postoperative complications.

Early learning experience in robotic anastomosis

Across surgeons who used robotic assistance, anastomosis time varied across sequential cases (Figure 2). Later cases demonstrated shorter recorded anastomosis times in several surgeon-procedure combinations, observed within lymphatic and arterial procedures, although variability remained across cases and procedure types. Anastomosis times were recorded in 10-minute intervals and are

Table 3 Operative and postoperative characteristics (ILR).

	Robotic N = 19	Manual N = 18
Concurrent procedure	9/19	10/18
Bilateral procedure	1/19	0/18
Procedure length, minutes		
Mean $\pm$ SD	112.5 $\pm$ 44.3	125.7 $\pm$ 95.7
Median (IQR)	102.0 (80.0-128.0)	79.5 (52.0-228.0)
Hospital stay, hours		
Mean $\pm$ SD	34.8 $\pm$ 27.6	25.6 $\pm$ 13.1
Median (IQR)	28.0 (24.0-41.0)	28.0 (13.0-33.0)
Postoperative complications		
Infection	3/19	0/18
Hematoma	0/19	0/18
Seroma	2/19	0/18
Reoperation	1/19	0/18
Dehiscence	0/19	0/18
Readmission	3/19	0/18
Anastomosis-level Data		
Total anastomoses (N)	21	18
Vessel Diameter (mm)		
Mean $\pm$ SD	0.51 $\pm$ 0.13	0.63 $\pm$ 0.28
Median (range)	0.50 (0.30-1.00)	0.50 (0.40-1.20)
Anastomosis revision	0/21	2/18
Reason for revision anastomosis	N=0	N=2
Leak	0/0	0/2
Tear	0/0	0/2
Venous occlusion	0/0	2/2
ILR without Concurrent Procedures		
Total Patients (N)	10	10
Procedure length, minutes		
Mean $\pm$ SD	92.4 $\pm$ 23.6	49.4 $\pm$ 18.1
Median (IQR)	81.5 (74.5-112.0)	50.0 (39.2-55.8)
Postoperative complications		
Infection	0/10	0/10
Hematoma	0/10	0/10
Seroma	1/10	0/10
Reoperation	0/10	0/10
Dehiscence	0/10	0/10
Readmission	1/10	0 /10

presented using interval midpoints, resulting in clustered datapoints at discrete values. Given the descriptive nature of the analysis and limited sample size within surgeon-procedure subgroups, data are presented descriptively.

Conversion from robotic to manual technique

Conversion from robotic to manual technique occurred in 11 of 36 robotic cases. Reported reasons for conversion are

summarized in [Supplemental Figure 1](#). The most common indication was patient-specific anatomic constraints (5/11), followed by challenging anastomoses (3/11), technical setup limitations (2/11), and other factors (1/11).

Discussion

This study describes early institutional experience with robotic-assisted microsurgery using the Symani Surgical System across multiple reconstructive procedures, including the first reported clinical series of robotic-assisted ILR. Prior clinical reports have been largely limited to small case series or single-procedure applications.^{1,7,11-15} By examining a heterogeneous cohort spanning free flap reconstruction, ILR, and LVB, this study provides a broader perspective on robotic-assisted microsurgery during early clinical adoption at a high-volume academic center, including variability in utilization and operative performance.

Across the procedure types, robotic-assisted microsurgery was implemented without an evident increase in major perioperative complications. Baseline comorbidities and treatment histories, including prior radiation exposure and neoadjuvant chemotherapy, were similar between the groups ([Table 1](#)). Postoperative events occurred in robotic and manual cohorts without a consistent pattern favoring either approach. Importantly, no complete flap loss occurred in the robotic cohort, and anastomotic revisions were observed in both groups ([Tables 2 and 3](#)). These findings support the technical feasibility of robotic-assisted microsurgery during early adoption, although interpretation remains limited by sample size and follow-up duration.

These findings align with preclinical studies demonstrating successful robotic anastomoses in animal and cadaveric models,^{3,4,16} and with recent translational work showing comparable patency rates and minimal stenosis with robotic-assisted microsurgery.^{17,18} Furthermore, the length of hospital stay remained similar between the robotic and manual cohorts for free flap and ILR, suggesting that robotic assistance does not adversely affect early postoperative recovery.

Operative duration was generally longer in robotic cases, consistent with previous reports during the early phase of adoption.^{5,6} In this cohort, median operative times were longer for free flap and ILR procedures ([Tables 2, 3](#)). Importantly, total operative time reflects microsurgical performance and workflow-related factors such as system setup, positioning, and intraoperative integration. Therefore, the observed differences in operative duration likely reflect a combination of technical learning and workflow-related factors rather than intrinsic limitations of robotic anastomosis. These observations are consistent with early workflow integration and underscore the importance of separating total operative duration from anastomosis-specific performance.

Consistent with this, sequential anastomosis-time data provide an early descriptive view of robotic-assisted microsurgical adoption ([Figure 2](#)). Although case-to-case variability remained, shorter recorded anastomosis times in later cases across several surgeon-procedure combinations are consistent with increasing familiarity with robotic

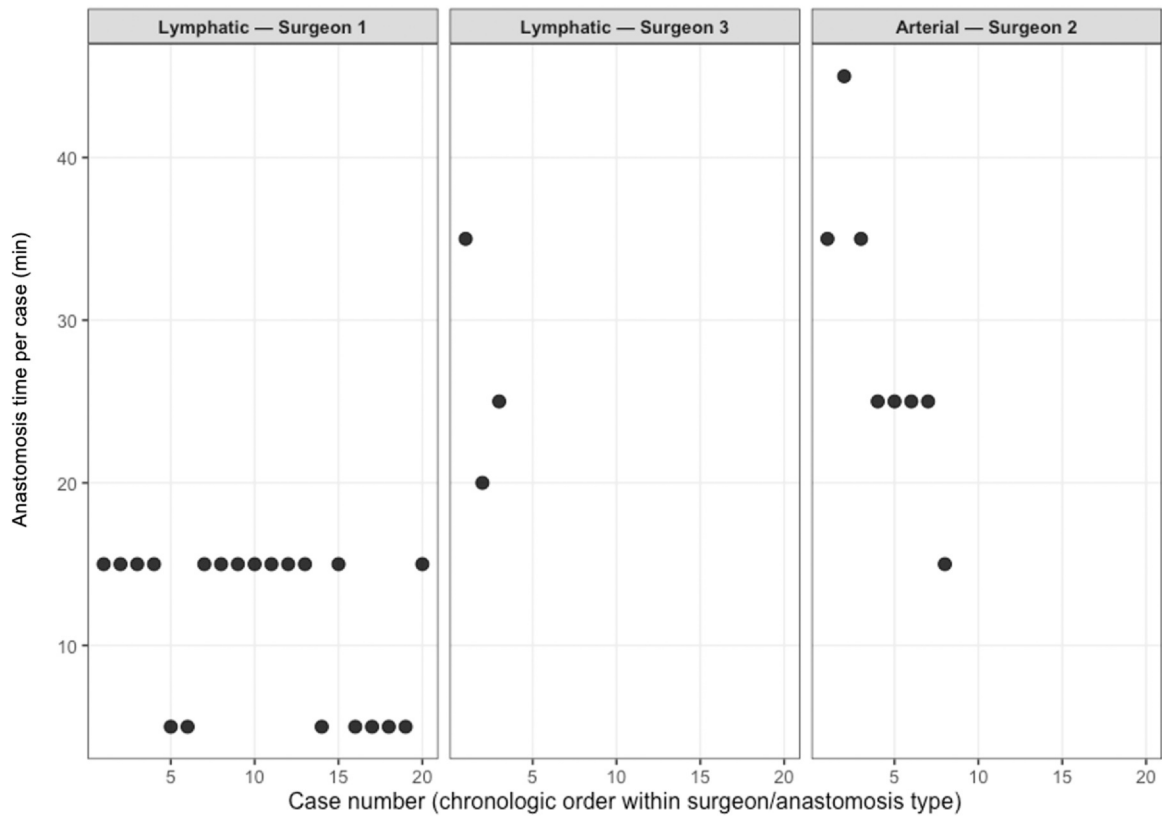


Figure 2 Anastomosis time by case order. Each point represents one case and reflects anastomosis time using interval midpoints from 10-minute categories. Panels are stratified by surgeon and anastomosis type; only surgeon-procedure combinations with sufficient observations for descriptive visualization are shown.

instrumentation, setup, and anastomotic workflow. These findings provide descriptive evidence of early efficiency gains during institutional adoption, although the small number of cases and interval-based time recording limit the precision with which incremental changes in anastomosis time can be assessed.

Surgeons demonstrated varying preferences in robotic utilization (Table 1), reflecting variations in practice specialization and adoption strategy. Surgeon 1 employed the robot almost exclusively for lymphatic anastomoses in ILR and LVB procedures (20 ILR/LVB vs. 2 free flap cases), whereas Surgeon 2 predominantly used it for arterial anastomoses (1 ILR vs. 8 free flap cases). Surgeon 3 exhibited a balanced use across indications (3 LVB vs. 2 free flap cases). Despite these differences, reductions in anastomosis time were observed across surgeons, suggesting that the platform can be integrated across varied operative contexts (Figure 2). Similar variability in utilization has been reported in early experiences from other centers.¹⁹ Importantly, differences in anastomosis time across surgeons also reflect variation in the types of anastomoses performed. Arterial anastomoses are generally more technically demanding and time-intensive than lymphatic anastomoses, which contributes to differences in observed operative times between the surgeons.

Intraoperative conversion from robotic to manual technique occurred in a subset of cases (11/36) and was most commonly attributed to patient-specific anatomic constraints, followed by challenging anastomoses and technical

setup limitations (Supplemental Figure 1). These findings highlight the role of intraoperative judgment during early adoption and underscore that robotic assistance currently functions as an adjunct rather than a replacement for conventional microsurgical technique. The ability to transition between approaches may be an important component of safe clinical integration.

Overall, these findings suggest that robotic-assisted microsurgery can be incorporated into reconstructive practice with acceptable early clinical outcomes and progressive improvement in operative performance. Rather than demonstrating superiority, these data characterize the initial phase of adoption, during which variability in utilization, workflow, and efficiency is expected.

As robotic microsurgery continues to evolve, several considerations warrant attention.^{12,20} Cost-effectiveness remains to be evaluated, particularly regarding initial capital investment and per-case costs. Training pathways are yet to be standardized, though early evidence suggests that focused application to specific procedures may accelerate skill acquisition.¹⁹ Integration with artificial intelligence may further enhance robotic capabilities by providing cognitive and visual support, such as predictive planning and real-time vessel tracking.²¹

Some limitations should be noted. First, the shorter follow-up for robotic cases (median 51-55 days) compared to manual cases (median 155-191 days, $p < 0.01$) reflects recent implementation. Although patients with less than 30 days of follow-up were excluded and this duration captures

acute complications, the impact on vessel integrity and long-term patency requires further evaluation, especially for supermicrosurgical procedures such as ILR and LVB.^{22,23} Second, the inability to distinguish anastomotic time from setup time limits conclusions about which component contributes most to operative duration. Granular time-motion data such as system setup, docking, and takedown were not available in this retrospective cohort and should be incorporated into future prospective studies. Third, the small sample size of the robotic cohort, particularly within procedure-specific subgroups, limits the ability to detect small differences or rare complications, and precludes formal statistical comparison. Finally, as a single-institution study conducted during the early adoption phase, the findings may reflect institutional or surgeon-specific practices.

Future studies should focus on prospective evaluation of workflow efficiency, standardization of training approaches, and assessment of long-term clinical outcomes. As experience grows, further studies will be necessary to define the role of robotic assistance within specific reconstructive indications and to determine where it may offer the greatest clinical value.

Conclusion

This study describes early institutional experience with robotic-assisted microsurgery across multiple reconstructive procedures. The findings demonstrate technical feasibility, acceptable early clinical outcomes, and progressive improvement in operative performance during the initial six months of adoption. Variation in adoption patterns across surgeons highlights the flexibility of integration within reconstructive practice. Continued evaluation is needed to define long-term outcomes, optimize workflow, and establish the role of robotic assistance in reconstructive microsurgery.

Ethical approval

This study was approved by the Institutional Review Board (IRB) at Yale New Haven Hospital under IRB# 2000038539 and IRB# 2000038540.

Lay Summary

This study describes the early institutional experience of robotic-assisted microsurgery in breast and lymphatic reconstruction. Findings showed feasibility, acceptable early outcomes, and improved performance during initial adoption.

Funding

This study was supported by the Medical Student Summer Research Grant from the American Society for Reconstructive Microsurgery.

Declaration of Competing Interest

Stav Brown is a paid consultant to Impedimed. Siba Haykal is a paid consultant to Stryker. Bohdan Pomahac is a paid consultant to Medical Microinstruments, Inc (MMI). All other authors have no relevant financial disclosures.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.bjps.2026.06.031](https://doi.org/10.1016/j.bjps.2026.06.031).

References

- Hulst R van der, Sawor J, Bouvy N. Microvascular anastomosis: is there a role for robotic surgery? *J Plast Reconstr Aesthet Surg* 2007;**60**(1):101–2. <https://doi.org/10.1016/j.bjps.2006.05.011>.
- Aitzetmüller MM, Klietz ML, Dermietzel AF, Hirsch T, Kückelhaus M. Robotic-assisted microsurgery and its future in plastic surgery. *J Clin Med* 2022;**11**(12):3378. <https://doi.org/10.3390/jcm11123378>.
- Innocenti M. Back to the future: robotic microsurgery. *Arch Plast Surg* 2022;**49**:287–8. <https://doi.org/10.1055/s-0042-1748020>.
- Malzone G, Menichini G, Innocenti M, Ballestín A. Microsurgical robotic system enables the performance of microvascular anastomoses: a randomized in vivo preclinical trial. *Sci Rep* 2023;**13**(1):14003. <https://doi.org/10.1038/s41598-023-41143-z>.
- von Reibnitz D, Weinzierl A, Barbon C, et al. 100 anastomoses: a two-year single-center experience with robotic-assisted micro- and supermicrosurgery for lymphatic reconstruction. *J Robot Surg* 2024;**18**(1):164. <https://doi.org/10.1007/s11701-024-01937-3>.
- van Mulken TJM, Schols RM, Scharnga AMJ, et al. First-in-human robotic supermicrosurgery using a dedicated microsurgical robot for treating breast cancer-related lymphedema: a randomized pilot trial. *Nat Commun* 2020;**11**(1):757. <https://doi.org/10.1038/s41467-019-14188-w>.
- Seth I, Lim K, Chang E, Rozen WM, Ng SKH. Evaluating the clinical utility of robotic systems in plastic and reconstructive surgery: a systematic review. *Sensors* 2025;**25**(10):3238. <https://doi.org/10.3390/s25103238>.
- Stögner VA, Pucciarelli DM, Pomahac B, Ayyala HS. Robotic-assisted microsurgery in lymphatic reconstruction. *J Craniofac Surg* 2025;**36**(1):359–62. <https://doi.org/10.1097/SCS.00000000000010608>.
- Milloy K.. MMI Receives FDA Authorization to Commercialize Symani® Surgical System in the U.S. MMI. April 8, 2024. <https://www.mmimicro.com/symani-awarded-de-novo-authorization/>. [Accessed November 3, 2025].
- Elm E von, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;**370**(9596):1453–7. [https://doi.org/10.1016/S0140-6736\(07\)61602-X](https://doi.org/10.1016/S0140-6736(07)61602-X).
- Paternoster JL, Shepherd H, Ruccia F, et al. Robotic microvascular anastomoses in free flap reconstruction - A first UK report. *J Plast Reconstr Aesthet Surg* 2025;**108**:63–5. <https://doi.org/10.1016/j.bjps.2025.07.013>.

12. Aitzetmüller MM, Kliezt ML, Dermietzel AF, Hirsch T, Kückelhaus M. Robotic-assisted microsurgery and its future in plastic surgery. *J Clin Med* 2022;11(12):3378. <https://doi.org/10.3390/jcm11123378>.
13. Innocenti M, Malzone G, Menichini G. First-in-human free flap tissue reconstruction using a dedicated microsurgical robotic platform. *Plast Reconstr Surg* 2023;151(5):1078–82. <https://doi.org/10.1097/PRS.00000000000010108>.
14. Sørensen RBA, Chakari W, Thomsen JB, Sørensen JA. Evaluation of microsurgical free flap procedures utilizing the Symani Surgical System: a preliminary analysis. *J Plast Reconstr Aesthet Surg* 2025;102:66–70. <https://doi.org/10.1016/j.bjps.2025.01.037>.
15. Chen WF, Cheong DCF, Tedone Clemente E, Salman M. Robot-assisted lymph node-to-vein anastomosis: lessons from the first 22 cases at a high-volume lymphatic supermicrosurgery center. *Curr Oncol Tor Ont* 2025;32(7):377. <https://doi.org/10.3390/curroncol32070377>.
16. van Mulken TJM, Boymans CAEM, Schols RM, et al. Preclinical experience using a new robotic system created for microsurgery. *Plast Reconstr Surg* 2018;142(5):1367–76. <https://doi.org/10.1097/PRS.0000000000004939>.
17. Menichini G, Malzone G, Tamburello S, et al. Safety and efficacy of Symani robotic-assisted microsurgery: assessment of vascular anastomosis patency, thrombus, and stenosis in a randomized preclinical study. *J Plast Reconstr Aesthet Surg* 2024;96:1–10. <https://doi.org/10.1016/j.bjps.2024.06.009>.
18. van Mulken TJM, Wolfs JAGN, Qiu SS, et al. One-year outcomes of the first human trial on robot-assisted lymphaticovenous anastomosis for breast cancer-related lymphedema. *Plast Reconstr Surg* 2022;149(1):151–61. <https://doi.org/10.1097/PRS.00000000000008670>.
19. Kueckelhaus M, Nistor A, van Mulken T, et al. Clinical experience in open robotic-assisted microsurgery: user consensus of the European Federation of Societies for Microsurgery. *J Robot Surg* 2025;19(1):171. <https://doi.org/10.1007/s11701-025-02338-w>.
20. Wessel KJ, Stögner VA, Yu CT, et al. Preclinical performance of the combined application of two robotic systems in microsurgery: a two-center study. *Plast Reconstr Surg Glob Open* 2024;12(4):e5775. <https://doi.org/10.1097/GOX.00000000000005775>.
21. Shen Y, Malek AJ, Gao R, Broyles JM. Artificial intelligence in breast reconstruction. *Artif Intell Surg* 2025;5(1):150–9. <https://doi.org/10.20517/ais.2024.71>.
22. Brown S, Shen Y, Klinitz FJ, et al. Lymphovenous bypass for the treatment of secondary lymphedema: a meta-analysis of prospective outcomes. *Breast Cancer Res Treat* 2025;215(1):42. <https://doi.org/10.1007/s10549-025-07867-4>.
23. Brown S, Shen Y, Klinitz FJ, et al. Immediate Lymphatic Reconstruction (ILR) for the Prevention of Lymphedema: a meta-analysis of prospective clinical trials. *Ann Surg Oncol* 2026;33(1):60–76. <https://doi.org/10.1245/s10434-025-18333-2>.