Accepted Manuscript online: 2024-01-05 Article published online: 2024-02-27

Conventional and Robot-Assisted Microvascular Anastomosis: Systematic Review

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J Reconstr Microsurg Open 2024;9:e27–e33.

Abstract

Background The complexity of plastic microsurgery yields many risks. Robot assistance has been sought to maximize outcome and minimize complications. Reportedly, it offers increased dexterity and flexibility with attenuated human flaws, such as tremors and fatigue. This systematic review will further investigate that claim.
Methods A systematic search was conducted for operative outcomes and operator experience of reconstructive plastic microsurgery compared between conventional and robot-assisted procedures. Data were summarized then meta-analyzed or qualitatively assessed and critically appraised to determine the difference robot assistance offers.
Results This review comprises four studies, mainly investigating robot-assisted microvascular anastomosis. Meta-analysis of anastomosis time reveals that robot assistance takes more time than conventional without offering substantial health-related improvements. However, it offers greater comfort, consistency, and flexibility for operators.
Conclusion Robot assistance lengthens operative times because of its relative lack of implementation and subsequent lack of experienced operators. Times were quick to be improved as repeated procedures were performed and technical complications can be resolved by more experience with robotic equipment. Furthermore, it generally offers better operator experience. Despite this, robot assistance does not offer a better health outcome compared with conventional anastomosis, although its benefits may lie in aesthetic outcomes instead. Exploration of that aspect as well as nonsummarizable health outcomes are the two primary limitations of this review that warrants further investigation into the subject.

Keywords
► microvascular anastomosis
► robot assistance
► plastic surgery

received
July 27, 2023
accepted after revision
December 18, 2023
accepted manuscript online
January 5, 2024

DOI https://doi.org/10.1055/a-2239-5212.
ISSN 2377-0813.

Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

Table 1 Inclusion and exclusion criteria for article selection

Inclusion	Exclusion
Comparison of robotics-assisted and conventional reconstructive plastic surgery	Secondary studies, case report, or review study
Primary studies	Articles unavailable in English
Published within 5 years (2018–2023)	Nonpatient subjects (silicone analogues, cadavers, etc.)
Reporting of outcomes	–

Surgery has been one of medicine's most crucial stepping stones, providing chances for curative and life quality improvement across the nation. Therefore, many have strived to improve surgery techniques to gain better outcomes, utilizing the latest technology and science. Despite already using the most advanced and up-to-date procedures, certain risks are still inevitable, prompting patients' safety throughout the process. Notably, plastic microsurgery is more complicated than other plastic surgery procedures, as highlighted by the American College of Surgeons Quality Improvement Program.[1]

Among various alternatives, robotic assistance has been sought as a potential method to maximize the outcome of surgery and minimize the complication rate. Robotic assistance provides the upper hand when it comes to precision and flexibility. Not to mention, it also allows minimally invasive approaches and reduces surgeon's errors, particularly tremors. Still, doubts linger around the time efficiency accomplished through this method.[2]

Therefore, this systematic review explores the superiorities and shortcomings of robotic-assisted microsurgery in plastic surgery compared with humans, based on time-lapse, morbidity, and user feasibility.

Methods

Studies comparing operating times, postoperative outcomes, and complications between robot-assisted and conventional microsurgery for plastic and reconstructive surgery procedures were searched for systematic review. All primary study types were included for data synthesis. Conversely, secondary studies were excluded. Additionally, primary studies comparing outcomes in nonpatient subjects, such as silicone analogs or cadavers, were excluded. The unfortunate lack of the author's linguistic resources excluded studies without full English texts available. Finally, this review limited its scope to literature published within 5 years (2018–2023) of writing. These criteria are summarized in ►**Table 1**.

MEDLINE, Embase, and CENTRAL databases were searched for articles that meet the stated eligibility criteria using PubMed, Cochrane Library, and Embase interfaces. The complete search queries and Boolean operators for each of these interfaces are displayed in ►**Table 2**. All these databases were accessed and had articles extracted from March 13, 2023. Three reviewers working independently conducted the search and subsequent selection process to provide a final list of articles to be included for synthesis. Discrepancies between them were resolved through open discussion.

Five different independent reviewers performed data extraction with the same resolution for disagreements. Outcomes extracted were intraoperative times, postoperative outcomes, and complications with no restriction on follow-up times. Synthesis was conducted qualitatively as a systematic narrative review.[3] Eligible data were meta-analyzed using Review Manager 5.4.1.[4]

A risk of bias assessment was then conducted by another eight reviewers independently and with open discussion for conflict resolution. All the final articles were determined to be either retrospective or prospective studies. Therefore, the Newcastle–Ottawa Scale (NOS) was chosen as the assessment tool.[5]

Results

►**Fig. 1** illustrates the article selection process. The search queries yielded 12, 1, and 13 results from Embase, Cochrane Library, and PubMed. Two duplicates were excluded then 18 studies were identified as secondary studies and excluded. Full-text screening of the remaining five articles revealed that none were eligible for the exclusion, thus included for analysis and synthesis. The specific procedures deployed are

Table 2 Search queries for each utilized search interface

Interface	Search query	Additional restrictions
Embase	("robot assisted surgery"/exp OR "robot assisted surgery") AND ("plastic surgery"/exp OR "plastic surgery") AND ("reconstructive surgery"/exp OR "reconstructive surgery" OR "reconstructive surgery") AND ("microsurgery" OR "microsurgery"/exp OR microsurgery) AND [2018-2023]/py AND "article"/it	–
Cochrane Library	("Robotic Surgical Procedures"[Mesh] OR "robotic") AND ("Surgery, Plastic"[Mesh] OR "plastic surgery") AND ("Microsurgery"[Mesh] OR "microsurgery") AND "reconstructive surgery"	Publication date: 2018–2023
PubMed	("Robotic Surgical Procedures"[Mesh] OR "robotic") AND ("Surgery, Plastic"[Mesh] OR "plastic surgery") AND ("Microsurgery"[Mesh] OR "microsurgery") AND "reconstructive surgery"	Publication date: 2018–2023

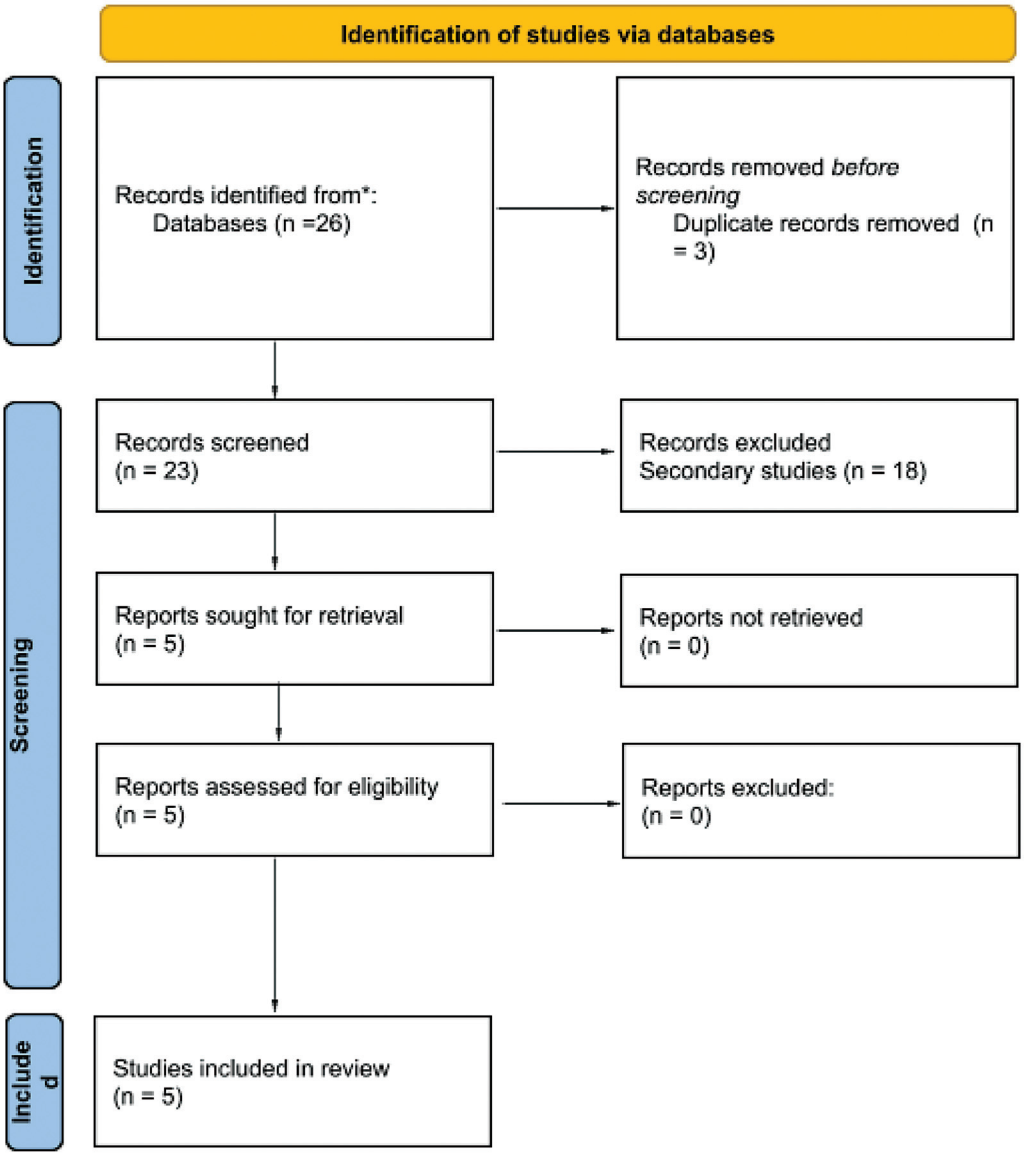

Fig. 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) flow diagram illustrating the article selection.

stated in ►**Table 3**. Studies extracted were treated as cohort studies by this review despite being classified as case series by the authors as it meets the criteria put forth by Mathes and Pieper,[6] considering the often unclear delineation.

The risk of bias assessment in this paper used NOS. Three main components are evaluated: Selection, Compatibility, Comparability, and Outcome.[5] In the Selection component, three out of four papers used did not concern selection aspects, whereas Dermietzel et al[7] lacked an explanation of the components of Representative of the exposed Cohort, Selection of the nonexposed Cohort, and Ascertainment of Exposure. Therefore, it is impossible to assess how generalizable or applicable the study is to a larger population. This can lead to biased or incorrect conclusions, which can be a significant problem regarding both scientific accuracy and practical implications. In the Comparability component, no study had issues. This indicates that all groups studied in the studies had similar characteristics on various important aspects, except for the aspect being studied. The outcome was also found to be adequate in all four studies. These findings are summarized in ►**Table 4**.

The papers showcase anastomosis in the context of flap transfers. All anastomoses fulfilled our inclusion criteria, regardless of flap harvest and transfer procedures. Individually, the studies report on different intraoperative or postoperative parameters, as shown in ►**Table 5**, except for Lindenblatt et al[8] who directly reported the comparison. Furthermore, they also report on qualitative, subjective data from operators performing the procedures. A common parameter investigated is operative time, as shown in ►**Table 6**. Consistently, robot-assisted procedures take significantly more time to finish. However, operators quickly learn the devices, and operative times drop quickly and consistently. Furthermore, van Mulken et al[9] presented that while robotic-

Table 3 Characteristics of included studies

Title	Author	Study type	Robotic equipment	Procedure
Robot-assisted microvascular anastomosis in head and neck free flap reconstruction: preliminary experiences and results	Lai et al[15]	Retrospective cohort	da Vinci Surgical System	Microvascular anastomosis before inset radial forearm flap in the oropharyngeal defect for extirpation of oropharyngeal cancer and cervical lymphadenectomy
First-in-human robotic supermicrosurgery using a dedicated microsurgical robot for treating breast cancer-related lymphedema: a randomized pilot trial	van Mulken et al[9]	Prospective cohort	MicroSure's MUSA	Lymphaticovenous anastomosis in patients suffering from Stage 1 and 2 of the International Society of Lymphology classification, mild, persistent, or fibrotic breast cancer-related unilateral lymphedema of the arm refractory to complex decongestive therapy
Exploring the learning curve of a new robotic microsurgical system for microsurgery	Barbon et al[10]	Retrospective cohort	Symani Surgical System	Lymphovenous anastomoses and arterial anastomoses for free-flap transfer or free vascularized lymph node transfers Lympholymphatic anastomoses and epineural coaptations for unspecified procedure
Early experience using a new robotic microsurgical system for lymphatic surgery	Lindenblatt et al[8]	Prospective cohort	Symani Surgical System	Lymphovenous, lympholymphatic, and arterial anastomoses for lymphedema, lymph node transfer, and postresection arterial flaps
Free flap breast reconstruction using a novel robotic microscope	Dermietzel et al[7]	Retrospective cohort	RoboticScope	Microvascular anastomoses for autologous breast reconstructions via free tissue transfer with DIEP or PAP flap

Abbreviations: DIEP, deep inferior epigastric perforator; PAP, profunda artery perforator.

Table 4 Summary of critical appraisal using Newcastle–Ottawa Scale for cohort studies

Study ID	Selection (max 4 stars)	Comparability (max 2 stars)	Outcome (max 3 stars)
Barbon et al[10]	****	**	**
van Mulken et al[9]	****	**	*
Dermietzel et al[7]	*	**	*
Lai et al[15]	****	**	*
Lindenblatt et al[8]	****	**	***

assisted operative times tend to drop and are more consistent, conventional operative times do not and have more extreme variation.

The times for a single microvascular anastomosis were eligible for meta-analysis. Data were available as summarized estimates and distributed heterogeneously among the four studies. Therefore, the inverse variance method and the random-effects model were deployed.[4] The analysis results are displayed in ►**Table 7** and ►**Fig. 2**.

Discussion

Robot-assisted microsurgery requires higher overall surgical time compared with conventional microsurgery. But the overall surgical time is reduced over time with every robot-assisted microsurgery, showing a steep learning curve. Besides overall surgical time, most surgical outcomes, such as ischemia time and intraoperative complications for robot-assisted and conventional microsurgery, do not differ significantly.

The general consensus among our included studies was that the increased intraoperative time was due to system errors and unfamiliarity with the equipment. Lindenblatt et al[8] highlighted the contribution of sticky instruments after usage toward the long surgery times. With increased case

Table 5 Objective parameters measured in each study

Author	No. of stitches	Recipient blood vessel diameter (mm)	Donor blood vessel diameter (mm)	Flap ischemia (min)	Discharge time (d)	Lymph-ICF at 1 month[a]	UEL at 1 month[a]	Lymph-ICF at 3 months[a]	UEL at 3 months[a]
Lai et al[15]	–	Conventional: 3.1 ± 1.1 Robot-assisted: 2.5 ± 0.7	Conventional: 2.5 ± 0.6 Robot-assisted: 2.1 ± 0.8	–	–	–	–	–	–
van Mulken et al[9]	–	–	–	–	–	Conventional: 29 ± 21 Robot-assisted: 28 ± 17	Conventional: 125 ± 20 Robot-assisted: 114 ± 24	Conventional: 29 ± 19 Robot-assisted: 22 ± 16	Conventional: 125 ± 19 Robot-assisted: 113.01 ± 21
Barbon et al[10]	Conventional: 6.1 ± 1.5 Robot-assisted: 6.8 ± 1.8	–	–	–	–	–	–	–	–
Dermietzel et al[7]	–	–	–	Conventional: 52 ± 22 Robot-assisted: 54 ± 8	Conventional: 6 ± 1 Robot-assisted: 7 ± 3	–	–	–	–

Abbreviations: Lymph-ICF, Lymphedema Functioning, Disability, and Health score; UEL, Upper Extremity Lymphedema index.
Note: Outcomes presented are extracted means and significant difference was found between robot-assisted and conventional groups.
[a]No significant difference between the periods.

experience and frequent tool washing, surgeons may close the gap between the operative times of robot-assisted surgeries and the conventional methods classically trained for. Another factor that increases the surgical time and the time of patients under anesthesia is the time used to set up and dock the robot. Another drawback of robot-assisted microsurgery is that blood staining makes the instrument sticky. Although these difficulties can be overcome by frequent instrument rinsing, this method will add another time loss to the overall surgical time.

The lack of haptic feedback is a drawback of currently implemented robotic systems. Barbon et al[10] specifically attribute this loss of tactility as the cause of thrombosis during anastomosis for breast reconstruction. Reportedly, the vessel lumen was dilated by a robot that applied force unadjusted by haptic feedback that damaged the intima. Although certain procedures may rely on visual cues instead of tactile feedback during manipulation, such as determining appropriate tension for tying knots, this requires better-trained personnel.[8]

The patient is neither the sole beneficiary nor recipient of potential pitfalls of robot-assisted surgery. The robotic arms can hold a position indefinitely and do not inevitably fatigue. No matter how well trained and experienced, fatigue is a physiological phenomenon coupled with uncontrollable physiological responses, such as twitching.[10] Tremor, precision, and accuracy are intrinsic to an individual's hand and are subjectively affected by a wide range of physiological and psychological factors.[11]

Robotic assistance also uncouples surgeons' posture from their vision and motion range. This allows maintenance of ergonomics with a straight spine and relaxed neck. The pain afflicting 21.6% of surgeons arising from operating microscope usage, as well as back illness and physical stress, may be alleviated by robot-assisted procedures.[12,13]

Postoperative outcomes were not found to be significantly different with robotic assistance. Neither improvement nor decline was found for survival and complications. However, literature other than those included in this review found that, aesthetically, robot-assisted surgery yielded better results than conventional surgery. Robot equipment can approach the procedure with smaller incisions that are less apparent and easier to conceal. The excellent field of vision provided by the robotic camera and the flexibility of its operating arms contribute to this ability. Furthermore, better control and visualization resulted in better symmetry of the final result and a smaller final scar and, despite absent statistical evidence, surgeons reported that, subjectively, robot assistance helps the more delicate movements required for fragile environments.[8,14]

The limitation of this review is that a lot of the studies use only one or two experienced surgeons. While limiting the study to a single surgeon's experience has advantages, such as precluding the factors from the surgical technique or decision-making, a larger trial is needed for better evidence. It is also better to vary the skill or experience of the surgeons to see the learning curve for younger microsurgeons. Furthermore, aesthetic outcomes were not evaluated despite

Table 6 Operative times from each study were extracted

Author	*N*		Operative time[a]	
	Conventional	Robot-assisted	Microvascular anastomosis only (min)	Total (h)
Lai et al[15]	17 vessels	26 vessels	Conventional: 28.0 ± 7.7 Robot-assisted: 38.4 ± 10.4	–
van Mulken et al[9]	14 vessels	26 vessels	Conventional: 9 ± 6 Robot-assisted: 25 ± 6	–
	12 patients	8 patients	–	Conventional: 81 Robot-assisted: 115
Barbon et al[10]	11 anastomoses	32 anastomoses	Conventional: 4.1 ± 4.3 Robot-assisted: 25.3 ± 12.3	–
Dermietzel et al[7]	10 patients	5 patients	Conventional: 25 ± 7 Robot-assisted: 31 ± 7	–
Lindenblatt et al[8]	10 vessels	8 vessels	Robot-assisted: up to 2–3 times slower than Conventional	–

Note: Bolded entries represent significant differences between conventional and robot-assisted groups.
[a]Outcomes presented are extracted means.

Table 7 Microvascular anastomosis time summary estimates and heterogeneity

Study	Robot-assisted		Conventional		Weight	Mean difference (95% CI)
	Mean microvascular anastomosis time (min)	No. of vessels	Mean microvascular anastomosis time (min)	No. of vessels		
Barbon et al[10]	25.3 (12.3)	32	4.1 (4.3)	11	26.0%	21.20 (16.24, 26.16)
Dermietzel et al[7]	31 (7)	5	25 (7)	10	20.8%	6.00 (−1.51, 13.51)
Lai et al[15]	38.4 (10.4)	26	28 (7.7)	17	25.1%	10.40 (4.98, 15.82)
van Mulken et al[9]	25 (6)	26	9 (6)	14	28.1%	16.00 (12.1, 19.9)
Total	–	89	–	52	100%	13.86 (8.08, 19.64)

Abbreviation: CI, confidence interval.
Notes: $Tau^2 = 27.02$; $Chi^2 = 14.53$; df = 3 (p = 0.002); $I^2 = 79\%$; Z = 4.70 ($p < 0.01$).

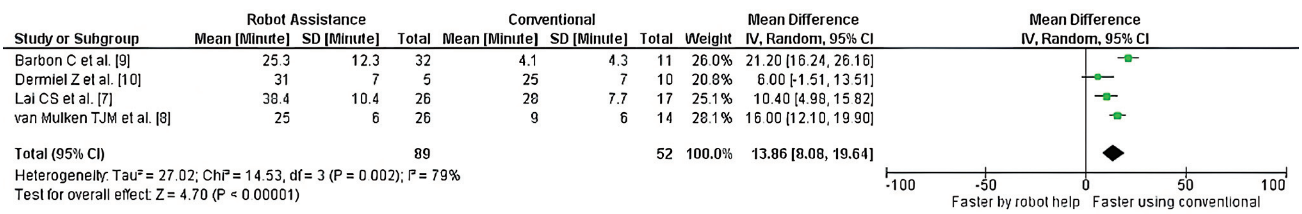

Fig. 2 Forest plot for microvascular anastomosis time. CI, confidence interval; SD, standard deviation.

being a major advantage of robot assistance. Another limitation of this review is that all the analyses were done qualitatively. Improvements can be made by doing the review again in the future when the studies are much more abundant, being more specific on the procedure and outcome that are analyzed and adding meta-analysis to the review.

Conclusion

Robot-assisted surgery provides an opportunity for a more comfortable postoperative surgical experience both for patients and operators. Patients can expect better aesthetic results and operators to have a less painful job experience in the long term. The major disadvantages of robot-assisted surgery, such as lack of haptic feedback and long operative times, stem from the novelty of its utilization and the lack of personnel specifically trained or experienced in these devices. Hence, it must be highlighted that robot-assisted surgery does not offer better surgical outcomes than conventional surgeries.

Conflict of Interest
None declared.

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