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Robot-assisted Microsurgery: Lessons Learned from 50 Consecutive Cases

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Background: The potential of robot-assisted surgery in plastic and reconstructive surgery remains to be established, especially in free tissue transfer. This prospective study aimed to present our experience and findings from the first 50 consecutive cases of robot-assisted microsurgery using the Symani surgical system.

Methods: A prospective database was maintained, recording patient demographics and surgical details for all cases of robot-assisted microsurgery in a large academic institution. All surgeons underwent an intensive training program with the Symani surgical system.

Results: A total of 50 patients who underwent robot-assisted microsurgical reconstruction were identified. Free microsurgical tissue transfer was performed in 45 cases, targeted muscle reinnervation in four cases, and lymphovenous anastomoses in a single case. A total of 94 robot-assisted anastomoses and coaptations were performed, (46 venous and 30 arterial anastomoses, 16 nerve coaptations, two lymphovenous anastomoses). Six cases involved perforator-to-perforator anastomoses. Ninety-eight percent of attempted anastomoses were completed using the robot. Size-mismatch anastomoses, seen in 37.8% of cases, took significantly longer. Minor complications occurred in three cases and major in six cases. There were three cases of microvascular compromise requiring revision. One partial flap loss and no complete flap loss occurred.

Conclusions: Our study highlights the immense potential of robot-assisted microsurgery, and a feasible and effective modality for various microsurgical procedures, with outcomes comparable to those of conventional microsurgery. Despite challenges, such as increased operating times and higher costs, the technology offers significant advantages, such as enhanced precision and motion scaling. We identify a slow learning curve and a necessity for higher caseloads. *(Plast Reconstr Surg Glob Open 2024; 12:e5685; doi: 10.1097/GOX.0000000000005685; Published online 13 March 2024.)*

INTRODUCTION

Since the approval of the first robotic surgical platform, namely the DaVinci platform, by the United States Food and Drug Administration, robotic surgery has been widely implemented in a variety of surgical specialties, spanning from general surgery, to gynecology, to urology.[1–3] Robotic surgery offers superior ergonomics, the elimination of tremor, and an increased range of movement.[4,5] Despite successful application of robot-assisted microsurgery by van Hulst and colleagues in 2007, and development of several robotic systems specialized for microsurgical applications.[6] Adoption of robotic assistance within the field of plastic surgery has been significantly slow. Application of the technology in free tissue transfer has remained equally limited, despite its potential to enhance surgical precision and reduce perioperative morbidity.

Robot-assisted microsurgery, specifically, offers potential benefits such as enhanced visualization and precision, minimized surgeon fatigue, and an improved ability to perform complex procedures, such as microvascular tissue transfer.[7] Robot-assisted microsurgery also allows the possibility

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to implement the use of artificial intelligence and other software enhancements and is amenable to remote virtual surgery for particularly complex cases.[8] The Symani robotic system consists of two robotic arms that are controlled by the surgeon via two manipulators similar to a pair of forceps. It offers seven to 20 times motion scaling with elimination of physiological tremor. The system has been successfully used in lymphatic surgery and free flap surgery.[9–11]

A 2023 literature review of all articles investigating robotic microsurgery in plastic surgery highlighted the gap in the literature with only 19 relevant articles identified, of which only five directly compared the robotic and conventional approaches.[12] The majority of these studies were preclinical animal studies or case reports. Furthermore, only three of the clinical studies reported on more than five patients, and so far, no larger prospective trials have been published.

Our study aimed to contribute to the growing body of evidence regarding the efficacy and feasibility of robot-assisted microsurgery. Primary endpoint of the study was the feasibility of the implementation of robotic assistance in our microsurgical practice. It details the perioperative data of 50 consecutive cases, providing details on operating time, types of anastomoses and flaps, and size and location of defects. By analyzing these cases, we seek to provide valuable insights into the clinical application of this innovative technology and discuss the lessons learned.

MATERIAL AND METHODS

Data Collection

A prospective database was maintained to include all cases of robot-assisted microsurgery at our large academic hospital between February and June 2023. In February 2023, we acquired a Symani surgical system and placed it in a specific operating room. All patients who underwent microsurgical interventions in our department and were scheduled for that OR were included in the study. Both patient demographics [age, sex, body mass index (BMI), comorbidities, risk factors] and surgical data (type of surgery, type of microsurgical reconstruction, duration of surgery, duration of anastomosis, number of stitches, surgical outcomes, and intra- and postoperative complications) were recorded. Vessel diameters were measured intraoperatively using a fine ruler. The study protocol adhered to the Declaration of Helsinki, and ethical approval was obtained from the local committee (Medical Commission Rhineland-Palatinate, Mainz, Germany; approval no.: 2023-16997). Size mismatch greater than 0.5 mm was considered clinically significant.

Robotic Training

All surgeons underwent an intensive, twelve-hour training program to ensure proficiency in handling and trouble-shooting the Symani Surgical System (Medical Microinstruments Inc., Wilmington, Del.). During the program, at least eight anastomoses of different vessel diameters (0.5–2.0 mm) were performed. Additionally, size-mismatch and end-to-side anastomoses were performed. A three-dimensional model was used to simulate impaired access and anastomosing small vessels in a deep surgical site condition.

Takeaways

Question: Is robot-assisted microsurgery feasible in a high-volume center?

Findings: In a prospective study, we included all patients who underwent microsurgical interventions (microvascular anastomosis, nerve coaptation, lymphaticovenous anastomosis) in our facility using the Symani surgical system. The primary endpoint was the completion of the microsurgical intervention using the robot. We report our experiences from 50 consecutive cases (94 anastomoses and coptations). Ninety-eight percent of attempted anastomoses were completed using the robot. There were three cases of microvascular compromise requiring revision.

Meaning: Robot-assisted microsurgery is feasible and effective for various microsurgical procedures, with outcomes comparable to conventional microsurgery.

Perioperative Protocol

All microsurgical reconstructions were performed using standard flap raising techniques as previously described.[13] All free flap reconstructions were performed using the regular microinstruments of the Symani Surgical System, with the super-microsurgical instruments utilized only for the lymphovenous anastomosis case. Optical magnification was achieved through conventional microscopy (Mitaka MM51, Mitaka Kohki Ltd., Tokyo, Japan) or digital exoscopy using 4K-3D screens (ORBEYE, Olympus, Tokyo, Japan).

Postoperatively, all free flaps were monitored hourly for 5 days, through clinical assessment of the recapillarization as well as conventional or implantable Doppler ultrasound. All patients received subcutaneous low-molecular weight heparin (30 mg twice daily for 5 days followed by 40 mg once daily until discharge). If microvascular compromise was suspected, the patient was immediately returned to the operating theatre for operative revision.

Statistical Analysis

The Student *t* test was used for the analysis of normally distributed data and the Mann Whitney *U* test for not normally distributed data. Categorical variables were analyzed using chi-square testing. Continuous variables are presented with mean and standard deviation (SD) or median and interquartile range (IQR). Categorical variables are displayed with frequencies and percentages. Statistical significance was defined as a *P* value less than 0.05. All data were analyzed and visualized using GraphPad Prism (Version 9.0.2, GraphPad Software, San Diego, Calif.).

RESULTS

Study Cohort

Fifty patients who underwent robot-assisted microsurgical reconstruction were identified. Of these patients, 32 were men (64.0%), the mean age was 53.8 ± 14.4 years, and the mean BMI was 25.5 ± 4.8 kg per m². The most frequently encountered comorbidity was hypertension (18 of 50; 36.0%), followed by smoking (13 of 52; 26.0%), obesity, and diabetes (both 10 of 50; 20.0%). The median American Society of Anesthesiologists classification was 2 (IQR:1). Table 1 summarizes the patient characteristics.

The main indication for surgery was trauma (21 of 50; 42%), followed by infection (10 of 50, 20%), post-breast cancer (seven of 50; 14%), traumatic nerve damage (four of 50; 8%), and lymphedema (one of 50; 2%). The most frequently used free flap was the anterolateral thigh (ALT) flap (21 of 45; 46.7%). Most microsurgical reconstructions were performed on the lower extremity (Figs. 1 and 2).

Surgical Characteristics

Free flap reconstruction was performed in most patients (45 of 50; 90%). Targeted muscle reinnervation was performed in four cases (four of 50; 8%) and lymphovenous anastomosis once (one of 50; 2%). The most used free flaps were the ALT (21 of 48; 46.7%), deep epigastric artery perforator (seven of 47; 15.5%), and latissimus dorsi flaps (five of 45; 11.1%). In the free flap cases, the most frequently used recipient vessels were the posterior tibial (11 of 45; 24.4%), anterior tibial (nine of 45; 20.0%), and radial artery (seven of 45; 15.6%). Figure 3 depicts an example of the cases performed, specifically a case of a neurotized ALT flap used to reconstruct an upper extremity defect. Table 2 summarizes the different procedures, and Table 3 provides detailed information on the recipient vessels. Table 4 shows information on the distribution of cases per surgeon. A total of 94 robot-assisted anastomoses and 50 coaptations were performed. [**See Video** (**online**), which shows the setup and utilization of the robotic system.]

Table 1. Baseline Demographics of Patients

Parameter	Cohort, n = 50
Age, mean years ± SD	53.8 ± 14.4
Male sex	32 (64)
ASA classification, median ± IQR	2 ± 1
Risk Factors	
Hypertension	18 (36)
Active smoking	13 (26)
Diabetes	10 (20)
Obesity (BMI ≥ 30kg/m²)	10 (20)
Peripheral arterial occlusive disease	3 (6)
Coagulopathy	2 (4)
History of thrombosis/embolism	2 (4)

Values are reported as n (%), unless otherwise stated.
ASA, American Society of Anesthesiologists.

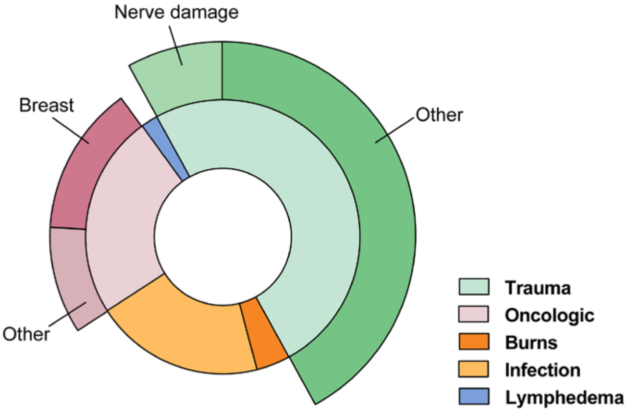

Fig. 1. Overview of the indications for the respective robot-assisted microsurgical interventions.

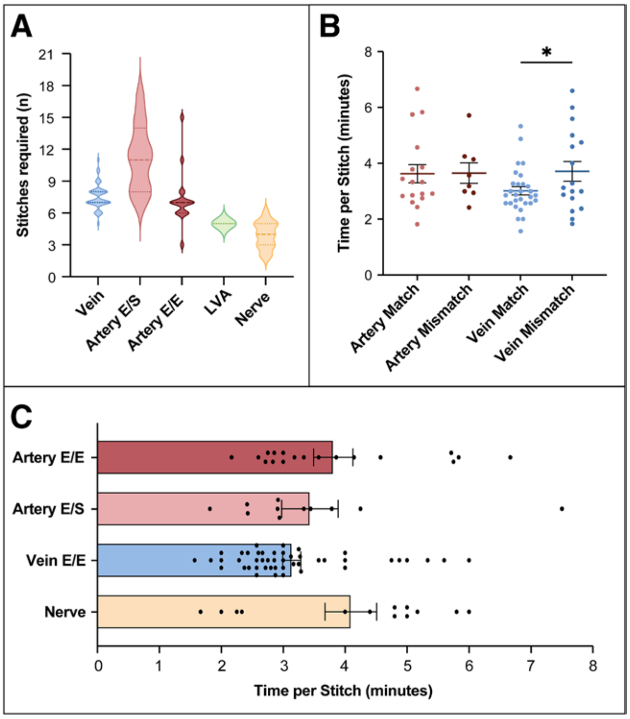

Fig. 2. A, Number of stitches required. B, Time per stitch for size-mismatched and size-matched arteries and veins. Size-mismatched venous anastomoses required significantly more time per stitch (P = 0.04). C, Time per stitch of the different vessels and nerve coaptation.

Venous Anastomoses

Venous anastomoses were performed 46 times (46 of 94; 49.0%), using the end-to-end technique. In 24 cases, a single vein was sutured, and in 11 cases, two veins were anastomosed. The mean vein diameter was 2.3 ± 0.6 mm. On average, a robot-assisted venous anastomosis required 23.8 ± 9.2 minutes, averaging at 3.4 ± 1.5 minutes per stitch. A median of seven stitches was completed (IQR:1). In 19 cases, 9-0 sutures were chosen (42.2%), and in two cases, 10-0 sutures (4.4%). Seventeen venous anastomoses had a clinically significant size-mismatch (17 of 45; 37.8%). Compared with size-matched anastomoses, no significant difference in the total anastomotic time ($P = 0.06$) was noted with size-mismatch. The time per stitch was, however, significantly higher with size-mismatch ($P = 0.04$).

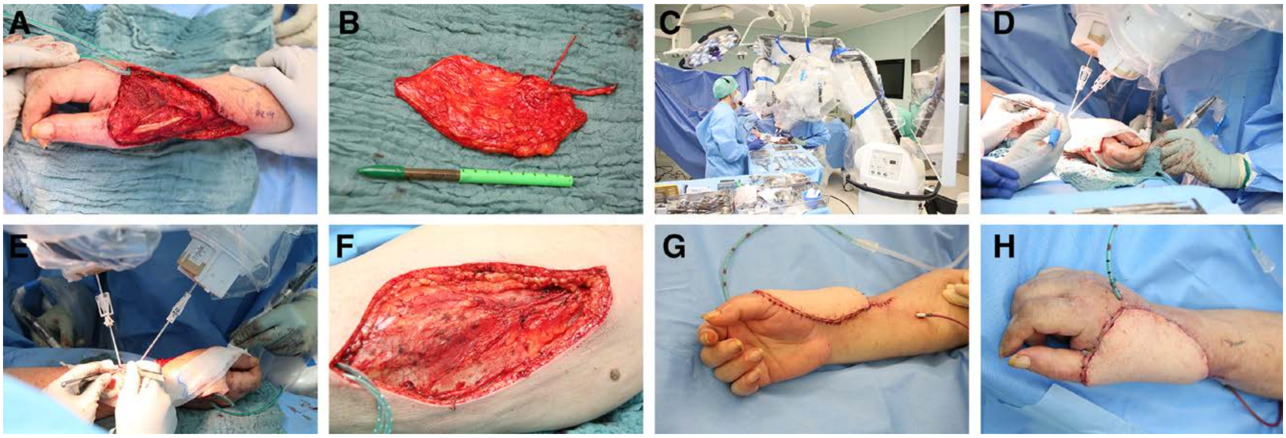

Fig. 3. Exemplary case of an ALT flap. A, Soft tissue defect on the right hand of a patient after a fulminant, phlegmonous infection after a rat bite. B, The neurotized ALT flap has been raised. C–E, Using the Symani robotic system and conventional microscopy, the anastomosis is performed. F, The small fascial defect has been closed and the donor site will be closed primarily. G–H, After the inset, the flap is well perfused.

Table 2. Procedure Distribution

Type of Procedure	Cohort, n = 50
Targeted muscle reinnervation	4 (8)
Lymphovenous anastomosis	1 (2)
Free flap reconstruction	45 (90)
ALT	21 (42)
Latissimus dorsi	5 (10)
DIEP	7 (14)
Gracilis	3 (6)
TMG	2 (4)
Parascapular	2 (4)
MSAP	1 (2)
Radial forearm	1 (2)
LICAP	1 (2)
Arterialized venous flow-through flap	1 (2)

Values are reported as n (%), unless otherwise stated.
DIEP, deep inferior epigastric perforator artery; LICAP, lateral intercostal artery perforator; MSAP, medial sural artery perforator; TMG, transverse myocutaneus gracilis.

Table 3. Recipient Artery Distribution

Recipient Artery	Free Flaps, n = 45
Posterior tibial	11 (24.4)
Anterior tibial	9 (20.0)
Radial	7 (15.6)
Internal mammary	6 (13.3)
Brachial	2 (4.4)
Superficial temporal	1 (2.2)
Facial	1(2.2)
Superior thyroid	1 (2.2)
Digital	1 (2.2)
Intercostal perforator	1 (2.2)

Values are reported as n (%), unless otherwise stated.

Arterial Anastomoses

Thirty arterial anastomoses were performed, of which 19 were end-to-end (63.3%) and 11 end-to-side (36.6%). The size of the vessels used in the end-to-side anastomoses (1.8 ± 1.1 mm) did not differ from that of vessels used for end-to-end anastomoses (2.2 ± 0.9 mm; P = 0.48). End-to-side anastomoses required significantly more stitches (P = 0.001) with a median of 11 compared with seven stitches in end-to-end anastomoses. Neither the total time required for the anastomosis, nor the time per stitch significantly differed between the two techniques (P = 0.83 and P = 0.13, respectively). Nine arterial anastomoses had a clinically significant size-mismatch (24.6%), of which three were performed in end-to-end and six in end-to-side fashion. When compared with size-matched anastomoses, no significant difference in the anastomotic times (total or per stitch; P = 0.16 and P = 0.2, respectively) was seen. There was no significant difference in vessel diameter between end-to-end and end-to-side anastomoses (P = 0.48). Six arterial anastomoses were performed in a perforator-to-perforator fashion with significantly smaller average vessel diameters (P = 0.001). Size 8-0 sutures were the most frequently used sutures for arterial anastomoses (19 of 30; 63.3%), although 9-0 sutures and 10-0 sutures were also utilized (six of 30; 20.0% and five of 30; 16.7%, respectively).

Epineural Coaptations

Sixteen epineural coaptations were performed in eight cases, of which four were targeted muscle reinnervations after upper extremity trauma and four were neurotized free flaps (two ALT and two gracilis flaps). The mean nerve diameter was 3.0 ± 1.3mm. A median of four stitches was used for the coaptations (IQR:2). The time per stitch was 4.1 ± 1.5 minutes. Size 9-0 sutures were used in all but one case, where a 10-0 suture was utilized. Table 5 provides an overview over the different types of anastomoses and their operative duration.

Intraoperative Outcomes and Complications

Intraoperative complications were seen in four patients (four of 50; 8.0%). Three venous anastomoses were intraoperatively deemed nonpatent and were resected and replaced with an anastomosis using a Coupler device

Table 4. Case Distribution Per Surgeon

	Free Flap Reconstruction						
Surgeon	**Upper Extremity**	**Lower Extremity**	**Head/Neck**	**Breast/Trunk**	**LVA**	**TMR**	**Total**
1	6	6	3	3	0	0	18
2	1	3	1	0	0	4	9
3	0	4	0	3	0	0	7
4	2	3	0	0	1	0	6
5	2	3	0	0	0	0	5
6	0	3	0	2	0	0	5
Total	11	22	4	8	1	4	50

LVA, lymphovenous anastomosis; TMR, targeted muscle reinnervation.

Table 5. Type of Anastomoses

Technique	Anastomoses n = 94	Diameter mm ± SD	Stitches Median ± IQR	Time per Stitch Minutes ± SD	Total Time Minutes ± SD
Artery end-to-end	19 (20.2)	1.8 ± 1.1	7 ± 1	4.6 ± 3.5	31.0 ± 20.7
Artery end-to-side	11 (11.7)	2.2 ± 0.9	11 ± 6	3.4 ± 1.5	37.4 ± 13.9
Vein end-to-end	46 (49.0)	2.3 ± 0.6	7 ± 1	3.1 ± 1.0	23.8 ± 9.2
Lymphovenous	2 (2.1)	0.4 ± 0.2	5 ± 0	5.6 ± 1.4	28.0 ± 7.1
Nerve coaptation	16 (17.0)	3.0 ± 1.3	4 ± 2	4.1 ± 1.5	16.5 ± 9.5

Values are reported as n (%), unless otherwise stated.

(three of 45; 6.7%). Conversion to the conventional anastomotic technique was necessary in one case (one of 50; 2.0%). Here, an arterial end-to-end anastomosis using a small intercostal perforator was attempted, in a previously irradiated patient undergoing autologous breast reconstruction. Owing to the history of irradiation, the fragility of the vessel wall prevented use of the robotic system.

Postoperative Outcomes and Complications

Minor complications occurred in three cases (three of 50; 6.0%), all of which were cases of delayed wound healing at the recipient site and were conservatively managed. A total of six major complications in five cases occurred (five of 50; 10.0%). Microvascular compromise was noted in three cases, with arterial thromboses occurring on the first postoperative day (three of 45; 6.7%). One case required two urgent revisions due to arterial and venous thrombosis, which was successfully treated with thrombectomy and reanastomosis of both vessels. All three flaps were salvaged with resection of the anastomosis followed by conventional anastomosis. A venous interpositional graft was used in one case. One partial flap loss occurred, requiring partial debridement and split thickness skin grafting, in the same case a hematoma at the recipient site lead to venous congestion of the flap. Wound healing complications at the donor site of a large ALT flap in one case required reoperation. No complete flap loss occurred. Table 6 summarizes the minor and major complications.

The mean length of stay in the hospital was 24.3 ± 15.6 days with an average length of postoperative stay of 15.5 ± 10.8 days. The mean follow-up duration was 66 ± 27 days.

Learning Curve

When comparing the final case time to the first case time, four of six surgeons improved when using the following formula: DeltaT% = $(T_{\text{final}} - T_{\text{initial}})/T_{\text{initial}}$*100% (S1: 45%; S2: −67.6%; S3: -52.8%; S4: 13.7%; S5: 57.1%; S6: 10.7%).

Table 6. Complications

Complication	Cohort n = 50
Major	6 (12)
Arterial compromise	3 (6)
Partial flap loss	1 (2)
Hematoma at recipient site	1 (2)
Wound healing disorder at donor site requiring skin graft	1 (2)
Minor	3 (6)
Delayed wound healing at recipient site	3 (6)

Values are reported as n (%), unless otherwise stated.

A Pearson correlation of the venous anastomoses of the senior author (S1) did not reveal a correlation of case time and number of cases (r = −0.15; *P* = 0.48). The last 50% of the venous anastomoses were not significantly faster than the first 50% (*P* = 0.53). Figure 4 depicts data on the learning curve in venous anastomoses.

DISCUSSION

In this prospective analysis of 50 cases of robot-assisted microsurgery, close to 100 individual anastomoses and coaptations were successfully performed, demonstrating the feasibility and safety of robot-assisted microsurgery.

Ever since the first robot-assisted microvascular anastomosis was performed by Van der Hulst et al in 2007 with the DaVinci Surgical System, robot-assisted microsurgery has been the topic of great scientific interest.[6] The DaVinci platform has been extensively used in plastic and reconstructive surgery, including for harvesting

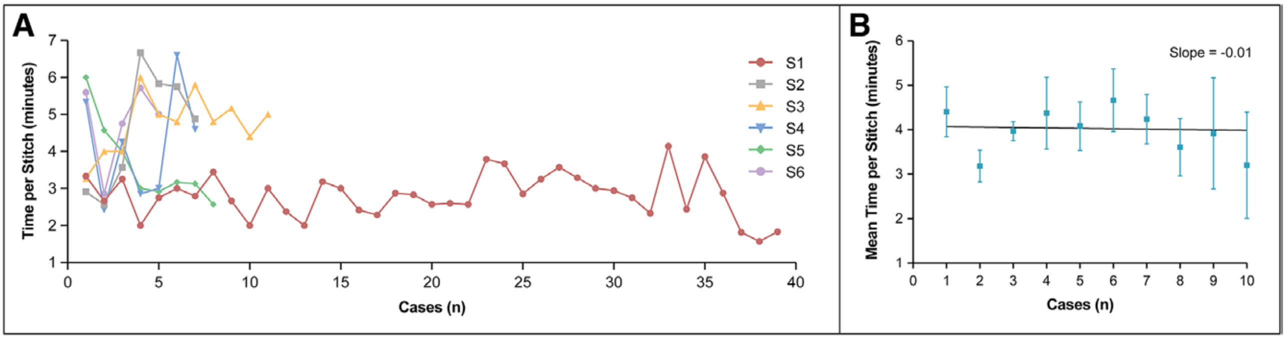

Fig. 4. A, Development of the time per stitch of venous anastomoses of the six participating surgeons (S1 is the senior author). B, Mean time per stitch for venous anastomoses of all participating surgeons.

the internal mammary vessels in autologous breast reconstruction or for vessel harvesting in latissimus dorsi free flap reconstruction.[14,15] The instruments of the DaVinci system, however, are not specifically designed for application in the field of microsurgery, and the robotic system is not compatible with conventional microscopes or exoscopes.

Prior literature has highlighted the presence of rapid learning curves in robot-assisted microsurgery, with operative time decreasing as the number of performed procedures and experience increase.[14] Notably, in two studies by van Mulken et al, providing data on silicone vessel and lymphatic anastomoses, although the final reported operating times of robotic procedures remained higher than the hand-sewn procedures, the trend appeared to suggest that with further experience the significant time difference would no longer be observed.[16,17] Barbon and colleagues also showed a learning curve for robot-assisted lymphovenous anastomoses.[18] In their clinical study of 32 robot-assisted anastomoses/coaptations, they showed a significantly longer time per lymphovenous anastomosis in the first half of the cases compared with conventional anastomoses. This difference was, however, insignificant in the second half of the cases, showing the steep learning curve associated with the procedure. A similar pattern was seen in our study, where a steep learning curve was also noted, albeit comparison of the first half of the senior authors' anastomoses to the second half, did not show any significant difference. Interestingly though, across the board, there was no significant correlation between number of anastomoses performed and time needed for anastomosis. It was noted that surgeons who irregularly used the robotic system displayed an increase in their operating times (Fig. 4). In most cases, the first performed anastomosis was the fastest. We hypothesize that this may be related to the longer intervals between the individual robot-assisted cases. This underlines the importance of steady exposure to robot-assisted microsurgery. When comparing our results with those of Barbon et al, it should be noted that in our cohort we mostly performed free flap reconstructions with venous and arterial anastomoses whilst Lindenblatt et al mostly performed lymphovenous anastomoses.[18] Furthermore, Lindenblatt et al did not mention their conversion rate, so that a bias due to earlier conversions compared with our cohort cannot be excluded.

Despite the extended time required for the robot-assisted anastomoses, we showed that robot-assisted microsurgery is safe and reliable with a low incidence of microvascular compromise and no complete flap losses in our study cohort. Our complication rates were comparable to those noted with conventional microsurgery, where the rate of microvascular compromise ranges from 5% to 10%.[19–21] Microsurgical complications were encountered in 6.0% of cases in our study. The rate of microvascular compromise of the free flap cases was 8.9%. All flaps were salvaged by emergent take-back and reanastomosis.

The prolonged operating times due to an increased time demand of robot-assisted microsurgery have been extensively reported by academic centers currently implementing robotic microsurgery.[6,16–18,22] Barbon et al compared hand-sewn to robot-assisted anastomoses and found a mean anastomotic time of 14 versus 25 minutes, respectively.[18] Lindenblatt et al reported that robot-assisted anastomoses required two to three times more time than conventional anastomoses.[9] Mulken and colleagues measured an average of 25 versus 9 minutes for robot-assisted and conventional lymphovenous anastomoses, respectively, using the MUSA robotic system.[17] Weinzierl and colleagues reported an average of 23 minutes in eight end-to-end arterial anastomoses.[23] In a randomized clinical trial comparing the use of a robotic platform with conventional laparoscopy in ventral hernia repair, Petro et al presented both an increase in operative time, as well as an increase in costs. Interestingly, the authors noted that the increase in costs was not associated with the expense of using disposable robotic instruments but rather was solely due to prolongation of the operative time. This highlights that with increased proficiency and, hence, efficiency of robotic surgery, costs can be contained.[24]

One of the procedures most amenable to the benefits of robot-assisted microsurgery is perforator-to-perforator anastomoses. In the current cohort, we performed six perforator-to-perforator anastomoses, enabling an end-to-end anastomosis of a short pedicle free flap to a side-branch of the recipient vessel. The concept of perforator-to-perforator free flap reconstruction in the lower extremity, which was popularized by Hong and Koshima,[25,26] remains relatively uncommon in most reconstructive centers. In a recent meta-analysis, Lo Torto et al found just 1047 reported cases of perforator-to-perforator flaps in the scientific literature.[27] The pooled flap failure rate reported was 6.8%. The six perforator-to-perforator flaps in our study cohort neither required revision nor suffered from complications. Perforator-to-perforator free flap transfer offers the benefits of shorter operating times, while simultaneously requiring less extensive dissection and, thus, being less invasive for the patient. This, however, comes at the price of an increased difficulty level and the necessity of superior microsurgical skills and instruments. With the use of robotic assistance, a wider range of microsurgeons may be able to successfully offer such more technically challenging procedures.

A commonly reported disadvantage of the robotic technique is a lack of tactile feedback, a disadvantage which is not, however, limited to robotics and has also been reported for manual microsurgery. Interestingly, the enhanced multidimensional visuals provided by the robot can compensate for this limitation.[28,29] Also reported by Lindenblatt et al and Innocenti et al, and seen in our experience, microsurgeons could learn a type of visual feedback that successfully replaced haptic feedback. Only in very fragile vessels were issues encountered due to lack of haptic feedback.[9–10] In our study cohort, we saw a very low incidence of conversion from robotic microsurgery to the conventional hand-sewn technique. Specifically, only one case had to be converted to the conventional technique: an arterial end-to-end anastomosis of a very fragile, and previously irradiated, intercostal perforator. Accordingly, 98% of the procedures scheduled for robotic microsurgery, had successful implementation of robotic assistance.

The results of this study need to be interpreted with consideration of its limitations. The greatest limitation of this study is the lack of randomization and comparison to the conventional standard technique of microsurgery. Furthermore, the mono-centric nature of this study predisposes to confounding bias. However, no patients were excluded based on demographic characteristics. In addition, as is frequently the case with studies involving surgical procedures, surgeons cannot be blinded to the procedure part of the study. Performance bias may also be present since not all procedures were performed by a single surgeon. All surgeons participating in this study, however, have extensive and comparable expertise in the field of microsurgery, procedures which they routinely perform. It should be noted that the variability among the surgeons' expertise was low enough to allow internal validity, but at the same time sufficiently different to reflect actual surgical practice and allow for external validity. Finally, the frequency with which the surgeons used the robotic system varied, which may have affected the operative times and performances.

CONCLUSIONS

Our study highlights the promising potential of robot-assisted microsurgery in a wide range of reconstructive scenarios. Despite the potential challenges, such as increased operating times and higher financial costs, the technology offers significant advantages, such as enhanced precision. Overall, our experience supports superior postoperative outcomes with robot-assisted surgery, although there seems to be a rather slow learning curve and a necessity for high caseloads and continuous, consistent, training. As proponents of robot-assisted surgery have previously stated, we must walk before we run.[30] Further studies, particularly of a larger and multicenter nature, are needed to refine the techniques and evaluate the longer-term outcomes and ergonomic benefits of robot-assisted microsurgery.

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DISCLOSURES

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