Review Article

Does plastic surgery need a rewiring? A survey and systematic review on robotic-assisted surgery ☆,☆☆,★

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A R T I C L E   I N F O

A B S T R A C T

Background: This is a paucity of data regarding plastic surgeons' opinions on robotic-assisted surgery (RAS). We developed a questionnaire aimed to survey plastic surgeons regarding training in robotics, concerns about widespread implementation, and new research directions.
Methods: A survey was created using Google Forms and sent to practicing plastic surgeons and trainees. Responses regarding desired conference proceedings about robotics, robotic residency training, and perceived barriers to implementation were elicited. Survey responses were utilized to direct a systematic review on RAS in plastic surgery.
Results: The survey received 184 responses (20.4%; 184/900). The majority (92.8%) of respondents were/are plastic surgery residents,

with the most common fellowships being microsurgery (39.2%). Overall, 89.7% of respondents support some integration of robotics in the future of plastic surgery, particularly in pelvic/perineum reconstruction (56.4%), abdominal reconstruction (46.5%), microsurgery (43.6%), and supermicrosurgery (44.2%). Many respondents (66.1%) report never using a robot in their careers. Respondents expressed notable barriers to widespread robotic implementation, with cost (73.0%) serving as the greatest obstacle. A total of 10 studies (pelvic/perineum = 3; abdominal = 3; microsurgery = 4) were included after full-text review.

Conclusions: Evidence from our survey and review supports the growing interest and utility of RAS within the plastic and reconstructive surgery (PRS) and mirrors the established trend in other surgical subspecialties. Cost analyses will prove critical to implementing RAS within PRS. With validated benefits, plastic surgery programs can begin creating dedicated curricula for RAS.

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Introduction

The use of robotics in surgery has captivated patients and physicians alike since its FDA-approval[1] and the first reported case of a robotic-assisted laparoscopic cholecystectomy in 2002.[2] Robotic-assisted surgery (RAS) publications have exponentially increased from over 100 in 2000[3] to over 3,000 by 2021. Many surgical subspecialties have readily embraced RAS, including urology,[4] gynecology,[5] and cardiothoracic surgery.[6] Yet, plastic and reconstructive surgery (PRS) has been slow to adopt RAS technology. Since the first publication of a porcine free flap by Katz et al. in 2005,[7] PRS publications on RAS have only modestly increased to 78 in 2021; compare this to other specialties that have hundreds to thousands of publications per year.

PRS is often considered an innovative specialty that has spearheaded innovation within the surgery. It is also a specialty that commonly works in tandem with other specialties that use RAS. Therefore, PRS surgeons should investigate potential uses for and learn how to incorporate RAS into their surgical armamentarium.

Only one study has previously surveyed PRS surgeons regarding RAS.[8] However, this study focused on surgeons who already practiced RAS and was limited in scope to head and neck surgery. This report aimed to nationally survey PRS residents, fellows, and physicians regarding RAS. To complement this survey data, we also present a systematic review focusing on the PRS subspecialties and preferred areas of research focus directed by the survey findings.

Materials and Methods

Survey

To direct the systematic review that follows, an 18-question survey was created using Google Forms (Google LLC, Mountain View, CA). The survey was sent to plastic surgeons and trainees using mailing lists and conference committees. Regional information collected included the respondents' current region of practice and size/type of city in which practice is located. Academic training data obtained included type of residency and fellowship training, years, and type of practice. Respondents were asked what type of plastic surgery field would likely most benefit from RAS. Responses regard-

ing desired conference proceedings about robotics, robotic residency training, and perceived barriers to implementation were elicited.

Systematic Review

The top three fields of plastic surgery perceived to most benefit from RAS by respondents directed the review of literature. Top conference topics and perceived barriers to implementation were used as primary outcome measures.

Study Identification

The following databases were queried (articles dating up to 2021) for relevant published studies: *PubMed, Cochrane, Embase, Scopus,* and *Web of Science.*

Search Terms and Data Extraction

The systematic review followed the PRISMA guidelines for systematic reviews. Search terms to identify studies involving RAS included PRS, plastic surgery, abdominal wall repair/reconstruction, ventral hernia, pelvic/perineum reconstruction, microsurgery, supermicrosurgery, da Vinci, robot-assisted, and robotic-assisted. After duplicates were removed, the remaining titles/abstracts were screened for relevance; selected abstracts were then reviewed for full-text review. Three reviewers critiqued abstracts, manuscripts, and extracted data from selected papers using a standardized collection table.

Inclusion/Exclusion Criteria

Studies in this systematic review included prospective and retrospective cohort studies, cross-sectional studies, randomized control trials, case-control, and case series. Only publications in English were reviewed. We excluded case reports, review papers, technical reports, and case series with fewer than 10 patients. To qualify for inclusion, studies had to focus on RAS in PRS. Regions of focus included pelvic/perineum, abdominal wall, microsurgery, and supermicrosurgery.

Outcome Measures

The primary outcome measures were the efficacy, cost, and complication rate of robotic-assisted plastic surgery. With this information, we synthesized the data extracted to help summarize the utility of RAS compared to non-robotic options.

Data Analysis

Given the heterogeneity of the papers, quantitative analysis was not performed. Instead, a qualitative analysis of the pertinent findings from each of the eligible papers is presented systematically in Tables 1, 2, and 3.

Results

Respondent Demographics

The survey received a 20.4% (184/900) response rate. Respondents lived and practiced in the Southwest (31.1%), Northeast (21.5%), Midwest (20.3%), Southeast (13.6%), and Northwest (6.2%). Over 82.8% lived in a major metropolitan area (> 250,000 residents) and 17.2% lived in a suburban area (100,000–250,000 residents). Most (62.8%) worked in an academic setting, whereas 16.1% worked in private practice. Residents made up 11.4% of those surveyed. One-third (33.5%) of respondents had been in practice for one to ten years. The most common residency training was PRS (92.8%). Common fellowships included microsurgery (39.2%), hand (26.8%), craniofacial (14.4%), and burn surgery (7.2%). A majority of respondents had never performed RAS (66.1%). A total of 89.7% of respondents believed that

Table 1
Characterization of all studies of robotic-assisted abdominal wall reconstruction with greater than 10 patients.

Author (Year)	Type of Study	Level of Evidence	Population	Cohort size	Control group	Mean age (%female)	Inclusion Criteria	Exclusion Criteria	Mean Follow-Up	Outcomes Measured	Results	Comments
Shakir et al. (2021)	retrospective	II	Endoscopic, laparoscopic, and robotic harvest of deep inferior epigastric vessels Pennsylvania, USA	135 3 (robotic)	94 (endoscopic) 38 (total extraperitoneal laparoscopic (TEP-lap))	52.2 (endoscopic) 51.7 (laparoscopic) 53.2 (robotic)	>18 yo. Underwent two-stage autologous breast reconstruction Preoperative computed tomographic angiography > 3 mo. follow-up	< 90 days follow-up	> 3 mo.	Flap survival Intraoperative complications related to harvest (conversion to open, bleeding, intra-abdominal injury) Postoperative complications	Flap loss (n=2) Abdominal wall hematoma (n=1) requiring operative takeback in endoscopic cohort No flap losses or abdominal wall complications in either TEP-lap or robotic cohorts	Endoscopic operative time: 344.0 min. Laparoscopic operative time: 425.2 min. Robotic operative time: 535.3 min. Additional disposable costs: Endoscopic: $250 TEP-lap: $500 Robotic: $1500
Choi et al. (2021)	Retrospective	IV	Deep inferior epigastric artery flap harvest Seoul, South Korea	17	4	N/A	Length of intramuscular pedicle less than 5 cm Either one large perforator or multiple perforators	N/A	N/A	Operative time of harvest Total operation time	Avg. operation time of robotic harvest: 65 mins Total operation time: 487 mins	No comparisons to convential flap harvest Mention of high cost but no cost analysis compared to conventional flap harvest
Pedersen et al. (2014)	Case series	IV	Rectus abdominis harvest for extremity coverage and pelvic surgery Chicago, USA	10	N/A	Not reported	Not reported	Not reported	less than 12 mo.	Hernia or bulge formation Infection	No hernia or bulge at final followup 1 patient: stage 1 decubitus ulcer	Average setup time: 15 min. Average harvest time: 45 min.

Table 2

Characterization of all studies of robotic-assisted microsurgery with greater than 10 patients.

Author (Year)	Type of Study	Level of Evidence	Population	Cohort size	Control group	Mean age (%female)	Inclusion Criteria	Exclusion Criteria	Mean Follow-Up	Outcomes Measured	Results	Comments
van Mulken et al., 2020	Prospective	II	Women with breast-cancer related lymphadema Maastricht, Netherlands	20 Robot, n = 8	Manual, n = 12	60 years (100%)	Women w/ breast cancer	Not reported	3 months	Use of compressive garment Manual lymph drainage Mean Lymph-ICF score Mean Upper Extremity Lymphadema (UEL) index of the affected arm	Daily compressive garment: Robot: 1/8 (12.5%) Manual: 2/12 (16.7%) No sig. differences in mean Lymph-ICF score at 1m or 3m No sig. differences in UEL index at 1m or 3m	Short f/u period Small sample size Neither surgeon nor patient was blinded to group assignment
Boyd et al., 2006	Case series	IV	Patients with need for TRAM, SGA, SIEA, and SGAP flaps Weston, Florida	20 (22 flaps)	N/A	53.7	Patients with need for TRAM, SGA, SIEA, and SGAP flaps	Not reported	Not reported	Mean time for robotic harvest Mean ICU time Mean chest tube time Mean admission Pedicle and flap properties	Mean robot harvest time: 113 min Mean ICU time: 2.95 days Mean chest tube time: 2.10 days Mean admission: 7.20 days Complications: Hematomas (n = 6), flap loss (n = 2), positional neuropraxia (n = 2), pneumothroax (n = 1), MRSA pneumonia (n = 1), Mild fat necrosis (n = 1)	High complication rate No long-term outcomes Expense of robot and difficulty training

Table 2 (continued)

Author (Year)	Type of Study	Level of Evidence	Population	Cohort size	Control group	Mean age (%female)	Inclusion Criteria	Exclusion Criteria	Mean Follow-Up	Outcomes Measured	Results	Comments
McCullough et al., 2018	Retrospective	IV	Men w/ sympathetic hypogonadism undergoing robot-assisted microscopic varicocelectomy (RAMV) Albany, NY	140	N/A	34.5 years (0%)	Normal karyotype and negative microdeletion studies >1 year of infertility Varicocoeles	No varicocele	Not reported	Operative time Testicular volume, median testosterone, sperm concentration, motility, and WHO morphology Complications Need for pain medications >24h	No sig. difference in operative time for RAMV vs. traditional Median T and free T increased by 44.3% (p < 0.001) Sperm concentration increased by 37.3% (p<0.03) No difference in sperm motility or WHO morphology 9/258 (3.5%) had complications 37.3% used pain medications >24 h	High failure rate/persistence rate: 9.7% Comparison to historical controls
Lai et al., 2019	Retrospective	IV	H/N Cancer Patients Taichung, China	15 17 robot-assisted microanastamoses	25 microanastamoses with standard operating microscope/hand sewing technique	52.93	Patients with H/N SCC	Not reported	115 months	Operating time Number of suture stitches needed for vessel anastomosis Vessel-related complications Flap survival Outcomes	Operating time sig. longer for robot No intraoperative complications All flaps survived Recipient blood vessel in robot group non-sig. smaller than traditional Donor blood vessel diameter in robot group sig. smaller than traditional	Small sample size

Table 3
Characterization of all studies of robotic-assisted pelvic/perineum reconstruction with greater than 10 patients.

Author (Year)	Type of Study	Level of Evidence	Population	Cohort size	Control group	Mean age (%female)	Inclusion Criteria	Exclusion Criteria	Mean Follow-Up	Outcomes Measured	Results	Comments
Chong et al., 2015	Retrospective	IV	Patients undergoing ab-dominoper-ineal reconstruc-tion with gracilis flap from 2010-2012 Dallas, TX	16	N/A	62 ± 8 years (31.3%)	Not reported	Not reported	5-40 months	OR time Major and minor perineal complication Donor site complication Abdominal wound complication Deep venous thrombosis 30 day mortality Hospitalization Days until ambulation	Major perineal wound complication: 6% minor perineal complication: 19% Gracilis donor site surgical site infection: 3 (19%) Abdominal surgical-site infections: 4 (25%) No abdominal, parastomal, or perineal hernias or bulges No flap losses	
Dy et al., 2021	Retrospective	IV	Transgender women undergoing Robotic-assisted peritoneal flap gender-affirming vaginoplasty (RPGAV) New York City, NY	100 (Xi = 47; SP = 53)	N/A	36.2 years (Not reported)	Not reported	Patients with <6 mo of follow-up were excluded.	11.9 months	Perioperative details (operative time and blood loss) Complications (intra- and postoperative) Postoperative neovaginal dimensions (patient-reported maximum dilator depth and size at the most recent follow-up)	Average procedure times were 4.2 and 3.7 h in Xi and SP cohorts (p <0.001). Complications: Transfusion (6%) - 5 (11%) in Xi and 1 (2%) in SP system (p=0.01) Vaginal stenosis (7%) - 6 (13%) in Xi and 1 (2%) in SP system (p=0.003) Rectovaginal fistula (1%) - 0 in Xi and 1 (2%) in SP system (p=0.181) Bowel obstruction (2%) - 0 in Xi and 2 (4%) in SP system (p=0.057)	Comparing da Vinci Xi robot (Xi) vs. da Vinci Single Port (SP) robot

Table 3 (*continued*)

| Author (Year)	Type of Study	Level of Evidence	Population	Cohort size	Control group	Mean age (%female)	Inclusion Criteria	Exclusion Criteria	Mean Follow-Up	Outcomes Measured	Results	Comments
Dy et al., 2021	Retrospective	IV	Patients underwent robotic peritoneal flap revision vaginoplasty from 2017 to 2020 New York City, NY	24 transgender women	N/A	39 years (100%)	Robotic peritoneal flap revision vaginoplasty Primary penile inversion vaginoplasty or vulvoplasty 6-month follow up appointment	Not reported	13.5 months	Postoperative neovaginal dimensions complications	No intraoperative peritoneal flap harvest complications Post-operative: 1: Bleeding from a prostatic neurovascular bundle requiring perineal suture ligation under anesthesia. 2: granulation tissue at the junction of the neovaginal skin and peritoneal flap 1: curettage and surgical release of scar tissue at 5 months post-op 1: curettage of granulation tissue at 6 months post-op	Revision vaginoplasty using robotic transabdominal canal dissection and harvest of peritoneal flaps 4 patients (17%) lost to further follow up Small sample size Short follow up
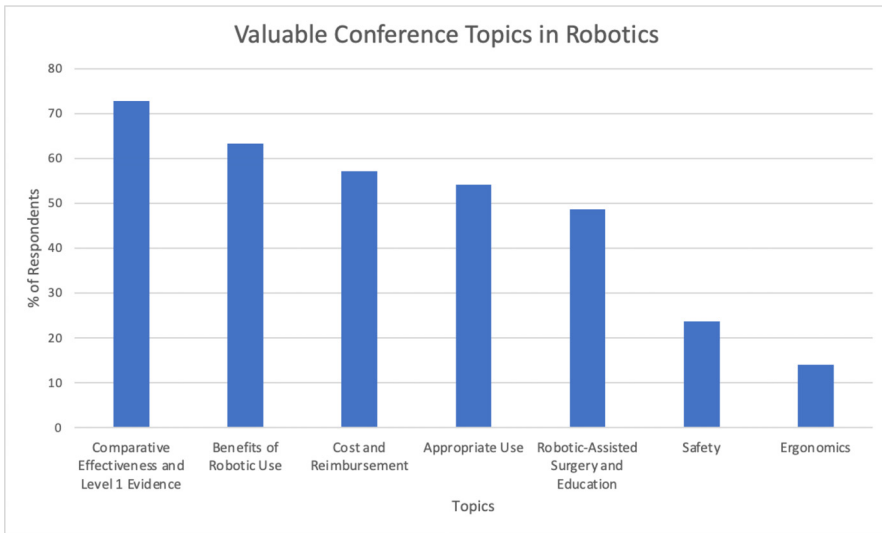
Figure 1. Valuable conference topics in robotic-assisted surgery.

RAS should be implemented into future plastic surgery residency training. Among residents (n = 21), 18 (85.7%) believed RAS should be implemented into training. Of those with greater than 21 years of experience (n = 50), 45 (90.0%) responded that RAS should be implemented. Overall, 10.3% (n = 18) believe RAS should not be integrated into residency training.

Most Valuable Conference Topics

Most respondents answered that the comparative effectiveness of RAS to non-robotic options and level 1 evidence (72.9%) was the most valuable conference topic (Figure 1). Other valuable conference topics included the benefits of robotic use (63.3%) and the cost and reimbursement of RAS (57.1%). Less than half (48.6%) wanted to learn about RAS training. Few of those surveyed (23.7%) found surgical safety a relevant conference topic.

Barriers to Implementation

The majority (73.0%) of respondents perceive cost to be a major barrier to robot implementation in plastic surgery. Respondents believed increased operative time (62.9%), lack of level 1 evidence (56.2%), and lack of adequate training (55.6%) to also be significant barriers. Safety and efficacy were cited by 38.2% as well (Figure 2).

Types of Plastic Surgery in which RAS would be Most Beneficial

The top five types of plastic surgery in which RAS was perceived to be most beneficial were as follows: (1) Pelvic/perineum reconstruction (56.4%), (2) abdominal wall reconstruction (46.5%), (3) microsurgery (43.6%), (4) supermicrosurgery (44.2%), and (5) flap tissue harvest (40.7%). Head and neck surgery (30.8%), breast reconstruction (18.0%), and aesthetic surgery (2.9%) were also cited (Figure 3).

Responses to Whether RAS Will Be Safe and Valuable in Different Types of Plastic Surgery

The majority of the respondents considered RAS safe and valuable in head and neck reconstruction (83.0%), microsurgical anastomosis/reconstruction (81.8%), abdominal wall reconstruction (74.4%), and breast reconstruction (62.1%) (Figure 4).
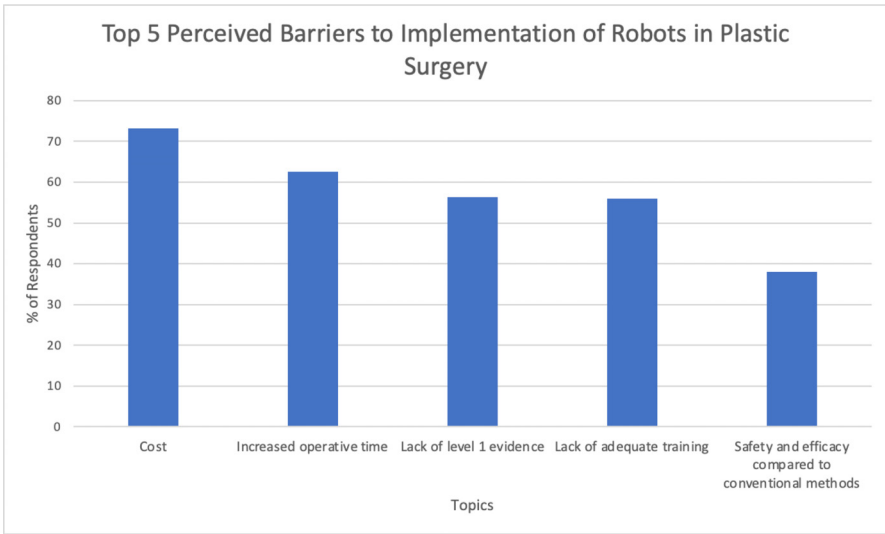
Figure 2. Top 5 perceived barriers to implementation of robotic-assisted surgery in plastic surgery.
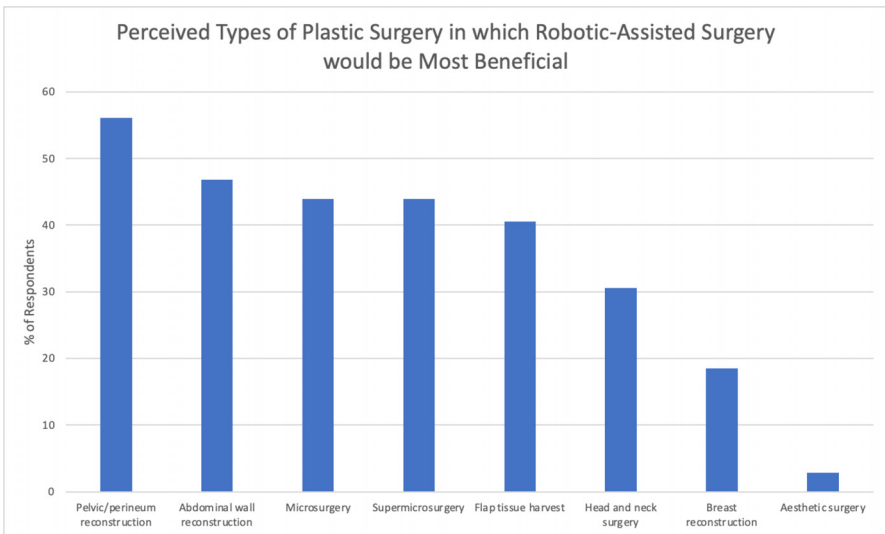

Figure 3. Perceived types of plastic surgery in which robotic-assisted surgery would be most beneficial.

Systematic Review

A total of 2,795 studies were initially found on database queries with 409 duplicates. After screening, 406 papers were eligible for full-text review and ten for qualitative synthesis (Figure 5). Sixteen studies had less than 10 total patients and were excluded from formal analysis (Supplemental Table 1).[9–24]

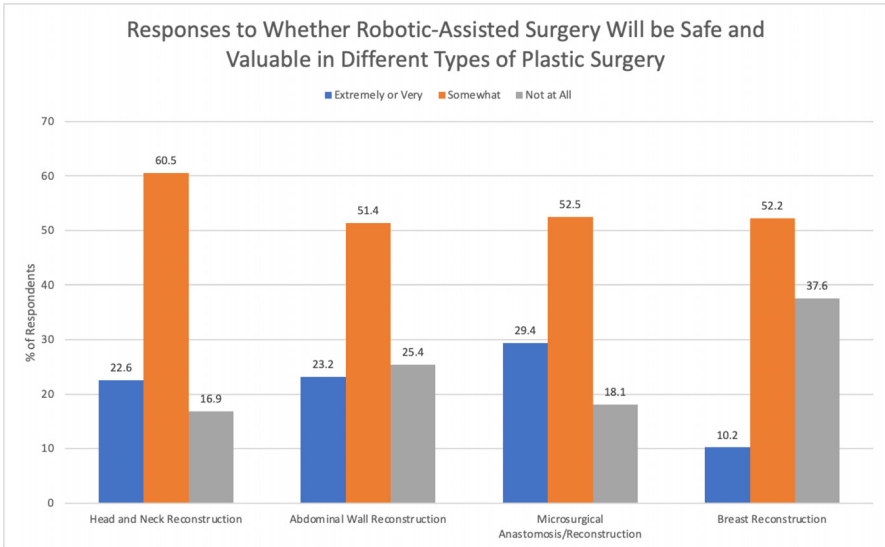**Figure 4.** Responses to whether robotic-assisted surgery will be safe and valuable in different types of plastic surgery.
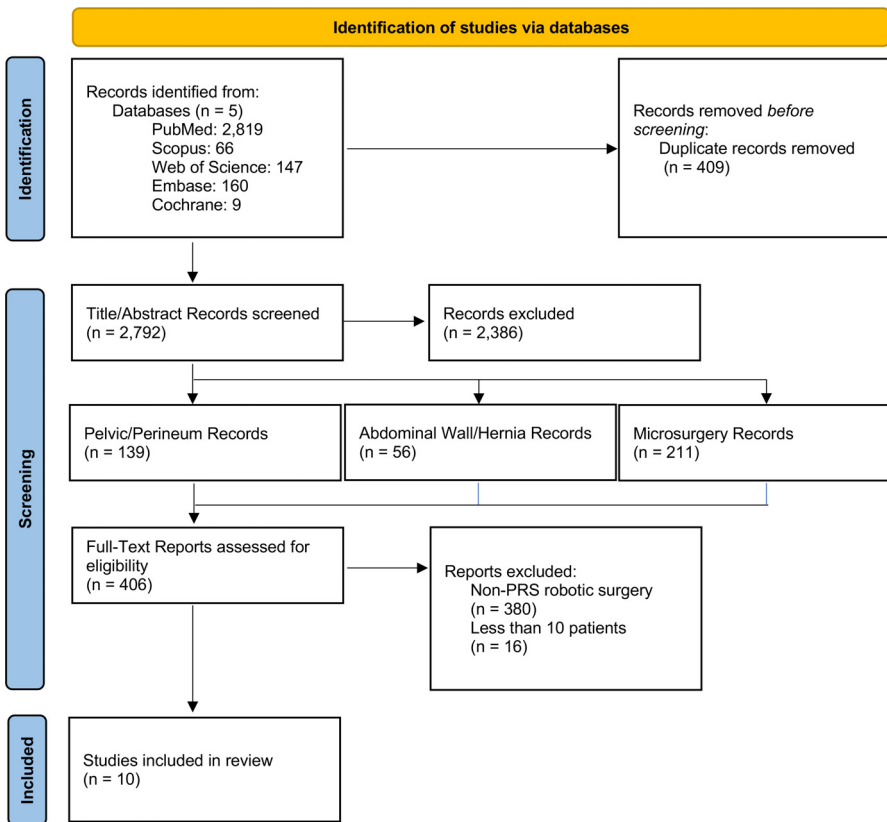

Figure 5. PRISMA diagram.

Abdominal Wall

Three studies met inclusion criteria (Table 1) with 53 studies being either case series/reports with n<10 (n=6) or non-PRS (n=47). The average age at surgery was 53.2 years old. No studies reported the sex distribution. Two studies were comparative retrospective studies[25,26], and the other was a case series.[27]

Outcomes

Shakir et al. (2021) compared endoscopic, laparoscopic, and robotic harvest of deep inferior epigastric perforator (DIEP) flaps for breast reconstruction.[26] There were 135 patients in total: robotic (n=3), endoscopic (n=94), and total extraperitoneal laparoscopic (TEP-lap) (n=38). There were no instances of complications in the robotic and laparoscopic cohort, compared to two cases of flap loss in the endoscopic cohort. The average operative time was 535.3 min in the robotic cohort, compared to 344.0 min and 425.2 min in the endoscopic and laparoscopic cohorts, respectively.

Choi et al. (2021) compared the use of RAS versus traditional dissection of the vascular pedicle of the DIEP flap for breast reconstruction.[25] Seventeen participants underwent robotic harvest compared to four who underwent traditional harvest. The average operative time was 65 min for robotic harvest with a total operative time of 487 min.

Pedersen et al. (2014) described the use of RAS for rectus abdominis harvest for extremity coverage and pelvic surgery.[27] Ten patients underwent RAS with a mean follow-up of approximately 12 months. At one year follow-up, no patients had hernias or bulges. The average set-up and harvest time were 15 min and 45 min, respectively.

Microsurgery

A total of four studies met inclusion criteria (Table 2) with the remaining seven consisting of studies with n<10. Across all studies, n=211. The average age among the study groups was 50.2 years old. Two studies were retrospective,[28,29] one was prospective,[30] and one was a case series.[31]

Outcomes

Van Mulken et al. (2020) compared the use of RAS vs. traditional surgery for women with breast cancer-related lymphedema.[30] They found that at three-month follow-up, 12.5% of patients in the robot group vs. 16.7% of patients in the traditional group used a daily compressive garment. However, they reported no significant differences in lymphedema indices across the two groups.

Boyd et al. (2006) studied RAS flap harvest and recorded harvest time (mean=113 min), ICU time (mean=2.95 days), chest tube time (mean=2.10), and admission days (mean=7.20).[31] Complications included hematoma (n=6), flap loss (n=2), pneumothorax (n=1), MRSA pneumonia (n=1), minimal fat necrosis (n=1), and positional neuropraxia (n=2).

Lai et al. (2019) conducted a retrospective study of head and neck cancer patients to evaluate RAS microanastomosis.[28] Compared to the standard technique, RAS microanastomosis had a significantly longer operating time. The donor blood vessel diameter in the robot group was significantly smaller than that in the traditional group. All flaps survived across both groups and neither group had any intraoperative complications.

McCullough et al. (2018) investigated robot-assisted varicocelectomy (RAMV) in men with sympathetic hypogonadism.[29] The complication rate was 3.5% (9/258), and 9.7% of patients had persistence of symptoms. Their findings demonstrated no significant differences in operative time among the two groups when comparing their cohort with a historical and traditional varicocelectomy control group.

Pelvic and Perineum Reconstruction

A total of three studies met inclusion criteria with the remaining three consisting of studies with n<10 (Table 3). Across all studies, n=139. The average age among the study groups was 39.6 years. All three studies were retrospective.

Outcomes

Chong et al. (2015) compared the use of RAS (n=7) vs. traditional surgery (n=9) for abdominoperineal resection for pelvic/perineal cancers.[32] Follow-up time ranged from 5 to 40 months. In the traditional surgery group, four patients had abdominal wound complications, and other patients had a major perineal complication. Minor perineal complications occurred in three patients, one in the RAS group and two in the traditional surgery group.

Dy et al. (2021) reported the use of RAS for peritoneal flap revision vaginoplasty.[33] All 24 patients had undergone primary penile inversion vaginoplasty or vulvoplasty, with revision surgery occurring after an average of 35.3 months. Out of 24 patients, only 18 patients presented at a 6-month follow-up and were included in the analysis. The average operative time was 280 min, and the average length of stay was 5.1 days. At 6-month follow-up, a mean increase in vaginal depth and width was 6.9 cm and 1.0 cm, respectively. There were no complications related to peritoneal flap harvest.

Dy et al. (2021) compared the use of two types of robots, da Vinci Xi (Xi) vs. da Vinci Single Port (SP) robot, for peritoneal flap harvest for gender-affirming vaginoplasty.[34] A total of 100 patients were included in the analysis, Xi = 47 and SP = 53, and followed up for a minimum of six months. The average operative time was 4.2 h in Xi cohort and 3.7 h in SP cohorts. Vaginal depth and width at 6-month follow-up were 13.6 and 3.7 cm in Xi and 14.1 and 3.7 cm in SP cohorts, respectively. Complications include transfusion (6%), rectovaginal fistula (1%), bowel obstruction (2%), pelvic abscess (1%), and vaginal stenosis (7%). SP robots significantly reduced operative times. However, the authors report that there was no difference in complication rates between two robotic approaches.

Discussion

Twenty years have passed since the first reported case of RAS. While many surgical specialties have embraced RAS,[4–6] adoption by plastic surgeons has been slow. Presumptions regarding RAS are that the technology solely allows for increased visualization to areas of the body that are difficult to access without a large incision. As such, plastic surgery which has generally not been limited by incisions and access has perceived RAS as lacking in utility. However, the evidence found in this report are indicators that the belief in the utility of RAS is changing among plastic surgeons.

There is a paucity of large comparative studies evaluating RAS. Further, many studies failed to conduct significance testing, only presenting descriptive statistics, making it difficult to ascertain any true differences between the two groups. Nonetheless, there were reports of success with the use of RAS. RAS was used to harvest DIEP flap for breast reconstruction that had no flap loss or abdominal complications, whereas endoscopic harvest elicited two instances of flap loss.[26] Three studies demonstrated no operative complications and flap survival in all patients at final follow-up;[27,28,33] two of the three studies failed to compare outcomes with traditional cohorts.[27,34] Lai et al. (2019) noted equal outcomes for both RAS and non-RAS, but also reported that the RAS group used significantly smaller vessels for microanastomosis than non-RAS.[28] Similarly, another study demonstrated that RAS improved some lymphedema-related symptoms more than non-RAS following surgical intervention for breast cancer-related lymphedema.[30]

In terms of complications, RAS was found to have lower complication rates in comparison with non-RAS during abdominoperineal resection of pelvic/perineal cancers.[32] Similarly, RAS had no flap loss compared with non-RAS in DIEP harvest.[26] Other studies that reported on complications, unfortunately, did not provide a non-RAS comparator group, precluding analysis.[27,31,33] One study instead compared two different robots, however, and did not find any differences in complication rates between the two groups.[34] Although there have been limited studies on outcomes and complications, there appears to be a weakly positive tendency for RAS over non-RAS. More prospective randomized controlled trials are needed to support this postulation.

Cost considerations for RAS have been a topic of concern and interest since the technology's inception. Over half of the survey respondents cited cost and reimbursement as a preferred conference topic. Shakir et al. (2020) reported that the average disposable material cost of robotic harvest of DIEP flaps was $1500[26] compared to $500 and $250 in TEP-lap and endoscopic approaches, respectively. Another study included in Supplemental Table 1 found that traditional DIEP cost $14,800 and robotic

DIEP cost $16,300.[17] While only two studies reported costs associated with different approaches, it is clear that robotic surgery is more expensive. However, no studies performed a true cost-effectiveness or utility analysis. Cost-effectiveness has been studied for robotic surgery in other subspecialties with conclusions varying greatly depending on region, hospital, and institution being analyzed.[35–37] With the market of robotic surgery soaring to $20 billion in 2021 from just $4 billion in 2014,[38] the impetus for a PRS-focused cost-effectiveness analysis is difficult to comprehend.

As mentioned above, survey respondents expressed concern about increased operative times in RAS implementation. Our findings were inconclusive with regards to the effect of using RAS on operative time. One study reported no significant difference in the operative time between robot-assisted and traditional varicocelectomy.[29] Dy et al. (2021) compared operative time between two different robots (Xi and SP), but did not compare operative time with traditional approaches, thus precluding analysis.[34] Shakir et al. (2021) found that robotic operative time was longer than endoscopic and laparoscopic cohorts but did not evaluate for significant differences across the three groups.[26] Finally, one study found that in head and neck RAS, the use of robots led to significantly greater operative times than traditional surgery. Unfortunately, there were limited studies reporting on this outcome measure, and thus further investigation is warranted to elucidate the impact of robot use on operative time.

The implementation of any technology requires adequate training. Current RAS training consists of online training modules, "dry" and "wet" simulation, bedside assists, and console surgery.[39] In general surgery, there are no validated RAS curriculums, and existing programs are highly variable.[40] Similar problems exist in other subspecialties such as urologic,[41] thoracic,[42] and gynecologic surgery.[43] To our knowledge, there are no validated RAS curricula in any plastic surgery residency programs. Yet, among respondents in our survey, nearly 90% believed that RAS should be implemented into future surgical education and training. Additionally, over half believed that a major barrier to RAS was a lack of adequate training. This reflects a growing understanding of the applicability of RAS, as well as the shortcomings of current RAS training within plastic surgery. Such findings should serve as an indicator to program directors to advocate for RAS curriculum development.

One limitation of this study is the low survey response rate, and as such, does not adequately constitute a true national survey, despite representation from all US regions. Moreover, the majority of our respondents were located from the Southwestern USA, major metropolitan cities, and academic centers, making it difficult to accurately assess the spectrum of perspectives regarding RAS.

Conclusion

Evidence from our survey and systematic review supports the growing interest and utility of RAS within PRS and mirrors the established trend in other surgical subspecialties. Cost analyses will prove critical to implementing RAS within PRS and, as highlighted in our review, have not been published. With validated benefits, plastic surgery programs can begin creating dedicated curricula for RAS.

Conflict of interest statement

None.

Funding Source

None.

Ethical Approval

Not applicable to this study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpra.2022.05.006.

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