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SPECIAL TOPIC

Reconstructive

The Value of a Co-surgeon in Microvascular Breast Reconstruction: A Systematic Review and Meta-analysis

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Summary: Using a co-surgeon model has been suggested to improve perioperative outcomes and reduce the risk of complications. Therefore, we evaluated if a co-surgeon model compared with a single microsurgeon model could decrease the surgical time, length of stay, rate of complications, and healthcare-associated costs in adult patients undergoing microvascular breast reconstruction (MBR). A comprehensive search was performed across PubMed MEDLINE, Embase, and Web of Science. Studies evaluating the perioperative outcomes and complications of MBR using a single-surgeon model and co-surgeon model were included. A random-effects model was fitted to the data. Seven retrospective comparative studies were included. Ultimately, 1411 patients (48.23%) underwent MBR using a single-surgeon model, representing 2339 flaps (48.42%). On the other hand, 1514 patients (51.77%) underwent MBR using a co-surgeon model, representing 2492 flaps (51.58%). The surgical time was significantly reduced using a co-surgeon model in all studies compared with a single-surgeon model. The length of stay was reduced using a co-surgeon model compared with a single-surgeon model in all but one study. The log odds ratio (log-OR) of recipient site infection (log-OR = −0.227; P = 0.6509), wound disruption (log-OR = −0.012; P = 0.9735), hematoma (log-OR = 0.061; P = 0.8683), and seroma (log-OR = −0.742; P = 0.1106) did not significantly decrease with the incorporation of a co-surgeon compared with a single-surgeon model. Incorporating a co-surgeon model for MBR has minimal impact on the rates of surgical site complications compared with a single-surgeon model. However, a co-surgeon optimized efficacy and reduced the surgical time and length of stay. *(Plast Reconstr Surg Glob Open 2024; 12:e5624; doi: 10.1097/GOX.0000000000005624; Published online 5 February 2024.)*

INTRODUCTION

To improve healthcare quality, perioperative outcomes of complex procedures such as operative time and length of stay are often subject to continuous assessment.[1] Due to the inherent intricacies of reconstructive microsurgical procedures and their associated extended anesthesia time, surgeons are often required to balance patient safety, efficiency, and optimal clinical results.[1] On this matter, previous reports have found that when approaching complex microsurgical cases by specialized multidisciplinary teams, outcomes are usually improved.[2,3]

To optimize perioperative results, several strategies have been developed. For instance, the use of virtual surgical planning and computed tomography angiography to identify adequate perforators has caused a reduction in surgical time and shorter length of stay.[4–6] Furthermore, the enhanced recovery after surgery protocol has been increasingly implemented across the United States, demonstrating reduced use of opioid analgesia and length of stay without negatively altering patient-reported outcomes or the rate of complications.[7–9]

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Other strategies to optimize perioperative outcomes include running simultaneous operating rooms by a single surgeon. Using this approach, the critical portion of a long procedure is performed by the attending surgeon, while the remaining portion can be safely completed by a competent surgical assistant/resident.[1] Nonetheless, some cases may require the attending surgeon to be present for almost all the procedure, making the use of simultaneous operating rooms unsafe or unfeasible.[1] Another strategy to optimize perioperative outcomes can be the incorporation of a co-surgeon.[10–15] With this modality, critical steps of complex microsurgical reconstructive procedures can occur concurrently rather than in sequence.[1]

Reduced operative time, shorter length of stay, and lesser healthcare-associated costs have been reported with a co-surgeon model for the ablative segment of breast oncologic procedures (mastectomy),[10–12] whereas reduced estimated blood loss,[14,15] complication rates,[14] requirements of narcotics,[15] operative time, and improved operating room utilization costs have been reported in the field of orthopedic and neurological surgery with a co-surgeon.[13–15] The purpose of this review was to evaluate the role of a co-surgeon model for microvascular breast reconstruction (MBR) in plastic surgery. Our research question was as follows: In adult patients undergoing MBR (population), can a co-surgeon model (intervention) when compared with a single microsurgeon model (comparison) decrease the surgical time, length of stay, the rate of complications, and healthcare-associated costs (outcome) during the perioperative period (time)?

PATIENTS AND METHODS

Literature Search

A comprehensive search was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[16,17] We searched PubMed, MEDLINE, Embase (Elsevier, Netherlands), and Web of Science (Clarivate Analytics PLC) from database inception through March 3, 2023. The following terms were used in different combinations: “co-surgeons,” “cosurgeons,” “co-surgeon,” “cosurgeon,” “surgeon,” “microsurgeons,” microsurgery,” “free flap,” “flap,” “microvascular,” “microsurgical,” “reconstruction,” “microsurgery/methods”[MeSH], “surgeons”[MeSH], and “perforator flap”[MeSH]. (**See appendix, Supplemental Digital Content 1,** which shows search strategy across different databases. **http://links.lww.com/PRSGO/D74**.) We manually searched the bibliography of relevant articles to complement our electronic search.

Selection Process

We included case-control studies, cohort studies, and randomized clinical trials evaluating the perioperative outcomes and complications of MBR using a single-surgeon model and co-surgeon model (two microsurgeons). Only articles written in English were included. Primary studies from different institutions were selected to decrease the probability of overlapping data. We excluded animal studies, reviews, case reports, conference abstracts, and poster presentations. We excluded articles reporting on MBR with simultaneous vascularized lymph node transfer, lymphovenous anastomosis/bypass, or innervated breast reconstruction (neurotization). Data evaluating clinical outcomes of three or more microsurgeons were not included in our analysis.

Takeaways

Question: Is there value in having two microsurgeons in breast reconstruction?

Findings: There is great value in having two surgeons in microsurgery.

Meaning: Having two microsurgeons is safer, and outcomes are better in breast reconstruction.

A two-stage screening process was performed by two independent reviewers (L.E. and J.M.E.). During the first stage, titles and abstracts were evaluated after duplicated references were removed. A full-text assessment was conducted during the second stage. The senior author (O.J.M.) addressed any conflicts for eligibility during the selection process.

Variables of Interest

Two independent reviewers extracted data on the number of patients, number of free flaps, follow-up, age, body mass index, comorbidities (eg, diabetes, hypertension), smoking status (current/nonsmoker), history of abdominal surgery, adjuvant systemic chemotherapy or radiotherapy, timing of reconstruction (immediate/delayed), type of free flaps used, laterality of the reconstruction (bilateral/unilateral), and surgical technique.

Perioperative surgical outcomes analyzed in this study included surgical time or anesthesia time (minutes), flap weight, number of perforators, length of stay (days), and healthcare-related costs. The complications analyzed for this review were as follows: return to the operating room (RTOR), red blood cell transfusion, pulmonary embolism, deep venous thrombosis, pneumothorax, seroma, surgical site infection, wound disruption, hernia, hematoma, fat necrosis, and flap loss.

A co-surgeon was defined as a microsurgeon who assisted partially or entirely during a case of MBR. RTOR was defined as any major complications requiring re-operation or the event of nonelective (urgent) operating room takeback. Wound dehiscence, delayed wound healing, and wound disruption were all incorporated within the spectrum of events defined as wound disruption. Superficial or deep surgical site infections were defined as surgical site infection.

Statistical Analysis

Estimates of the patients’ characteristics were calculated as weighted means ($\Sigma^{n}_{i=1}[xi*wi]/\Sigma^{n}_{i=1}wi$). For studies with an intervention group (co-surgeon model) and a control group (single-surgeon model), the analysis was carried out using the log odds ratio (log-OR) as the outcome measure with Jamovi.1.2.27.0 (Jamovi, Sydney, Australia). Back-transform from log-OR into OR was performed for all models. A random-effects model was fitted to the data. The

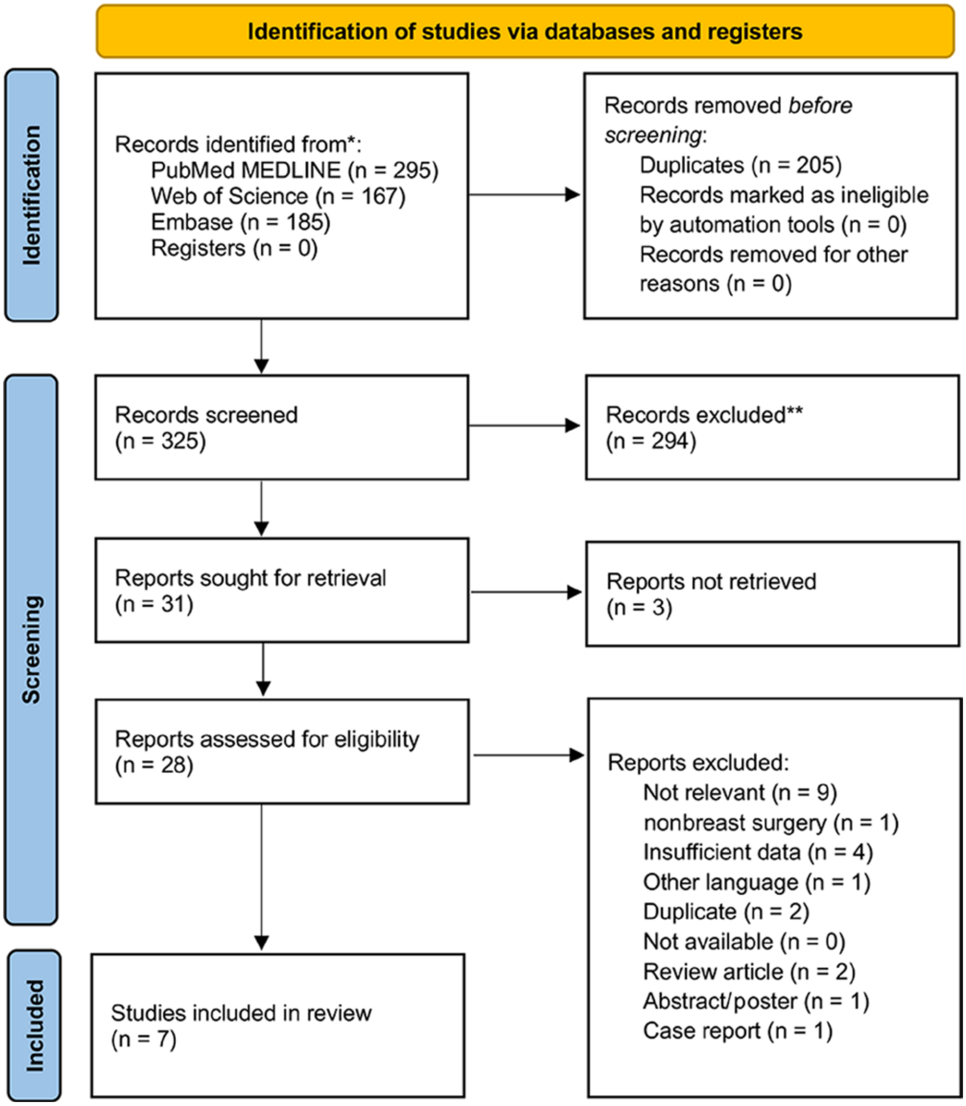


Fig. 1. PRISMA flowchart for the selection of studies. Outcomes of the systematic review of the literature by record identification, screening, and analysis in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement flow diagram. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

amount of heterogeneity (ie, tau^2) was estimated using the Sidik-Jonkman estimator.[18] In addition to the estimate of tau^2, the Q-test for heterogeneity and the I^2 statistic were reported.[19] Heterogeneity was regarded as moderate, substantial, and considerable when I^2 was between 30%–60%, 50%–90%, and more than 90%, respectively.[20] A regression test, using the standard error of the observed outcomes as a predictor, was used to check for funnel plot asymmetry.[21]

Quality Assessment

The level of evidence was assessed with the Oxford Center for Evidence-Based Medicine.[22] The Risk of Bias in Non-randomized Studies - of Interventions (ROBINS-I) instrument was used to evaluate the risk of bias in nonrandomized cohort studies.[23,24] Funnel plots were used to qualitatively assess the risk of bias for the models evaluating RTOR and total flap loss.

RESULTS

Study Characteristics

Seven retrospective comparative studies were included after the two-stage screening process was completed (Fig. 1).[1,25–30] The number of patients and flaps and the types of flaps used in each study are reported in Table 1. Most studies presented their outcomes using a two-cohort methodology evaluating the results of a single surgeon versus co-surgeon model.[25,27–30] Gösseringer et al presented a

Table 1. Authors and Characteristics of Included Studies

Authors	Period	Type	LOE	Patients*	Type of Flaps	Flaps*	Follow-up (Mo)
Haddock et al[1]	2011–2016	Retr.	IV	128	DIEP	256	1
Bauermeister et al[25]	2010–2016	Retr.	IV	50	MS-TRAM (74%) DIEP (24%) SIEA (2%)	77	NR
Gösseringer et al[26]	2011–2013	Retr.	IV	100	DIEP (100%)	100	NR
Razdan et al[27]	2014–2016	Retr.	IV	136	MS-TRAM DIEP SIEA	272	NR
Weichman et al[28]	2011–2014	Retr.	IV	157	DIEP (60%) MS-TRAM (20.2%) SIEA (1.6%) PAP (12.5%) TUG (0.4%) SGAP (2%) Stacked DIEP (3.2%)	248	NR
Asaad et al[29]	2010–2017	Retr.	III	8680†	NR	13,537†	3
Mericli et al[30]	2016–2018	Retr.	III	150†	B/L DIEP (59.3%) DIEP/TRAM (18%) B/L TRAM (14%) B/L PAP or TUG (7.3%) SIEA/DIEP (NR) SIEA/TRAM (NR)	300†	15

*Before propensity score matching.

†The number of patients/flaps included in the formal analysis could be different depending on the subjects included in the "single surgeon" and "co-surgeon" group.

B/L, bilateral; DIEP, deep inferior epigastric perforator; LEO, level of evidence; MS, muscle-sparing; PAP, profunda artery perforator; Retr., retrospective; SIEA, superficial inferior epigastric artery; SGAP, superior gluteal artery perforator; TRAM, transverse rectus abdominis muscle; TUG, transverse upper gracilis; NR, not reported.

comparative study evaluating outcomes using one, two, and three microsurgeons.[26] The cohort in which three microsurgeons participated was excluded.[26] Haddock et al presented a three-cohort analysis: a single surgeon group and two co-surgeon cohorts.[1] The two co-surgeon cohorts were as follows: (1) a CSR-I group (in which co-surgery was performed by both surgeons for the entire case) and (2) CSR-II (where co-surgeons appropriately assisted in two concurrent or staggered cases and therefore both surgeons were not present for the entire case).[1] For this study by Haddock et al,[1] the former group (CSR-I) was included in our analysis, and the latter was excluded, as insufficient data were provided for the segments in which both microsurgeons were present (CSR-II).[1]

Characteristics of Patients

Ultimately, 1411 patients (48.23%) underwent MBR using a single-surgeon model, representing 2339 flaps (48.42%). On the other hand, 1514 patients (51.77%) underwent MBR using a co-surgeon model, representing 2492 flaps (51.58%). Three studies only included bilateral reconstructions (Table 2).[1,27,30] One study included only unilateral reconstructions.[26] Three studies included both unilateral and bilateral reconstructions.[25,28,29] The mean or median age of patients ranged from 47.4 to 54 years.[1,25–30] The mean or median body mass index of patients ranged from 25.4 to 31.2 kg per m^2.[1,25–30] One study included only delayed reconstructions.[26] The rest of the studies included delayed and immediate reconstructions in their analysis.[1,25,27–30]

The percentages of patients with a medical history of diabetes or hypertension were similar between the co-surgeon and single-surgeon groups in most studies.[1,25,29,30] Likewise, the proportion of smokers who underwent reconstruction with a co-surgeon and single-surgeon model were similar in most studies.[1,25–28,30] The percentage of patients who had systemic chemotherapy or radiotherapy was also comparable between the co-surgeon and single surgeon cohorts in most studies (Table 3).[1,25–27,29,30]

Surgical Outcomes

Six studies evaluated the surgical or anesthesia time and the length of stay comparing the co-surgeon versus the single-surgeon model (Table 4).[1,25–28,30] The surgical time was significantly reduced using a co-surgeon model in all studies compared with a single-surgeon model (Fig. 2).[1,25–28,30] In the study by Mericli et al, the role of a co-surgeon was more common during recipient vessel dissection plus elevation of one of the flaps (22.2%) or during recipient vessel dissection only (22.2%).[30] The authors from this study highlighted that the greatest reduction in surgical time was achieved when a co-surgeon performed the recipient vessel dissection and anastomoses and the primary surgeon performed flap elevation, inset, and donor-site closure ($P < 0.05$).[30]

The length of stay was reduced using a co-surgeon model compared with a single-surgeon model in all but one study (Fig. 3).[1,25–28,30] Although an increased length of stay was evident using a co-surgeon model compared with single surgeon-model in the study by Razdan et al, the difference was not significant (5.0 ± 2.2 days versus 4.8 ± 1.5 days, $P = 0.54$).[27]

Complications

The rates of different complications for the recipient site/breast are summarized in Table 5.[1,25–30] Although

Table 2. Demographic and Surgical Characteristics of Included Subjects

Study	Modality	Patients	Flaps	Laterality	Age (y)	BMI (kg/m^2)	Timing
Haddock et al[1]	SS	35 (27%)	70 (27%)	Bilateral: 35 (100%)	50 (range, 32—66)	29.2 (range, 19.2–37.1)	Immediate: 50% Delayed: 50%
	CoS	69 (54%)	138 (54%)	Bilateral: 69 (100%)	51 (range, 30—68)	31.2 (range, 24–44)	Immediate: 15.2% Delayed: 84.8%
Bauermeister et al[25]	SS	27 (54%)	40 (52%)	Bilateral: 13 (48.1%) Unilateral: 14 (51.9%)	51 (IQR, 48.5–56)	30.9 (IQR, 26.6–33.1)	Delayed: 27 (100%)
	CoS	23 (46%)	37 (48%)	Bilateral: 14 (60.9%) Unilateral: 9 (39.1%)	54 (IQR, 45–57.5)	28.3 (IQR, 26.1–31.6)	Immediate: 3 (13%) Delayed: 20 (87%)
Gösseringer et al[26]	SS	16 (16%)	16 (16%)	Unilateral: 16 (100%)	52.6 ± 9.29	25.4 ± 3.1	Delayed: 16 (100%)
	CoS	64 (64%)	64 (64%)	Unilateral: 64 (100%)	51.8 ± 8.5	26 ± 3.4	Delayed: 64 (100%)
Razdan et al[27]	SS	80 (59%)	160 (59%)	Bilateral: 80 (100%)	48.6	30.7	Immediate: 54 (67.5%) Delayed: 26 (32.5%)
	CoS	56 (41%)	112 (41%)	Bilateral: 56 (100%)	48.1	30.6	Immediate: 49 (87.5%) Delayed: 7 (12.5%)
Weichman et al[28]	SS	54 (34.4%)	78 (31.5%)	Unilateral: 30 (55.6%) Bilateral: 24 (44.4%)	51.48 ± 9.7	28.81 ± 5.8	Immediate: 64 (82.1%) Delayed: 14 (25.9%)
	CoS	103 (65.6%)	170 (68.5%)	Unilateral: 36 (35%) Bilateral: 67 (65%)	48.8 ± 8.2	25.7 ± 4.9	Immediate: 126 (74.1%) Delayed: 44 (25.9%)
Asaad et al[29]	SS	1149* (50%)	1875*	Bilateral: 726 (63%) Unilateral: 423 (37%)	50 ± 8	NR	Immediate: 655 (57%) Delayed: 494 (43%)
	CoS	1149* (50%)	1871*	Bilateral: 722 (63%) Unilateral: 427 (37%)	50 ± 8	NR	Immediate: 649 (56%) Delayed: 500 (43%)
Mericli et al[30]	SS	50* (50%)	100* (50%)	Bilateral: 50 (100%)	47.6	29.8	Immediate: 50.9% Delayed: 49.1%
	CoS	50* (50%)	100* (50%)	Bilateral: 50 (100%)	47.4	30.1	Immediate: 51.3% Delayed: 48.7%

*After propensity score matching.
CoS, co-surgeon model; IQR, interquartile range; NR, not reported; SS, single surgeon.

Table 3. Surgical History, Medical History, and Adjuvant Oncologic Treatment of Included Subjects

Author	Modality	Single	Previous Abd. Surgery	Smoker	Hypertension	Diabetes	Adj. ChT	RT
Haddock et al[1]	SS	35 (27%)	26 (74.3%)	13 (37.1%)	15 (42.9%)	3 (8.6%)	9 (25.7%)	13 (18.6%)
	CoS	69 (54%)	56 (81.2%)	27 (39.1%)	20 (29%)	7 (10.1%)	18 (26.1%)	35 (25.4%)
Bauermeister et al[25]	SS	27 (54%)	16 (59%)	1 (4%)	7 (26%)	4 (15%)	22 (81%)	6 (22%)
	CoS	23 (46%)	15 (65%)	2 (9%)	6 (26%)	3 (13%)	17 (74%)	3 (13%)
Gösseringer et al[26]	SS	16 (16%)	——	0 (0%)	—	—	—	10 (62.5%)
	CoS	64 (64%)	—	1 (1.6%)	—	—	—	45 (70.3%)
Razdan et al[27]	SS	80 (59%)	—	0 (0%)	—	—	—	29 (18.1%)
	CoS	56 (41%)	—	1 (1.8%)	—	—	—	17 (15.2%)
Weichman et al[28]	SS	54 (34.4%)	—	0 (0%)	—	—	—	—
	CoS	103 (65.6%)	—	0 (0%)	—	—	—	—
Asaad et al[29]	SS	1149* (50%)	—	—	365 (32%)	94 (8%)	—	107 (9%)
	CoS	1149* (50%)	—	—	368 (32%)	100 (9%)	—	123 (11%)
Mericli et al[30]	SS	50* (50%)	—	1.7%	4.6%	6.6%	—	38.6%
	CoS	50* (50%)	—	2%	4.5%	7.2%	—	39.4%

*After propensity score matching.
Abd., abdominal; Adj, adjuvant; ChT, chemotherapy; RT, radiotherapy.

there was a tendency toward a lower log-OR of RTOR or major complications requiring re-operation using a co-surgeon model compared with a single-surgeon model, no statistical difference was found [log-OR = −0.437; 95% confidence interval (CI) = −1.107 to 0.234; $P = 0.201$; Fig. 4]. Heterogeneity was moderate for the analysis of RTOR ($I^2 = 42.18\%$; Q = 10.689; $P = 0.579$). Although there was a tendency toward a lower log-OR of flap loss using a co-surgeon model compared with a single-surgeon model, no statistical difference was found (log-OR = −0.419; 95% CI = −1.504 to 0.665; $P = 0.4484$; Fig. 5). Heterogeneity for the analysis of flap loss was not clinically significant ($I^2 = 25.85\%$; Q = 4.418; $P = 0.6203$).

We evaluated the rate of recipient site infection, wound disruption, hematoma, and seroma. [**See Supplemental Digital Content 2,** which shows the effect of co-surgeon on the rate of recipient site infection, wound disruption, seroma, hematoma, and donor-site wound disruption. Point estimates and 95% CIs are shown (random-effects calculations for the meta-analysis.) **http://links.lww.com/PRSGO/D75.**] The log-OR of recipient site infection (log-OR = −0.227; 95% CI = −1.211 to 0.757; $P = 0.6509$),

Table 4. Surgical Time and Length of Stay Comparing Single Surgeon versus Co-surgeon Model

	Surgical Time (min)		Length of Stay (d)	
Study	**Single Surgeon**	**Co-surgeon**	**Single Surgeon**	**Co-surgeon**
Haddock et al[1]	678 (range, 423–1063)	485 (208–868)	5 (range, 3–11)	3.9 (range, 2–9)
Bauermeister et al[25]	588 (IQR, 450–666)	402 (IQR, 300–468)	4.8 (range, 4–8)	3.7 (range, 4–8)
Gösseringer et al[26]	286 ± 84 (range, 215–570)	265 ± 57 (range, 150–435)	6.9 ± 1.1	6.7 ± 0.62
Razdan et al[27]	608 (range, 419–1097)	555 (range, 334–1000)	4.8 ± 1.5	5 ± 2.2
Weichman et al[28]*	602.9 ± 117	468.5 ± 90.1	5.4 ± 2.1	4.1 ± 1.6
Weichman et al[28]†	385.9 ± 126	335.8 ± 129	5.5 ± 3.5	3.7 ± 1.0
Asaad et al[29]	—	—	—	—
Mericli et al[30]	681 ± 17.5	574 ± 10.3	5.5 ± 0.7	5.2 ± 0.13

*Bilateral reconstructions for Weichman et al.

†Unilateral reconstructions for Weichman et al.

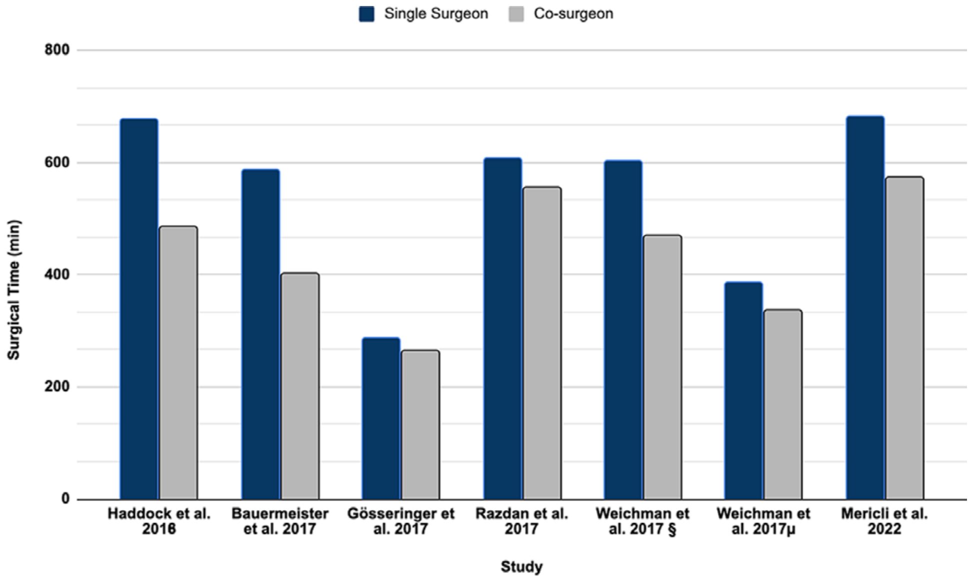


Fig. 2. Surgical time of included studies. §, Bilateral reconstructions for Weichman et al.[28] µ, Unilateral reconstructions for Weichman et al.[28]

wound disruption (log-OR = −0.012; 95% CI = −0.746 to 0.721; $P = 0.9735$), hematoma (log-OR = 0.061; 95% CI = −0.656 to 0.777; $P = 0.8683$), and seroma (log-OR = −0.742; 95% CI = −1.654 to 0.169; $P = 0.1106$) did not significantly decrease with the incorporation of a co-surgeon for MBR compared with a single-surgeon model. Heterogeneity was not clinically relevant for any of these models.

Donor-site complications or systemic complications were not thoroughly evaluated in all studies. However, the most consistent donor-site complication assessed in the included citations was wound disruption. Although there was a tendency towards a lower log-OR of donor-site wound disruption using a co-surgeon model compared with single-surgeon model, no statistical difference was found (log-OR = −0.593; 95%CI = −1.46 to 0.274; $P = 0.1802$). Heterogeneity was moderate for this analysis ($I^2 = 45.52\%$; $Q = 4.354$; $P = 0.3602$). (**See table, Supplemental Digital Content 3,** which shows systemic complications and donor-site morbidity. **http://links.lww.com/PRSGO/D76**.)

Cost Analysis

Although Haddock et al[1] acknowledged that costs related to operative minutes can vary to a great extent due to the region, type of procedure, and the inclusion/exclusion of fixed overhead costs,[31] they determined a cost savings of $4751.66 using a co-surgeon model compared with a single-surgeon model per case.[1] Using the estimates from previous reports,[32–34] Weichman et al estimated that a co-surgeon model would save as much as $7226.10 in bilateral reconstructions and $5865.90 in unilateral reconstruction.[28]

Initially, using time-driven activity-based costing principles for assistant, associate, and full professors, the implementation of a co-surgeon model increased the surgeon personnel costs relative to the single-surgeon model,

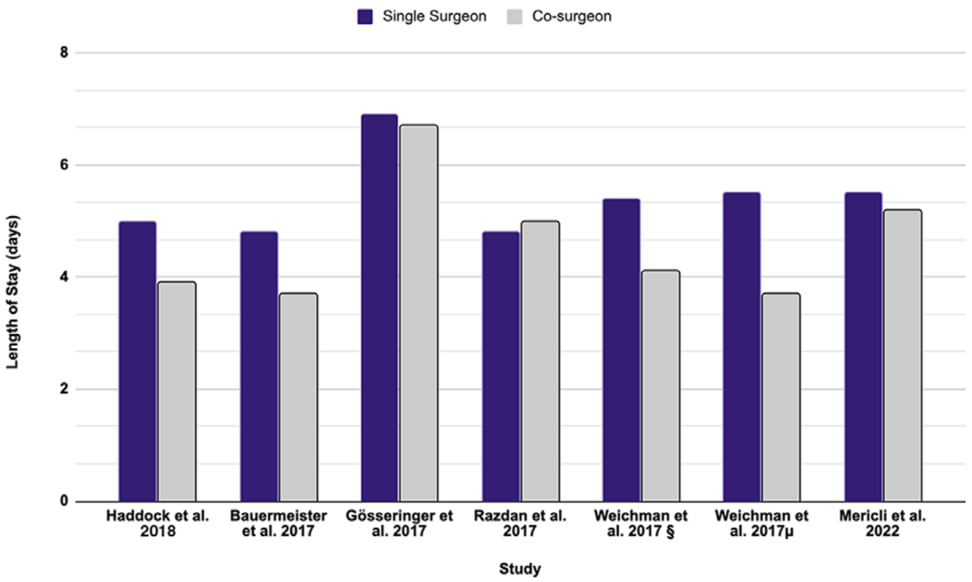


Fig. 3. Length of stay of included studies. §, Bilateral reconstructions for Weichman et al.[28] μ, Unilateral reconstructions for Weichman et al.[28]

Table 5. Recipient Site Complications

	Single Surgeon							Co-surgeon						
Author	**RTOR**	**Flap Loss**	**Fat Necrosis**	**SSI**	**Wound**	**Seroma**	**Hematoma**	**RTOR**	**Flap Loss**	**Fat Necrosis**	**SSI**	**Wound**	**Seroma**	**Hematoma**
Haddock et al[1]	8.6%	1.4%	4.3%	4.3%	21.4%	7.1%	2.9%	4.3%	1.4%	5.1%	3.6%	16.7%	2.2%	1.5%
Bauermeister et al[25]	4%	4%	—	4%	15%	0%	0%	4%	0%	—	0%	26%	0%	4%
Gösseringer et al[26]	25%	12.5%	—	—	—	—	—	14%	0%	—	—	—	—	—
Razdan et al[27]	16.2%	3.75%	5%	5%	—	1.25%	1.25%	3.57%	0.9%	0%	0%	—	0.9%	0%
Weichman et al[28]	—	0%	2.6%	—	2.6%	—	2.5%	—	0.6%	4.7%	—	4.1%	—	2.9%
Asaad et al[29]	5.83%	0.44%	—	1.57%	—	1.65%	1.22%	7.31%	0.52%	—	2.44%	—	0.96%	1.57%
Mericli et al[30]	13.9%	0%	—	3.2%	11.8%	3.7%	5.7%	5%	0%	—	0%	7.6%	0%	4%

SSI, surgical site infection.

according to Mericli et al ($2507.7 ± $52.27 versus $2148.9 ± $85.3; $P < 0.001$).[30] However, when evaluating the total cost (facility and surgeon personnel cost), using a co-surgeon model saved $1015.5 per case compared with a single-surgeon model ($8491.3 ± $157.7 versus $9506.80 ± $282; $P = 0.002$).[30] The authors highlighted that the greatest reduction in costs was achieved when the primary surgeon performed the flap elevation, inset, and donor-site closure, and a co-surgeon performed recipient vessel dissection and the anastomoses.[30]

Using a national database, Asaad et al demonstrated that 90-day overall healthcare costs (including surgery, admission, and follow-up) were higher, implementing a co-surgeon model compared with a single-surgeon model (US $76,227 versus $61,340; $P < 0.001$).[29] Using multivariable regression analysis, a co-surgeon model was identified to be a significant predictor for higher healthcare costs relative to a single-surgeon model (+13.5%).[29]

Quality Assessment

Five studies had a level of evidence of IV,[1,25–28] whereas two studies had a level of evidence of III.[29,30] Two studies had a propensity score-matched methodology, which decreased the impact of confounders or effect modifiers.[29,30] One study used the MarketScan Commercial Claims and Encounters database, which limited the granularity of data for clinical outcomes.[29] The funnel plot graphic for RTOR ($P = 0.1914$) and flap loss ($P = 0.4846$) suggested no evidence of publication bias, which was further supported by the Egger test meta-regression models (Fig. 6). Most studies had a moderate risk of bias (Fig. 7). These issues were mostly related to confounding factors altering the postoperative outcomes and concerns regarding patient selection for MBR with a co-surgeon model.

DISCUSSION

Apprehensions regarding the technical complexity, prolonged surgical time, surgical-site morbidity, poor

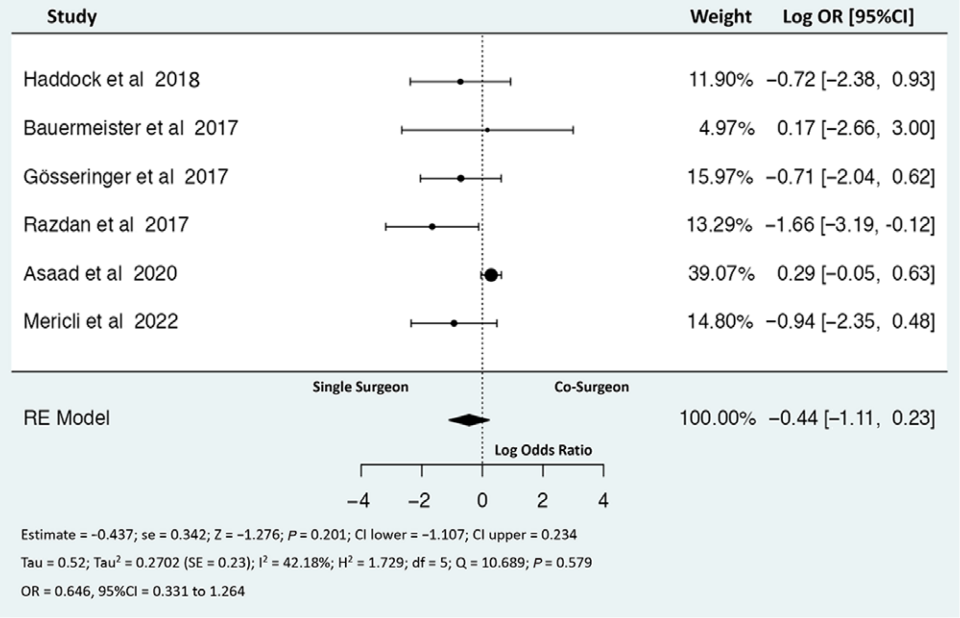


Fig. 4. Effect of co-surgeon on the rate of RTOR or major complications requiring re-operation. Point estimates and 95% CIs are shown (random-effects calculations for the meta-analysis).

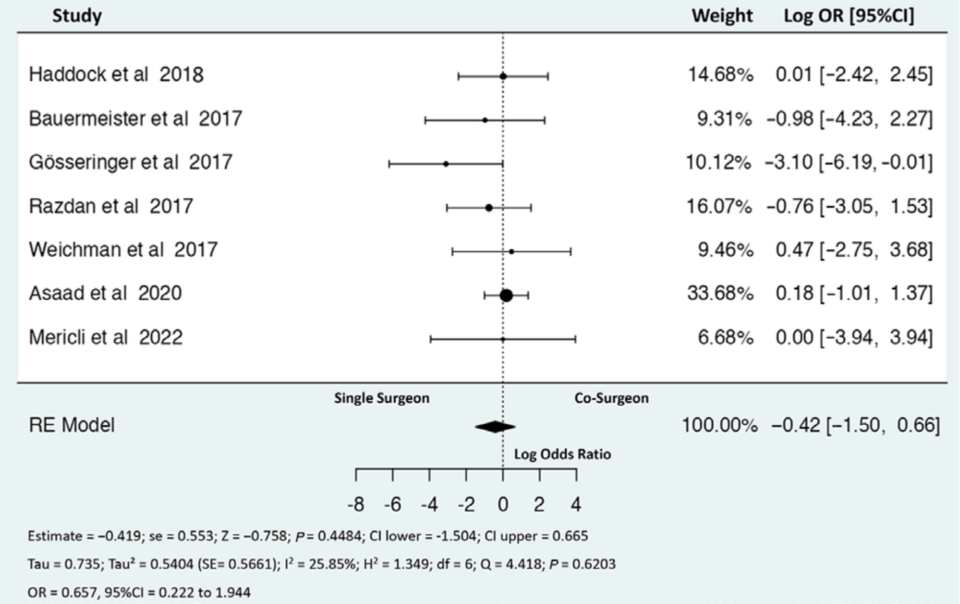


Fig. 5. Effect of co-surgeon on the rate of flap loss. Point estimates and 95% CIs are shown (random-effects calculations for the meta-analysis).

reimbursement patterns, and prolonged recovery with free tissue transfer continue to represent obstacles to the wide adoption of autologous breast reconstruction.[35–41] Therefore, implant-based breast reconstruction remains the most common technique.[35–41] In this setting, current efforts from surgeon scientists and researchers have been focused on strategies to reinforce patient safety and improve the postoperative course of autologous breast reconstruction.[42–44] The incorporation of a co-surgeon to optimize operative time and reduce general anesthesia duration has been promoted as a versatile strategy for increasing effectiveness while reducing the rate of complications related to MBR.[1,25,30,45]

In this systematic review, although we identified a tendency toward lower log-OR of RTOR, flap loss, and donor site wound disruption using a co-surgeon model compared with a single-surgeon model, we did not find that morbidity was significantly affected by the addition of a co-surgeon. On the other hand, adding a co-surgeon optimized efficacy by reducing the surgical time and length

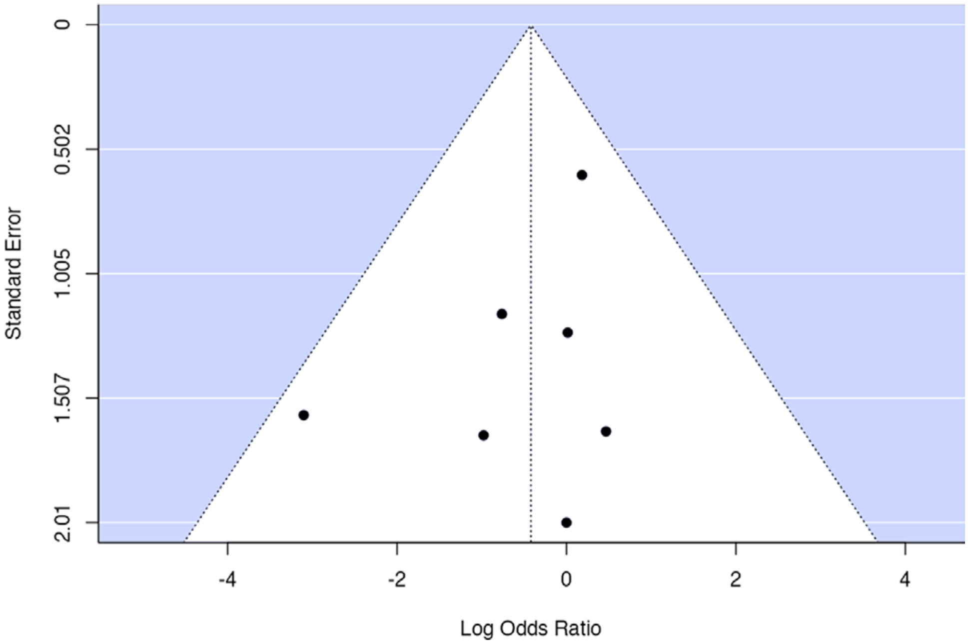
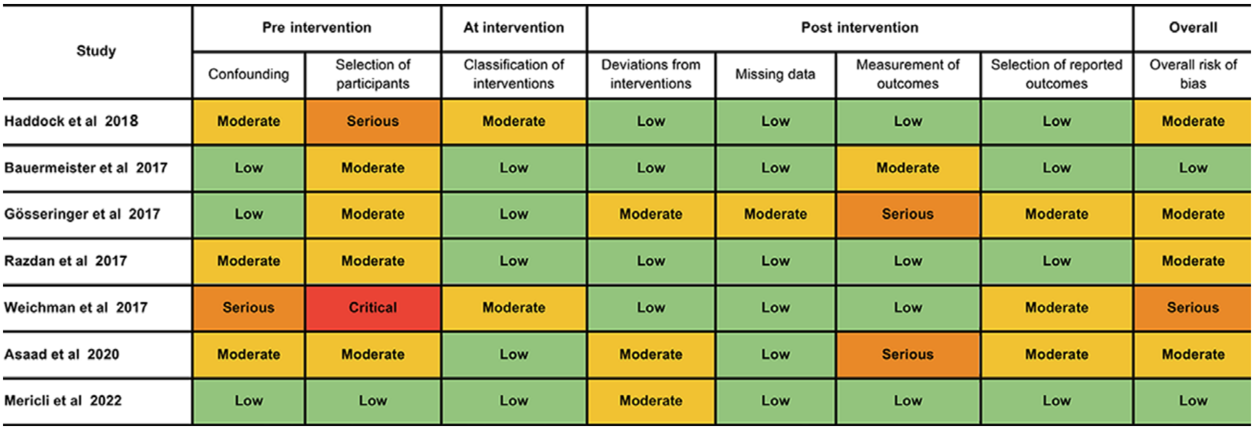


Fig. 6. Forrest plot evaluating the risk of bias for the rate of flap loss.



Study	Pre intervention		At intervention	Post intervention				Overall
	Confounding	Selection of participants	Classification of interventions	Deviations from interventions	Missing data	Measurement of outcomes	Selection of reported outcomes	Overall risk of bias
Haddock et al 2018	Moderate	Serious	Moderate	Low	Low	Low	Low	Moderate
Bauermeister et al 2017	Low	Moderate	Low	Low	Low	Moderate	Low	Low
Gösseringer et al 2017	Low	Moderate	Low	Moderate	Moderate	Serious	Moderate	Moderate
Razdan et al 2017	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
Weichman et al 2017	Serious	Critical	Moderate	Low	Low	Low	Moderate	Serious
Asaad et al 2020	Moderate	Moderate	Low	Moderate	Low	Serious	Moderate	Moderate
Mericli et al 2022	Low	Low	Low	Moderate	Low	Low	Low	Low

Fig. 7. Assessment of risk of bias with ROBINS-I, a tool for assessing risk of bias in nonrandomized studies of interventions.

of stay. Several studies have established a robust correlation between operation time and complications[46–50]; however, the association between this reduction in operative time and a reduction in the rate of complication is still uncertain for the specific case of a co-surgeon model. For instance, it has been hypothesized that by using a co-surgeon and the associated time-savings, morbidity can be reduced, as the primary surgeon can take additional time to inset the flap more carefully.[30]

In terms of cost-effectiveness, conflicting outcomes have been reported in published studies. For instance, one study found that the co-surgeon model was an independent predictor for higher healthcare costs (+13.5%) versus single-surgeon models.[29] Nonetheless, this study only evaluated the 90-day outcomes and did not account for a faster operating room turnover associated with reduced surgical time per case.[30] Furthermore, co-surgeons may engage in other clinical activities during the segments and their presence is not required, thus providing the opportunity or potential to increase productivity. On this matter, studies evaluating the cost-effectiveness of a co-surgeon model did not consider variables associated with co-surgeon reimbursement such as the use of modifiers, the different coding strategies, institution-specific and insurer-specific contractual details, and insurance company carve-outs, among others.[30] Finally, it is important to highlight that although a shorter anesthesia time may not signify a reduction in the charge billed to insurance companies, it may reduce costs incurred by healthcare institutions.[29]

Working closely with a peer attending or surgeon is not a novel model in healthcare.[51] Aside from the objective outcomes and quantitative parameters that can be evaluated, the intangible advantages of a co-surgeon model need to be discussed. Current practice in surgical and medical specialties favors the implementation of multidisciplinary teams, as it has been shown to improve patient outcomes and team dynamics.[51] Shared decision-making, mentorship, supervision, and the combination of experience and skills are facilitated by interactions with other attendings.[51,52] These features are of special consideration when approaching unacquainted, challenging, or less common procedures.[51] Furthermore, operating with an experienced surgeon offers a sense of peer-to-peer support, boosts confidence, and reduces the cognitive load and burnout among surgeons and the whole surgical team.[51] On this matter, further studies are required to determine if the incorporation of a co-surgeon model improves satisfaction and wellness among the members of the surgical team.

The co-surgeon approach, besides allowing for mentorship, is a good opportunity to learn new techniques, tips, and tricks to improve perioperative outcomes in a bi-directional way.[12] For instance, it can reduce or prevent fatigue when performing long surgical procedures and reduce the risk of error, an indicator of difficult assessment.[27,51,53] Although the co-surgeon model is both operator and procedure dependent, a judicious assessment of the surgical skills and personal reflection can guide the decision to incorporate a second set of hands from another colleague.[51,54] In academic medical centers, a co-surgeon model can improve teaching and supervision, making residents more familiar with these types of procedures.

Limitations

The presence of multiple surgeons, residents, or physician assistants is a common occurrence during MBR.[55] Unfortunately, these operative characteristics were not ubiquitously analyzed in all included studies.[55] In other fields of reconstructive microsurgery such as limb reconstruction, the addition of a second operating attending did not significantly reduce surgery time, hospital length of stay, need for revision surgery, or complication rates.[56] This may reflect limitations regarding the external validity and reproducibility of the outcomes of several studies included in our meta-analysis.

The inclusion of a co-surgeon increases over the years for MBR in most practices,[29] as it concurrently does the experience of surgeons.[29] In this setting, an increased experience of surgeons due to the learning curve can be regarded as an effect modifier affecting the outcomes of surgical time and length of stay. Additionally, in most studies, it is difficult to assess how the concept of a co-surgeon matures over time. Certainly, most surgical teams learn over time how to optimize the assistance of a second microsurgeon, thereby generating an important reduction in the overall cost of care.[29]

CONCLUSIONS

Our results indicate that with the incorporation of a co-surgeon model for MBR, the rates of complications for donor site and recipient site are comparable relative to a single-surgeon model. On the other hand, adding a co-surgeon optimized efficacy and reduced the surgical time and length of stay. Due to heterogeneity in how outcomes are measured, conflicting results were reported in several studies evaluating the cost-effectiveness of a co-surgeon model compared with a single-surgeon model. The co-surgeon model is unlikely to be necessary for all microsurgical cases but can be exceedingly valuable when planning for long, complex cases or when more than one flap is required (eg, bilateral reconstruction, stacked deep inferior epigastric perforator and profunda artery perforator flaps).

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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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