Original Article

Robotic and laparoscopic sacrocolpopexy for pelvic organ prolapse: a systematic review and meta-analysis

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Background: Sacrocolpopexy is the gold standard procedure for treating pelvic organ prolapse (POP) patients with apical defects. Different surgical approaches have emerged and been utilized successively, including traditional laparoscopy, single-hole laparoscopy, robotic laparoscopy, vaginal-assisted laparoscopy, and transvaginal approaches. Robotic sacrocolpopexy (RSC) has attracted increasing attention as an emerging surgical technique and has unique advantages, such as a "simulated wrist" mechanical arm and high-definition three-dimensional (3D) visual field, which has gradually begun to be utilized in the clinical setting.

Methods: We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) reporting checklist, and a systematic literature search was conducted on six databases from their inception to 1st March 2020. We evaluated patients with POP who underwent RSC or laparoscopic sacrocolpopexy (LSC), outcomes (including perioperative outcomes: blood loss, operating times, blood transfusion, and hospital stay), surgery-related complications, as well as cure and recurrence rates.

Results: A total of 49 articles were available, including 3,014 patients, among which 18 were comparative studies on LSC *vs.* RSC, and 31 were non-comparative single-arm studies on RSC. For RSC, median operative time was 226 [90–604] minutes, estimated blood loss was 56 [5–1,500] mL, and hospital stay was 1.55 [1–16] days. Intraoperative complications and postoperative complications occurred in 74 (2.7%) and 360 (13.0%) patients, respectively. Of 2,768 RSC patients, 40 had been converted from a robot-assisted approach to other approaches, and 134 of 1,852 patients (7.2%) have recurrent prolapses of any compartment. Compared to LSC, RSC was associated with significantly lower blood loss and lower conversion rate. However, more operative time was observed in RSC. No significant differences were observed in perioperative transfusion, intraoperative and postoperative complications, or objective recurrence between RSC and LSC.

Conclusions: RSC's application seems to contribute some advantages compared to conventional laparoscopic surgery, although both approaches appear to promote equivalent clinical outcomes. Notably, heterogeneity among studies might have affected the outcome of the study. Consequently, high-quality and large-sample randomized trials comparing both techniques are necessitated.

Keywords: Pelvic organ prolapse (POP); robotic sacrocolpopexy (RSC); laparoscopic sacrocolpopexy (LSC); meta-analysis

Submitted May 29, 2020. Accepted for publication Nov 20, 2020.
doi: 10.21037/atm-20-4347
View this article at: http://dx.doi.org/10.21037/atm-20-4347

Introduction

Pelvic organ prolapse (POP) is a gynecological disease group that includes uterine prolapse and anterior and posterior vaginal wall bulge. Studies have illustrated that approximately 30% of middle-aged and older women experience prolapse of different degrees (1), among whom 11–19% of POP patients undergo surgical treatment (2). Laparoscopic sacrocolpopexy (LSC) is one of the classic and effective surgical procedures for POP treatment (3). Based on the operational requirements, LSC's standard suture fixation site is the anterior longitudinal ligament on the pelvic surface of the S1 vertebral body, which attaches to the sacrococcygeal curve concavity posteriorly. The laparoscopic surgical field in this area is severely limited, and damage to the presacral vascular plexus causes uncontrollable bleeding.

Consequently, LSC operation has a higher risk and more complicated operation challenges (3). The robotic surgery system has obtained prominent clinical application potential with the advantages of three-dimensional (3D) magnification of the visual field, flexible operation in narrow spaces, and physiological vibration filtering. Moreover, numerous clinical centers have carried out robotic sacrocolpopexy (RSC). Although few studies have summarized and compared LSC and RSC, most have contained a small series of cases detailing RSC application over a relatively short time frame. Technical barriers for surgeons were present in the early applications of RSC. After the extensive application of RSC over recent years, a large number of surgeons have been trained, which may lead to a paradox compared to early results. In this study, we conducted a systematic review and meta-analysis by collating the relevant data of worldwide studies over recent years, exploring and comparing the clinical efficacy of LSC and RSC in order to further evaluate the application potential of RSC.

We present the following article following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) reporting checklist (available at http://dx.doi.org/10.21037/atm-20-4347).

Methods

Search strategy

Two independent investigators searched the databases PubMed (Medline), Scopus, EMBASE, CNKI, WanFang DATA, and the Cochrane Library systematically, using the terms 'sacrocolpopexy or sacral colpopexy', 'robot-assisted sacrocolpopexy or robotic sacrocolpopexy', and 'laparoscopic sacrocolpopexy or robotic-assist laparoscopic sacropopexy'. The 'related articles' function was used to broaden the search, and all citations were considered relevant. The retrieval time was not limited, and the last iteration of the searching procedure was 1st March 2020.

Criteria for considering studies for this review

Inclusion criteria

All studies were reviewed carefully to make sure that they met the following inclusion criteria: (I) comparing the clinical efficacy of RSC and LSC and published before March 2020; (II) reported at least one essential outcome of RSC and LSC comparative data such as operation time, intraoperative bleeding volume, intraoperative complications, conversion, average hospital stay, POP cure (POP ≤1 grade), postoperative complications, subjective recurrence, objective recurrence, and reoperation *et al.*; (III) LSC cases ≥5 for each study; and (IV) in the case of duplicate data, the latest study or larger sample size was included.

Exclusion criteria

The exclusion criteria were as follows: (I) letters, editorials, review articles, case series; (II) RSC cases ≤5; (III) insufficient data or unclear data reporting; (IV) absence of original data available for extraction; and (V) duplicate publications with the same unit or the same author. Any differences in opinion were resolved through discussion and in consultation with the first author.

Types of studies

Published controlled trials comparing RSC and LSC's clinical efficacy before March 2020 were eligible for inclusion for the meta-analysis. Non-comparative single-arm studies on RSC were included in the systematic review.

Types of participants

For the meta-analysis, women undergoing sacrocolpopexy (robotic or robot-assisted) for POP, for any reason, were eligible for inclusion. Women who were treated by single-arm RSC were included in the systematic review.

Types of interventions

Trials comparing robotic or robot-assisted sacrocolpopexy used to treat POP *vs.* LSC were eligible for inclusion. Only interventions performed during, immediately before, or within the 24 hours before surgery were considered for this review, compared to LSC, the interventions that were considered in this meta-analysis were robotic or robot-assisted sacrocolpopexy.

Outcomes of interest

Outcomes were used to compare RSC and LSC as follows: (I) intraoperative parameters, including operative time (minutes), blood loss (mL), conversion to other approaches, bladder injury, bowel injury, vascular injury, ureteral injury, and all intraoperative complications; (II) postoperative parameters, including the length of hospital stay, perioperative blood transfusion, anorectal dysfunction, dyspareunia, mesh erosion, and all postoperative complications; (III) POP cure (POP ≤1 grade), recurrence and reoperation at 24 months. All data sets involved the most recent updates of information.

Data extraction

All data were extracted by two researchers independently. The extracted data included: name of the first author, year of publication, study design, number of participants in robotic and laparoscopic groups, preoperative characteristics (POP classification, history of hysterectomy, history of pop related surgery), intraoperative variables (urinary incontinence surgery, hysterectomy, operation time, intraoperative bleeding, conversion, bladder injury, intestinal injury, vascular injury, ureteral injury, and other complications), postoperative variables (length of stay, perioperative blood transfusion, anorectal dysfunction, dyspareunia, mesh erosion, and other complications), POP cure (POP ≤1 grade), and recurrence and reoperation.

Assessment of methodological quality

For single-arm RSC, studies meeting the inclusion criteria were assessed by two independent reviewers for methodological validity before inclusion in the review using a standardized critical appraisal tool from the Joanna Briggs Institute (JBI) for case series (4). Any disagreements that arose between the reviewers were resolved through discussion. All studies, regardless of their methodological quality, underwent data extraction and synthesis. For the meta-analysis component, we used the quality evaluation tool of clinical intervention research, the methodological index for non-randomized studies (MINORS) developed by French surgeon Karem Slim (5) in 2003 on a comprehensive review of literature and consensus of experts. There were 12 items in total, each of which scored 0–2 points. A score of 0 indicated no report; 1 indicated insufficient information; and 2 indicated sufficient information. Twelve indexes evaluated the literature quality, and research with a quality score ≥ of 18 was included in the meta-analysis.

Statistical analysis

Statistical analysis was performed with Cochrane Review software [Review Manager (RevMan) version 5.3 for Windows] and Stata 12 (version 12.0, StataCorp., College Station, TX, USA). Weighted mean difference (WMD) was used for continuous variable data, and the odds ratio (OR) was calculated for dichotomous variables. Both WMD and OR were expressed by a 95% confidence interval (95% CI). The heterogeneity was presented by using I^2 values. If $P>0.1$, $I^2 \leq 50\%$, it was considered that there was no obvious heterogeneity among the included studies, and the fixed effect model was used to calculate the combined statistics. If it was considered that there was heterogeneity ($P \leq 0.1$, $I^2>50\%$), the random effect model was used to calculate the combined statistics. A significant statistical difference was considered if $P<0.05$. Mean, median, and the ratio was performed for the single-arm studies to act as simple descriptive analysis parameters.

Results

For the final analysis, a total of 49 articles were available, including 3,014 patients. Of these, 18 were comparative studies on LSC *vs.* RSC, and 31 were non-comparative single-arm studies on RSC. Study selection as a PRISMA flowchart is summarized in *Figure 1*.

Outcomes of RSC

Perioperative outcomes

A summary of perioperative results in the RSC series is presented in *Table 1*. Two thousand nine hundred and sixteen patients had undergone RSC from 2004 to 2020. Median operative time was 226 [90–604] minutes, estimated

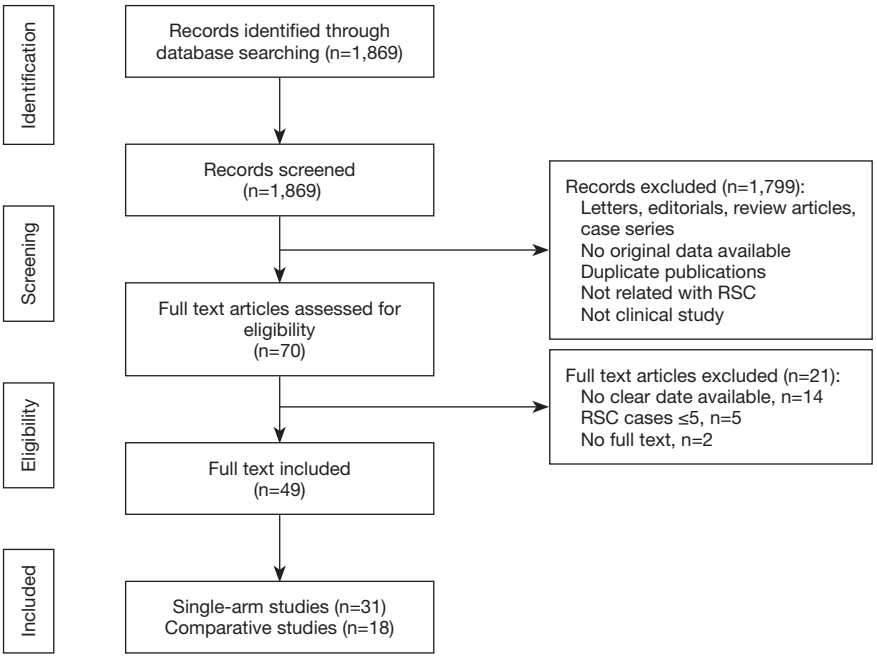

Figure 1 Flowchart of Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) diagram. RSC, robotic sacrocolpopexy.

blood loss was 56 [5–1,500] mL, and hospital stay was 1.55 [1–16] days. Of these patients, five had undergone blood transfusions.

Operative time reflects the surgical volume and execution of concomitant procedures and evaluates the surgeon's proficiency in performing RSC. We found that the operative time of RSC varied across different studies. In a large retrospective cohort study, Nosti *et al*. reported 262 RSCs with a median operative time of 316 [interquartile range (IQR): 109–604] minutes (27), and Ploumidis *et al*. reported 95 RSCs with a median operative time of 101 (IQR: 90–120) minutes (7,33). The difference among different institutions may be due to the execution of different concomitant procedures. RSC is inevitably combined with transobturator tape (TOT) implantation in patients with POP and stress urinary incontinence (SUI), and many patients opt for a concomitant hysterectomy during RSC. We observed that 21.7% and 25% of patients had performed hysterectomy and anti-incontinence procedures during RSC, respectively, leading to a great increase in operation time.

Blood loss is an important parameter to evaluate the quality of surgery. According to the results we observed, median blood loss was 56 mL, and the least blood loss was 5 mL during RSC (44); as an attractive parameter to minimally invasive surgery, this minimal loss implied a hugely promising application of RSC. Although few studies have reported that RSC was also associated with a higher rate of estimated blood loss of ≥500 mL (7,27,29,44), previous laparotomy and subsequent adhesion formation may still be the underlying risk factor of higher blood loss, as opposed to the mode of the surgery itself (29). The hospital stay was 1–2 days for most participants; however, the hospital stay of one patient was 16 days due to syncopal crisis when standing up from postoperative day 1, which was attributed to excessive tension in the posterior mesh. Robot-assisted laparoscopic reoperation was carried out to free posterior mesh and anchor it without tension. The ensuing postoperative course was uneventful, and she was discharged 14 days after the first surgical procedure (17).

The perioperative transfusion rate was 0.12% (n=5) (23,37,40,49,50). Blood loss caused by RSC was the cause of 40% (n=2) of transfusion; one case involved hemorrhage due to placement of retropubic midurethral sling, and the other was postoperative blood loss (23,40). Blood loss caused by chronic disease accounted for 40% (n=2) of transfusion, including anemia secondary to chronic hemorrhoids in the postoperative period and transfusion recommended by hematology due to factor V Leiden deficiency combined with an estimated blood loss of 100 mL (37,50).

Table 1 A summary of perioperative results in the RSC series

Study	Institution	Study design	Robotic cases	Concomitant anti-incontinence procedure rate (%)	Concomitant hysterectomy rate (%)	Median/mean operative time, min	Median/mean blood loss, ml	In-hospital stay, d	Transfusion rate (%)
Ferrando *et al*. (6)	Cleveland Clinic, Cleveland, OH, USA	RCT	24	NA	NA	214.2±51.5	NA	NA	NA
Geller *et al*. (7)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	147	NA	NA	259 [124–532]	100 [5–1,500]	NA	0 (0.0)
Elliott *et al*. (8)	Mayo Clinic, Rochester, MN, USA	PS	42	26 (61.9)	NA	186 [129–285]	NA	NA	NA
Mueller *et al*. (9)	Loyola University Chicago Stritch School of Medicine, Chicago, IL, USA	RCT	40	22 (55.0)	21 (52.5)	NA	NA	NA	NA
Elliott *et al*. (10)	Mayo Clinic, Rochester, MN, USA	RS	31	11 (35.4)	0 (0.0)	192 [135–285]	NA	1 [1–2]	0 (0.0)
Shariati *et al*. (11)	UMDNJ New Jersey Medical School, Newark, NJ, USA	RS	77	NA	3 (3.8)	273 [205–359]	NA	2 [2–10]	0 (0.0)
Collins *et al*. (12)	University of Connecticut Health Center, Hartford, CT, USA	PS	30	9 (30.0)	21 (70.0)	262.8±51.8	83.3±47	NA	NA
Elliott *et al*. (13)	Mayo Clinic, Rochester, MN, USA	PS	20	8 (40.0)	NA	192 [135–270]	NA	1 [1–2]	0 (0.0)
Awad *et al*. (14)	Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	40	12 (30.0)	37 (92.5)	186 [105–345]	48±55	2 [1–5]	0 (0.0)
Paraiso *et al*. (15)	Cleveland Clinic, Cleveland, OH, USA	RCT	40	NA	NA	340 [278–479]	NA	1.5 [1–10]	0 (0.0)
Chan *et al*. (16)	The Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong, China	RS	16	3 (18.7)	NA	230±42	131.0±79.3	7.5±7	0 (0.0)
Moreno Sierra *et al*. (17)	Hospital Clinico San Carlos, Universidad Complutense, Madrid, Spain	PS	31	NA	NA	186 [150–230]	NA	4.6 [1–16]	0 (0.0)
Shimko *et al*. (18)	Mayo Clinic, Rochester, MN, USA	RS	40	24 (60.0)	0 (0.0)	186 [129–300]	NA	1.2 [1–7]	0 (0.0)
Linder *et al*. (19)	Mayo Clinic, Rochester, MN, USA	PS	84	55 (65.4)	0 (0.0)	160 [135–180]	50 [25–100]	NA	NA
Elliott *et al*. (20)	Mayo Clinic, Rochester, MN, USA	PS	30	11 (36.6)	NA	186	NA	1 [1–3]	0 (0.0)

Table 1 (*continued*)

Table 1 (*continued*)

Study	Institution	Study design	Robotic cases	Concomitant anti-incontinence procedure rate (%)	Concomitant hysterectomy rate (%)	Median/mean operative time, min	Median/mean blood loss, mL	In-hospital stay, d	Transfusion rate (%)
Osmundsen *et al*. (21)	Oregon Health & Science University, Portland, OR, USA	RS	102	NA	45 (44.1)	NA	NA	NA	NA
Belsante *et al*. (22)	UT Southwestern Medical Centre, TX, USA	RS	35	NA	NA	288 [210–390]	71 [NA]	1.7 [NA]	NA
Pulliam *et al*. (23)	Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA	RS	43	15 (34.8)	4 (9.3)	242±54	83±78	1±0	1 (2.3)
Jambusaria *et al*. (24)	Abington Memorial Hospital, Abington, PA, USA	RS	38	27 (71.0)	23 (60.5)	274.5 [NA]	106 [NA]	1.4 [NA]	NA
Kenton *et al*. (25)	Northwestern University, Feinberg School of Medicine, Chicago, IL, USA	RCT	40	NA	NA	NA	NA	NA	NA
Mueller *et al*. (26)	The Loyola University Chicago, Stritch School of Medicine, Maywood, IL,USA	RS	226	117 (51.7)	151 (66.8)	255±66	99±74.3	NA	NA
Nosti *et al*. (27)	FPMRS Medstar Washington Hospital Center, Georgetown University School of Medicine, Washington, DC, USA	RS	262	NA	NA	316 [109–604]	100 [10–1,000]	1 [1–16]	0 (0.0)
Geller *et al*. (28)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	PS	28	13 (46.4)	0 (0.0)	133±31	NA	NA	NA
Unger *et al*. (29)	Cleveland Clinic, Cleveland, OH, USA	RS	121	NA	NA	275±56	NA	NA	NA
Biler *et al*. (30)	University of Health Sciences Tepecik Training and Research Hospital, Izmir, Turkey	PS	20	6 (30.0)	NA	217±40.9	55±30	5.1±1.1	0 (0.0)
Matthews *et al*. (31)	Virginia Commonwealth University Medical Center, Richmond, VA, USA	PS	85	39 (45.8)	37 (43.5)	195±54	50±48	1.6±0.72	0 (0.0)
Xylinas *et al*. (32)	CHU Henri Mondor, Créteil, France	RS	12	6 (50.0)	NA	144 [120–180]	60 [20–200]	3.4 [NA]	0 (0.0)
Ploumidis *et al*. (33)	OLV Vattikuti Robotic Surgery Institute, Aalst, Belgium	RS	95	NA	NA	101 [90–120]	30 [20–50]	4 [3–5]	0 (0.0)

Table 1 (*continued*)

Table 1 (*continued*)

Study	Institution	Study design	Robotic cases	Concomitant anti-incontinence procedure rate (%)	Concomitant hysterectomy rate (%)	Median/mean operative time, min	Median/ mean blood loss, mL	In-hospital stay, d	Transfusion rate (%)
Elliott *et al*. (34)	Stanford University, Stanford, CA, USA	RS	40	NA	NA	226 [NA]	NA	1 [0–10]	0 (0.0)
Illiano *et al*. (35)	Andrology and Urogynecology Clinic, Santa Maria Terni, Italy	PS	49	NA	NA	234.4±50	56.57±34.57	3.7 [NA]	NA
Anger *et al*. (36)	Cedars-Sinai Medical Center, Los Angeles, CA, USA	RCT	40	26 (65.0)	25 (62.5)	202.8±46.0	41.3±37.0	NA	NA
Barboglio *et al*. (37)	Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA	RS	127	NA	NA	NA	NA	NA	1 (0.7)
Cucinella *et al*. (38)	"Villa Sofia-Cervello" Hospital, University of Palermo, Palermo, Italy	RCT	20	NA	NA	140.7±11	56±12.65	2.8±0.63	0 (0.0)
Geller *et al*. (39)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	23	NA	NA	NA	151±111	NA	NA
Tan-Kim *et al*. (40)	University of California, San Diego, CA, USA	RS	43	NA	NA	281±58	86±42	1±0	1 (2.3)
Louis-Sylvestre and Herry (41)	Institut Mutualiste Montsouris, Paris, France	RS	90	NA	49 (54.4)	246 [180–415]	NA	3.48 [2–11]	0 (0.0)
Di Marco *et al*. (42)	Mayo Clinic, Rochester, MN, USA	RS	5	NA	NA	222	NA	1 [NA]	0 (0.0)
Zhao and Martin (43)	University of Alberta, Edmonton, AB, Canada	RS	47	32 (68.0)	25 (53.1)	190.6±33.6	NA	1.4 [NA]	NA
Akl *et al*. (44)	Mayo Clinic, Phoenix, AZ, USA	RS	80	NA	4 (5.0)	197.9±66.8	96.8 [25–3,000]	2.6 [NA]	0 (0.0)
Antosh *et al*. (45)	Washington Hospital Center, Washington, DC, USA	RS	65	20 (30.7)	28 (43.0)	334 [205–537]	50 [10–1,000]	1 [1–5]	0 (0.0)
Matanes *et al*. (46)	Rambam Health Care Campus, and Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	25	2 (8.0)	20 (80.0)	190 [114–308]	30 [10–300]	2 [1–4]	0 (0.0)
Salamon and Culligan (47)	Division of Urogynecology, Atlantic Health System, Morristown, NJ, USA	RS	64	38 (59.3)	41 (64.0)	165.6±23.0	58.1±55.9	1 [1–2]	0 (0.0)

Table 1 (*continued*)

Table 1 (*continued*)

Study	Institution	Study design	Robotic cases	Concomitant anti-incontinence procedure rate (%)	Concomitant hysterectomy rate (%)	Median/mean operative time, min	Median/mean blood loss, mL	In-hospital stay, d	Transfusion rate (%)
Culligan *et al*. (48)	Atlantic Health System, Morristown, NJ, USA	PS	150	128 (85.3)	NA	148±27.6	51.2±32	1 [NA]	0 (0.0)
Benson *et al*. (49)	Southern Illinois University, Carbondale, IL, USA	RS	33	NA	12 (36.3)	194 [137–280]	50 [25–150]	1 [1–2]	0 (0.0)
Siddiqui *et al*. (50)	Duke University Medical Center, Durham, NC, USA	RS	125	52 (41.6)	61 (48.8)	NA	90±89.3	NA	1 (0.8)
Bedaiwy *et al*. (51)	University Hospitals Case Medical Center, Cleveland, OH, USA	RS	41	27 (65.8)	27 (65.8)	328.5±56	50±50	NA	1 (2.4)
Mourik *et al*. (52)	Maasstad Hospital, Rotterdam, Netherlands	PS	50	NA	NA	223 [103–340]	50 [NA]	3 [2–5]	0 (0.0)
Overall	–	–	2,916	729 (25.0)	634 (21.7)	226 [90–404]	56 [5–1,500]	1.55 [1–16]	5 (0.1)

RSC, robotic sacrocolpopexy; PS, prospective study; RCT, randomized controlled trial; RS, retrospective study; NA, not applicable.

Surgical-related complications

A summary of surgical-related complications in the RSC series is presented in *Tables 2,3*. Intraoperative complications and postoperative complications occurred in 74 and 360 patients out of the 2,768 RSC series, respectively, and 58 cases of mesh erosion were included in the postoperative complications. We classified the intraoperative complications into three grades of severity according to the Satava severity system: grade 1 complications, no consequence for the patient; grade 2 complications, treated intraoperatively with endoscopic surgery or required endoscopic retreatment; and grade 3 complications, incidents requiring open or laparoscopic surgery (37,55). The severity of postoperative complications was classified using the Clavien-Dindo severity system, ranging from a slight deviation from the normal postoperative course (grade 1) to death (grade 5) (56).

Procedural complications were observed in 2.7% (n=74) of cases. There were 0.07% (n=2), 1.84% (n=51), and 0.14% (n=4) complications classified as grade 1, 2, and 3, respectively. Bladder injury [48.6% (n=37)] was the most common intraoperative complication, and intestinal injury, vascular injury, ureteral injury, and others were 11.8% (n=9), 10.5% (n=8), 3.94% (n=3), and 25% (n=19), respectively. Although the occurrence rate of intraoperative complications was low, postoperative complications were reported at a rate of 13.0% (360/2,768). The numbers of postoperative grade 1, 2, 3a, 3b, and 4a complications were 73 (2.63%), 85 (3.07%), 27 (0.97%), 31 (1.11%), and 5 (0.18%), respectively, with no grade 4b and 5 complications recorded. In the postoperative grade 4a complication, one patient developed postoperative surgical emphysema and pulmonary edema, and she was readmitted to the surgical intensive care unit (SICU) (50). Another patient had a postoperative acute myocardial infarction, which was successfully treated (17). As the predominant long-term postoperative complication, mesh erosion occurred at a rate of 2.09% (n=58). Urinary dysfunction [40% (n=144)] was the most of the postoperative complications, including urinary infection, de novo urinary stress incontinence, and dysuria. The prevalence of ileus and defecatory dysfunction, wound infection/abscess, dyspareunia, and pelvic hematoma were 13.0% (n=47), 5.55% (n=20), 3.61% (n=13), and 1.11% (n=4), respectively. The predominance of other postoperative complications, such as vaginal bleeding, vaginal cuff dehiscence pelvic pain, pneumonia, deep venous thrombosis, and vaginal cuff dehiscence, was 20.6% (n=79).

A total of 40 patients had been converted from a robot-assisted approach to other approaches, of which 6

Table 2 A summary of intraoperative complications in the RSC series

Study	Institution	Study design	Robotic cases	Intraoperative complications (%)						Conversion (%)	Savata classification (%)		
				Bladder injury	Bowel injury	Vascular injury	Ureteral injury	Other injury	Total		Grade 1	Grade 2	Grade 3
Ferrando *et al*. (6)	Cleveland Clinic, Cleveland, OH, USA	RCT	24	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geller *et al*. (7)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	147	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Elliott *et al*. (8)	Mayo Clinic, Rochester, MN, USA	PS	42	NA	NA	NA	NA	NA	NA	2 (4.76)	NA	NA	NA
Thubert *et al*. (53)	Pitié Salpétrière Hospital, APHP, Paris, France	RCT	95	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (3.15)	1 (1.05)	0 (0.0)	3 (3.15)	0 (0.0)
Mueller *et al*. (9)	Loyola University Chicago Stritch School of Medicine, Chicago, IL, USA	RCT	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shariati *et al*. (11)	UMDNJ New Jersey Medical School, Newark, NJ, USA	RS	77	0 (0.0)	1 (16.6)	0 (0.0)	0 (0.0)	5 (83.3)	6 (7.79)	1 (1.29)	0 (0.0)	5 (6.49)	1 (1.29)
Elliott *et al*. (13)	Mayo Clinic, Rochester, MN, USA	PS	20	NA	NA	NA	NA	NA	NA	1 (5.0)	NA	NA	NA
Awad *et al*. (14)	Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Paraiso *et al*. (15)	Cleveland Clinic, Cleveland, OH, USA	RCT	40	2 (40.0)	1 (20.0)	0 (0.0)	0 (0.0)	2 (40.0)	5 (12.5)	3 (7.5)	1 (2.5)	3 (7.5)	1 (2.5)
Chan *et al*. (16)	The Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong, China	RS	16	2 (66.6)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	3 (18.7)	NA	0 (0.0)	2 (12.5)	1 (6.25)
Moreno Sierra *et al*. (17)	Hospital Clinico San Carlos, Universidad Complutense, Madrid, Spain	PS	31	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	2 (6.45)	1 (3.22)	0 (0.0)	2 (6.45)	0 (0.0)
Shimko *et al*. (18)	Mayo Clinic, Rochester, MN, USA	RS	40	NA	NA	NA	NA	NA	NA	3 (7.5)	NA	2 (5.0)	NA
Linder *et al*. (19)	Mayo Clinic, Rochester, MN, USA	PS	84	NA	NA	NA	NA	NA	NA	14 (16.6)	NA	NA	NA
Elliott *et al*. (20)	Mayo Clinic, Rochester, MN, USA	PS	30	NA	NA	NA	NA	NA	NA	1 (3.33)	NA	NA	NA
Osmundsen *et al*. (21)	Oregon Health & Science University, Portland, OR, USA	RS	102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Belsante *et al*. (22)	UT Southwestern Medical Centre, TX, USA	RS	35	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pulliam *et al*. (23)	Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA	RS	43	NA	NA	NA	NA	2 (100.0)	2 (4.65)	1 (2.32)	0 (0.0)	1 (2.32)	0 (0.0)
Jambusaria *et al*. (24)	Abington Memorial Hospital, Abington, PA, USA	RS	38	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.63)	1 (2.63)	0 (0.0)	1 (2.63)	0 (0.0)
Mueller *et al*. (26)	The Loyola University Chicago, Stritch School of Medicine, Maywood, IL,USA	RS	226	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.32)	0 (0.0)	NA	NA	NA
Nosti *et al*. (27)	FPMRS Medstar Washington Hospital Center, Georgetown University School of Medicine, Washington, DC, USA	RS	262	4 (80.0)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	5 (1.90)	1 (0.38)	NA	NA	NA
Borahay *et al*. (54)	The University of Texas Medical Branch at Galveston, Galveston, TX, USA	RS	20	NA	NA	NA	NA	3 (100.0)	3 (15.0)	0 (0.0)	1 (5.0)	2 (10.0)	0 (0.0)
Geller *et al*. (28)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	PS	28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unger *et al*. (29)	Cleveland Clinic, Cleveland, OH, USA	RS	121	4 (50.0)	3 (37.5)	1 (12.5)	0 (0.0)	0 (0.0)	8 (6.61)	5 (4.13)	0 (0.0)	5 (4.13)	0 (0.0)
Biler *et al*. (30)	University of Health Sciences Tepecik Training and Research Hospital, Izmir, Turkey	PS	20	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (10.0)	1 (5.0)	NA	NA	NA
Matthews *et al*. (31)	Virginia Commonwealth University Medical Center, Richmond, VA, USA	PS	85	2 (66.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (3.52)	0 (0.0)	0 (0.0)	6 (7.05)	0 (0.0)
Ploumidis *et al*. (33)	OLV Vattikuti Robotic Surgery Institute, Aalst, Belgium	RS	95	2 (66.6)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	3 (3.15)	NA	0 (0.0)	3 (3.15)	0 (0.0)
Elliott *et al*. (34)	Stanford University, Stanford, CA, USA	RS	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Illiano *et al*. (35)	Andrology and Urogynecology Clinic, Santa Maria Terni, Italy	PS	49	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anger *et al*. (36)	Cedars-Sinai Medical Center, Los Angeles, CA, USA	RCT	40	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	2 (5.0)	NA	0 (0.0)	1 (2.5)	1 (2.5)
Barboglio *et al*. (37)	Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA	RS	127	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.57)	NA	0 (0.0)	2 (1.57)	0 (0.0)

Table 2 (*continued*)

Table 2 (*continued*)

Study	Institution	Study design	Robotic cases	Intraoperative complications (%)						Conversion (%)	Savata classification (%)		
				Bladder injury	Bowel injury	Vascular injury	Ureteral injury	Other injury	Total		Grade 1	Grade 2	Grade 3
Geller *et al*. (39)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	23	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tan-Kim *et al*. (40)	University of California, San Diego, CA, USA	RS	43	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Louis-Sylvestre and Herry (41)	Institut Mutualiste Montsouris, Paris, France	RS	90	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	NA	0 (0.0)	1 (1.11)	0 (0.0)
Louis-Sylvestre and Herry (41)	Institut Mutualiste Montsouris, Paris, France	RS	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zhao and Martin (43)	University of Alberta, Edmonton, AB, Canada	RS	47	2 (33.3)	0 (0.0)	3 (50.0)	1 (16.6)	0 (0.0)	6 (12.7)	0 (0.0)	NA	NA	NA
Akl *et al*. (44)	Mayo Clinic, Phoenix, AZ, USA	–	80	2 (50.0)	1 (25.0)	0 (0.0)	1 (25.0)	0 (0.0)	4 (5.0)	4 (5.0)	0 (0.0)	4 (5.0)	0 (0.0)
Antosh *et al*. (45)	Washington Hospital Center, Washington, DC, USA	RS	65	3 (75.0)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)	4 (6.15)	0 (0.0)	0 (0.0)	4 (6.15)	0 (0.0)
Matanes *et al*. (46)	Rambam Health Care Campus, and Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	25	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Salamon and Culligan (47)	Division of Urogynecology, Atlantic Health System, Morristown, NJ, USA	RS	64	NA	NA	NA	NA	NA	NA	0 (0.0)	NA	NA	NA
Benson *et al*. (49)	Southern Illinois University, Carbondale, IL, USA	RS	33	NA	NA	NA	NA	4 (100.0)	4 (12.1)	NA	NA	NA	NA
Siddiqui *et al*. (50)	Duke University Medical Center, Durham, NC, USA	RS	125	2 (66.6)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	3 (2.4)	NA	0 (0.0)	2 (1.6)	0 (0.0)
Bedaiwy *et al*. (51)	University Hospitals Case Medical Center, Cleveland, OH, USA	RS	41	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	2 (4.87)	0 (0.0)	0 (0.0)	2 (4.87)	0 (0.0)
Mourik *et al*. (52)	Maasstad Hospital, Rotterdam, Netherlands	PS	50	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Overall	–	–	2,768	37 (48.6)	9 (11.8)	8 (10.5)	3 (3.94)	19 (25.0)	76 (2.74)	40 (1.44)	2 (0.07)	51 (1.84)	4 (0.14)

RSC, robotic sacrocolpopexy; PS, prospective study; RCT, randomized controlled trial; RS, retrospective study; NA, not applicable.

Table 3 A summary of postoperative complications in the RSC series

Study	Institution	Study design	Robotic cases	Postoperative complication (%)							Clavien-Dindo classification (%)						
				Pelvic hematoma	Wound infection	Urinary dysfunction	Ileus and defecatory dysfunction	Dyspareunia	Mesh erosion	Total	Grade 1	Grade 2	Grade 3a	Grade 3b	Grade 4a	Grade 4b	Grade 5
Ferrandom *et al*. (6)	Cleveland Clinic, Cleveland, OH, USA	RCT	24	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geller *et al*. (7)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	147	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Elliott *et al*. (8)	Mayo Clinic, Rochester, MN, USA	PS	42	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.76)	4 (9.52)	0 (0.0)	2 (4.76)	2 (4.76)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Thubert *et al*. (53)	Pitié Salpétrière Hospital, APHP, Paris, France	RCT	95	0 (0.0)	0 (0.0)	21 (80.7)	3 (11.5)	0 (0.0)	2 (2.10)	26 (27.3)	NA	NA	NA	NA	NA	NA	NA
Mueller *et al*. (9)	Loyola University Chicago Stritch School of Medicine, Chicago, IL, USA	RCT	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shariati *et al*. (11)	UMDNJ New Jersey Medical School, Newark, NJ, USA	RS	77	0 (0.0)	0 (0.0)	5 (29.4)	5 (29.4)	5 (29.4)	0 (0.0)	17 (22.0)	5 (6.49)	9 (11.6)	3 (3.89)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Elliott *et al*. (13)	Mayo Clinic, Rochester, MN, USA	PS	20	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (5.0)	4 (20.0)	0 (0.0)	2 (10.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Awad *et al*. (14)	Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	40	1 (25.0)	0 (0.0)	3 (75.0)	0 (0.0)	0 (0.0)	NA	4 (10.0)	NA	NA	NA	NA	NA	NA	NA
Paraiso *et al*. (15)	Cleveland Clinic, Cleveland, OH, USA	RCT	40	0 (0.0)	3 (20.0)	5 (33.3)	2 (13.3)	0 (0.0)	2 (5.0)	15 (37.5)	0 (0.0)	0 (0.0)	10 (25.0)	0 (0.0)	3 (7.5)	0 (0.0)	0 (0.0)
Chan *et al*. (16)	The Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong	RS	16	NA	NA	NA	NA	NA	NA	2 (12.5)	(0.0)	1 (6.25)	(0.0)	1 (6.25)	0 (0.0)	0 (0.0)	0 (0.0)
Moreno Sierra *et al*. (17)	Hospital Clinico San Carlos, Universidad Complutense, Madrid, Spain	PS	31	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.45)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.22)	1 (3.22)	0 (0.0)	0 (0.0)
Shimko *et al*. (18)	Mayo Clinic, Rochester, MN, USA	RS	40	0 (0.0)	0 (0.0)	9 (81.8)	0 (0.0)	0 (0.0)	2 (5.0)	11 (27.5)	1 (2.5)	1 (2.5)	(0.0)	2 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Linder *et al*. (19)	Mayo Clinic, Rochester, MN, USA	PS	84	NA	NA	NA	NA	NA	NA	NA	0 (0.0)	0 (0.0)	0 (0.0)	2 (2.38)	0 (0.0)	0 (0.0)	0 (0.0)
Elliott *et al*. (20)	Mayo Clinic, Rochester, MN, USA	PS	30	0 (0.0)	2 (66.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (10.0)	1 (3.33)	2 (6.66)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Osmundsen *et al*. (21)	Oregon Health & Science University, Portland, OR, USA	RS	102	NA	NA	NA	NA	NA	8 (7.84)	NA	NA	NA	NA	NA	NA	NA	NA
Belsante *et al*. (22)	UT Southwestern Medical Centre, TX, USA	RS	35	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pulliam *et al*. (23)	Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA	RS	43	NA	NA	NA	NA	NA	NA	1 (2.32)	0 (0.0)	1 (2.32)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Jambusaria *et al*. (24)	Abington Memorial Hospital, Abington, PA, USA	RS	38	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.63)	2 (5.26)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.63)	0 (0.0)	0 (0.0)	0 (0.0)
Mueller *et al*. (26)	The Loyola University Chicago, Stritch School of Medicine, Maywood, IL,USA	RS	226	0 (0.0)	0 (0.0)	0 (0.0)	8 (80.0)	NA	2 (0.88)	10 (4.42)	0 (0.0)	5 (2.21)	0 (0.0)	3 (1.32)	0 (0.0)	0 (0.0)	0 (0.0)
Nosti *et al*. (27)	FPMRS Medstar Washington Hospital Center, Georgetown University School of Medicine, Washington, DC, USA	RS	262	NA	NA	NA	NA	NA	5 (1.90)	5 (1.90)	NA	NA	NA	NA	NA	NA	NA
Borahay *et al*. (54)	The University of Texas Medical Branch, Galveston, Texas,USA	PS	20	NA	NA	NA	NA	NA	0 (0.0)	3 (15.0)	2 (10.0)	0 (0.0)	0 (0.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geller *et al*. (28)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	PS	28	NA	NA	NA	NA	NA	2 (7.14)	4 (14.2)	0 (0.0)	2 (7.14)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Unger *et al*. (29)	Cleveland Clinic, Cleveland, OH, USA	RS	121	0 (0.0)	1 (7.14)	0 (0.0)	0 (0.0)	0 (0.0)	4 (3.30)	14 (11.5)	5 (4.13)	5 (4.13)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Biler *et al*. (30)	University of Health Sciences Tepecik Training and Research Hospital, Izmir, Turkey	PS	20	0 (0.0)	0 (0.0)	1 (16.6)	1 (16.6)	0 (0.0)	0 (0.0)	6 (30.0)	4 (20.0)	1 (5.0)	0 (0.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Matthews *et al*. (31)	Virginia Commonwealth University Medical Center, Richmond, VA, USA	PS	85	0 (0.0)	0 (0.0)	11 (57.8)	6 (31.5)	0 (0.0)	1 (1.17)	19 (22.3)	1 (1.17)	15 (17.6)	0 (0.0)	2 (2.35)	0 (0.0)	0 (0.0)	0 (0.0)
Ploumidis *et al*. (33)	OLV Vattikuti Robotic Surgery Institute, Aalst, Belgium	RS	95	0 (0.0)	0 (0.0)	10 (90.9)	0 (0.0)	0 (0.0)	1 (1.05)	11 (11.5)	1 (1.05)	1 (1.05)	0 (0.0)	1 (1.05)	0 (0.0)	0 (0.0)	0 (0.0)
Elliott *et al*. (34)	Stanford University, Stanford, CA, USA	RS	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Illiano *et al*. (35)	Andrology and Urogynecology Clinic, Santa Maria Terni, Italy	PS	49	1 (5.26)	0 (0.0)	6 (31.5)	6 (31.5)	4 (21.0)	2 (4.08)	19 (38.7)	9 (18.3)	1 (2.04)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 3 (*continued*)

Table 3 (*continued*)

Study	Institution	Study design	Robotic cases	Postoperative complication (%)							Clavien-Dindo classification (%)						
				Pelvic hematoma	Wound infection	Urinary dysfunction	Ileus and defecatory dysfunction	Dyspareunia	Mesh erosion	Total	Grade 1	Grade 2	Grade 3a	Grade 3b	Grade 4a	Grade 4b	Grade 5
Anger *et al*. (36)	Cedars-Sinai Medical Center, Los Angeles, CA, USA	RCT	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barboglio *et al*. (37)	Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA	RS	127	0 (0.0)	0 (0.0)	20 (76.9)	3 (11.5)	0 (0.0)	3 (2.36)	26 (20.4)	2 (1.57)	13 (10.2)	0 (0.0)	7 (5.51)	0 (0.0)	0 (0.0)	0 (0.0)
Cucinella *et al*. (38)	"Villa Sofia-Cervello" Hospital, University of Palermo, Palermo, Italy	RCT	20	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geller *et al*. (39)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	RS	23	NA	NA	NA	NA	NA	2 (8.69)	4 (17.3)	0 (0.0)	2 (8.69)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tan-Kim *et al*. (40)	University of California, San Diego, CA, USA	PS	43	NA	NA	NA	NA	NA	2 (4.65)	5 (11.6)	1 (2.32)	2 (4.65)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Louis-Sylvestre and Herry (41)	Institut Mutualiste Montsouris, Paris, France	PS	90	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.5)	4 (50.0)	1 (1.11)	8 (8.88)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Di Marco *et al*. (42)	Mayo Clinic, Rochester, MN, USA	PS	5	NA	NA	NA	NA	NA	NA	1 (20.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Zhao and Martin (43)	University of Alberta, Edmonton, AB, Canada	RS	47	2 (5.55)	1 (2.77)	16 (44.4)	2 (5.55)	0 (0.0)	1 (2.12)	36 (76.5)	25 (53.1)	7 (14.8)	2 (4.25)	2 (4.25)	0 (0.0)	0 (0.0)	0 (0.0)
Akl *et al*. (44)	Mayo Clinic, Phoenix, AZ, USA	PS	80	0 (0.0)	1 (9.09)	0 (0.0)	1 (9.09)	(0.0)	5 (6.25)	11 (13.7)	0 (0.0)	2 (2.5)	4 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Antosh *et al*. (45)	Washington Hospital Center, Washington, DC, USA	RS	65	NA	2 (7.69)	19 (73.0)	NA	NA	2 (3.07)	26 (40.0)	0 (0.0)	3 (4.61)	0 (0.0)	2 (3.07)	0 (0.0)	0 (0.0)	0 (0.0)
Matanes *et al*. (46)	Rambam Health Care Campus, and Ruth and Bruce Rappaport Faculty of Medicine, Technion, Haifa, Israel	RS	25	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	NA	1 (4.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	0 (0.0)	0 (0.0)
Salamon and Culligan (47)	Division of Urogynecology, Atlantic Health System, Morristown, NJ, USA	PS	64	NA	NA	NA	NA	NA	1 (1.56)	3 (4.68)	0 (0.0)	0 (0.0)	1 (1.56)	1 (1.56)	0 (0.0)	0 (0.0)	0 (0.0)
Benson *et al*. (49)	Southern Illinois University, Carbondale, IL, USA	RS	33	NA	NA	NA	NA	NA	0 (0.0)	4 (12.1)	0 (0.0)	2 (6.06)	0 (0.0)	2 (6.06)	0 (0.0)	0 (0.0)	0 (0.0)
Siddiqui *et al*. (50)	Duke University Medical Center, Durham, NC, USA	RS	125	0 (0.0)	6 (27.2)	0 (0.0)	7 (31.8)	0 (0.0)	3 (2.4)	22 (17.6)	NA	NA	NA	NA	NA	NA	NA
Bedaiwy *et al*. (51)	University Hospitals Case Medical Center, Cleveland, OH, USA	RS	41	0 (0.0)	0 (0.0)	18 (64.2)	1 (3.57)	0 (0.0)	3 (7.31)	28 (68.2)	15 (36.5)	6 (14.6)	3 (7.31)	1 (2.43)	1 (2.43)	0 (0.0)	0 (0.0)
Mourik *et al*. (52)	Maasstad Hospital, Rotterdam, Netherlands	PS	50	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	3 (6.0)	0 (0.0)	0 (0.0)	1 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Overall	–	–	2,768	4 (1.11)	20 (5.55)	144 (40.0)	47 (13.0)	13 (3.61)	58 (2.09)	360 (13.0)	73 (2.63)	85 (3.07)	27 (0.97)	31 (1.11)	5 (0.18)	0 (0.0)	0 (0.0)

RSC, robotic sacrocolpopexy; PS, prospective study; RCT, randomized controlled trial; RS, retrospective study; NA, not applicable.

Table 4 A summary of recurrence rate in the RSC series

Study	Institution	Study design	Robotic cases	Follow up cases	Median follow up duration	Prolapse recurrence (%)					Reoperation for prolapse recurrence (%)				
						Anterior	Apical	Posterior	Anterior and posterior	Total	Vaginal colporrhaphy or sacrocolpopexy	RSC	LSC	ASC	Total
Ferrando *et al*. (6)	Cleveland Clinic, Cleveland, OH, USA	RCT	24	24 (100.0)	6 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Elliott *et al*. (8)	Mayo Clinic, Rochester, MN, USA	PS	42	42 (100.0)	36 [12–48]	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	2 (4.76)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)
Thubert *et al*. (53)	Pitié Salpétrière Hospital, APHP, Paris, France	RCT	78	78 (100.0)	12 [6–19.75]	1 (50.0)	0 (0.0)	1 (50.0)	0 (0.0)	2 (2.56)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)
Paraiso *et al*. (11)	UMDNJ New Jersey Medical School, Newark, NJ, USA	RS	77	53 (68.8)	NA	NA	NA	NA	NA	3 (5.66)	NA	NA	NA	NA	NA
Elliott *et al*. (13)	Mayo Clinic, Rochester, MN, USA	PS	20	20 (100.0)	5.1 [1–12]	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	1 (5.0)	NA	NA	NA	NA	NA
Paraiso *et al*. (15)	Cleveland Clinic, Cleveland, OH, USA	RCT	40	26 (65.0)	12 [NA]	NA	NA	NA	NA	3 (11.5)	NA	NA	NA	NA	NA
Chan *et al*. (16)	The Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong, China	RS	16	16 (100.0)	19 [3–36]	NA	NA	NA	NA	1 (6.25)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Moreno Sierra *et al*. (17)	Hospital Clinico San Carlos, Universidad Complutense Madrid, Spain	PS	31	31 (100.0)	24.5 [16–33]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Shimko *et al*. (18)	Mayo Clinic, Rochester, MN, USA	RS	40	40 (100.0)	62 [36–84]	1 (33.3)	0 (0.0)	2 (66.6)	0 (0.0)	3 (7.5)	NA	NA	NA	NA	NA
Linder *et al*. (19)	Mayo Clinic, Rochester, MN, USA	PS	84	70 (83.3)	72 [39–114]	2 (50.0)	1 (25.0)	1 (25.0)	0 (0.0)	4 (5.71)	3 (75.0)	0 (0.0)	0 (0.0)	1 (25.0)	4 (100.0)
Elliott *et al*. (20)	Mayo Clinic, Rochester, MN, USA	PS	30	30 (100.0)	24 [16–39]	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	2 (6.66)	1 (50.0)	0 (0.0)	0 (0.0)	1 (50.0)	2 (100.0)
Belsante *et al*. (22)	UT Southwestern Medical Centre, TX, USA	RS	35	35 (100.0)	6 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Kenton *et al*. (25)	Northwestern University, Feinberg School of Medicine, Chicago, IL, USA	RCT	40	40 (100.0)	12 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mueller *et al*. (26)	The Loyola University Chicago, Stritch School of Medicine, Maywood, IL, USA	RS	226	181 (80.0)	3.25 [0.2–67]	NA	NA	NA	NA	26 (14.3)	NA	NA	NA	NA	4 (15.3)
Nosti *et al*. (27)	FPMRS Medstar Washington Hospital Center, Georgetown University School of Medicine, Washington, DC, USA	RS	262	262 (100.0)	8 [NA]	NA	NA	NA	NA	45 (17.1)	NA	NA	NA	NA	NA
Borahay *et al*. (54)	The University of Texas Medical Branch at Galveston, Galveston, TX, USA	RS	20	20 (100.0)	17.3 [12–24]	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (5.0)	NA	NA	NA	NA	NA
Geller *et al*. (28)	University of North Carolina at Chapel Hill, Chapel Hill, NC, USA	PS	28	28 (100.0)	12 [NA]	0 (0.0)	0 (0.0)	1 (50.0)	1 (50.0)	2 (7.14)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)
Biler *et al*. (30)	University of Health Sciences Tepecik Training and Research Hospital, Izmir, Turkey	PS	20	20 (100.0)	16 [10–36]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Xylinas *et al*. (32)	CHU Henri Mondor, Créteil, France	RS	12	12 (100.0)	19.1 [8–28]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Ploumidis *et al*. (33)	OLV Vattikuti Robotic Surgery Institute, Aalst, Belgium	RS	95	95 (100.0)	14.8 [19–49]	2 (50.0)	0 (0.0)	1 (25.0)	1 (25.0)	4 (4.21)	NA	NA	NA	NA	NA
Barboglio *et al*. (37)	Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA	PS	127	92 (72.4)	12 [NA]	7 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	7 (7.60)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (28.5)
Cucinella *et al*. (38)	"Villa Sofia-Cervello" Hospital, University of Palermo, Palermo, Italy	RCT	20	20 (100.0)	6 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tan-Kim *et al*. (40)	University of California, San Diego, CA, USA	RS	43	40 (93.0)	6.25±5.75	1 (33.3)	0 (0.0)	2 (66.6)	0 (0.0)	3 (7.5)	NA	NA	NA	NA	NA
Di Marco *et al*. (42)	Mayo Clinic, Rochester, MN, USA	RS	5	5 (100.0)	4 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Zhao and Martin (43)	University of Alberta Edmonton, AB, Canada	RS	47	47 (100.0)	NA	0 (0.0)	0 (0.0)	5 (71.4)	2 (28.5)	7 (14.8)	NA	NA	NA	NA	NA
Akl *et al*. (44)	Mayo Clinic, Phoenix, AZ, USA	RS	80	80 (100.0)	NA	1 (33.3)	1 (33.3)	1 (33.3)	0 (0.0)	3 (3.75)	2 (66.6)	1 (33.3)	0 (0.0)	0 (0.0)	3 (100.0)
Antosh *et al*. (45)	Washington Hospital Center, Washington, DC, USA	RS	65	65 (100.0)	3 [NA]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA	NA	NA	NA
Salamon and Culligan (47)	Division of Urogynecology, Atlantic Health System, Morristown, NJ, USA	RS	64	64 (100.0)	12 [NA]	3 (50.0)	1 (16.6)	2 (33.3)	0 (0.0)	6 (9.37)	NA	NA	NA	NA	NA
Culligan *et al*. (48)	Atlantic Health System, Morristown, NJ, USA	PS	150	149 (99.3)	12 [NA]	3 (50.0)	1 (16.6)	2 (33.3)	0 (0.0)	6 (4.02)	NA	NA	NA	NA	NA
Benson *et al*. (49)	Southern Illinois University, Carbondale, IL, USA	RS	33	33 (100.0)	38.4 [NA]	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	1 (3.03)	NA	NA	NA	NA	NA
Siddiqui *et al*. (50)	Duke University Medical Center, Durham, NC, USA	RS	125	84 (67.2)	NA	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)	3 (3.57)	NA	NA	NA	NA	3 (100.0)
Mourik *et al*. (52)	Maasstad Hospital, Rotterdam, Netherlands	PS	50	50 (100.0)	16 [8–29]	NA	NA	NA	NA	1 (2.00)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Overall	–	–	2,029	1,852 (91.2)	12 [0.2–114]	26 (18.9)	7 (5.10)	24 (17.5)	4 (2.91)	137 (7.39)	15 (60.0)	1 (4.0)	0 (0.0)	2 (8.0)	25 (18.2)

PS, prospective study; RCT, randomized controlled trial; RS, retrospective study; NA, not applicable; ASC, sbdominal sacrocolpopexy; LSC, laparoscopic sacrocolpopexy; RSC, robotic sacrocolpopexy.

conversions (15%) from robotic to laparoscopy and 35 (85%) to open surgery were recorded (8,11,13,15,17-20,23,24,27,29,43,52,57). The conversions to LSC were due to adhesions [n=1 (16.7%)], robot malfunctions [n=2 (33.3%)], and technical problems that were related to the robot [n=3 (50%)]. The cases of RSC converted to abdominal sacrocolpopexy (ASC) were due to difficult exposure or adhesions [n=26 (76.5%)], pneumoperitoneum intolerance [n=1 (2.9%)], obesity [n=1 (2.9%)], vascular injury [n=1 (2.9%)], cystotomies [n=1 (2.9%)], cystotomies and injury to the sigmoid colon [n=1 (2.9%)], and other complications [n=3 (8.8%)].

Cure and recurrence rate

A summary of the recurrence rate in the RSC series is presented in *Table 4*. We only summarized the objective rather than subjective cure rates due to the different studies assessed outcomes considering different variables, thus making the subjective results between studies of no comparative significance. Thirty-four studies recorded 2,029 RSC patients' treatment outcomes, and 1,852 (91.3%) RSC patients have been followed up, with a median postoperative follow-up duration of 12 [1–62] months. Overall, we observed that 134 of 1,852 patients (7.2%) had recurred prolapses of any compartment (POP-Q ≥ grade 2) according to gynecological examination results, and RSC ensured a cumulative cure rate that ranged from 82.35–100%. There were 26 RSC patients (19.4%) with recurrence in the anterior compartment, 24 (17.9%) in the posterior compartment, 4 (3.0%) in both the anterior and posterior compartments, and 7 (5.2%) with recurred apical prolapse. Although the cure rate of apical prolapse was higher than that of anterior and posterior recurrent prolapse, ranging from 96.7% to 100%, there were 77 (57.5%) RSC patients without records of the type of recurred prolapses. Also, few studies had a long follow-up duration of over 24 months, so determining the actual recurrence rate of apical prolapse needs more long-term follow-up results. A total of 25 patients (18.7%) had been reported to reoperation because of prolapse. The surgeons almost always recommended recurrent prolapse patients to undergo reoperation through vaginal colporrhaphy or sacrocolpopexy [60% (n=15)]. Only 1 (4%) and 2 patients (8%) had undergone RSC and ASC, respectively. The participants who underwent reoperation through RSC and ASC were those who had recurred apical prolapse.

Robot-assisted sacrocolpopexy compared with the laparoscopic approach

Intraoperative outcomes and complications

The intraoperative outcomes are summarized in *Figure 2* and Table S1. A total of 9 (14,16,23,26,35,36,38,40,57) studies reported intraoperative blood loss. The results showed that the intraoperative blood loss in the RSC group was significantly less than that in the LSC group (WMD =−58.48 mL, 95% CI: −100.58 to −16.39, P=0.006) with a high heterogeneity (P<0.00001, I^2=98%) (*Figure 2A*). A total of 11 (6,15,16,23,26,29,35,36,38,40,57) studies reported the operation times, which revealed a significant difference between RSC and LSC (WMD =37.35 minutes, 95% CI: 24.46 to 50.24, P<0.00001) with a high heterogeneity (P<0.00001, I^2=82%) (*Figure 2B*). A total of 8 (14,23,26,29,44,57-59) studies reported the rate of conversion, and the results showed that there was much lower conversion rate in RSC than that in LSC (OR =0.35, 95% CI: 0.15 to 0.79, P=0.01) without significant statistical heterogeneity (P=0.51, I^2=0%) (*Figure 2C*).

A total of 13 (6,14-16,23,26,29,36,40,44,57-59) studies reported intraoperative complications. The meta-analysis showed no statistically significant difference in the rate of intraoperative complications between RSC and the LSC (pooled OR =0.70, 95% CI: 0.46 to 1.06, P=0.09) without significant statistical heterogeneity (P=0.4, I^2=4%) (*Figure 2D*). Among them, 10 (6,15,16,26,29,36,40,44,58,59) studies reported intraoperative bladder injury, 9 (6,15,16,26,29,36,40,58,59) studies reported intraoperative intestinal damage, 6 (6,16,29,36,44,59) studies reported intraoperative vascular injury, and 5 (6,16,26,29,59) studies reported intraoperative ureteral injury, respectively. Similarly, the results showed no statistical significance in the rate of intraoperative bladder injury (RSC 2.2% *vs.* LSC 3.1%, P=0.17), rate of intraoperative intestinal damage (RSC 0.6% *vs.* LSC 1.1%, P=0.43), rate of intraoperative vascular injury (RSC 0.8% *vs.* LSC 0.8%, P=0.66), and the rate of intraoperative ureteral injury (RSC 0.2% *vs.* LSC 0.0%, P=0.41) (*Figure 2E,F,G,H*).

Postoperative outcomes and complications

The postoperative outcomes are summarized in *Figure 3* and Table S2. Length of hospital stay was reported in 9 (14-16,23,38,40,44,57,59) studies. There was no significant differences in length of hospital stay between the RSC and the LSC (WMD =0.31, 95% CI: −0.64

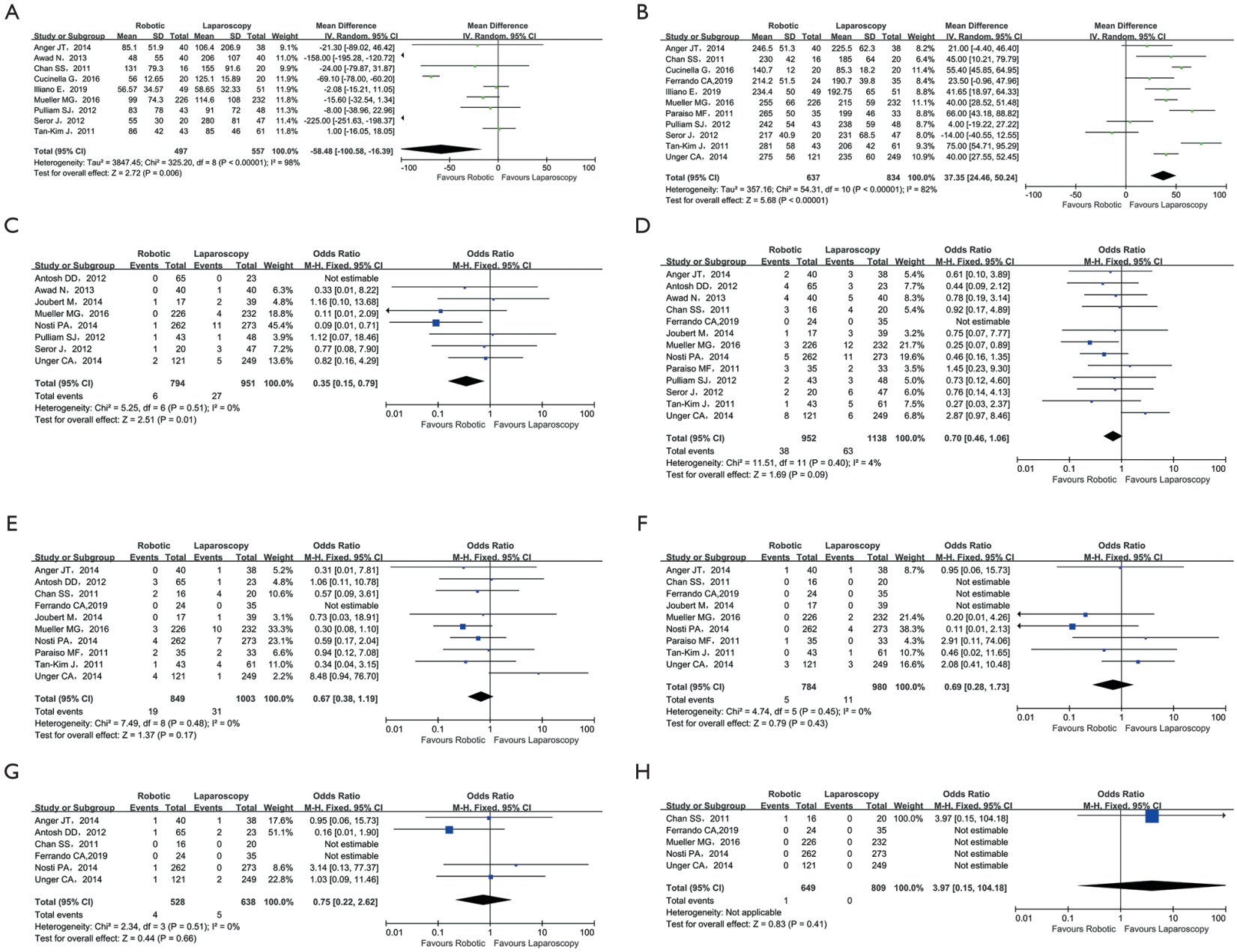

Figure 2 Meta-analysis of patients demographics. (A) Intraoperative blood loss; (B) operation time; (C) conversion rate; (D) intraoperative complication; (E) intraoperative bladder injury; (F) intraoperative intestinal injury; (G) intraoperative vascular injury; (H) intraoperative ureteral injury. CI, confidence interval.

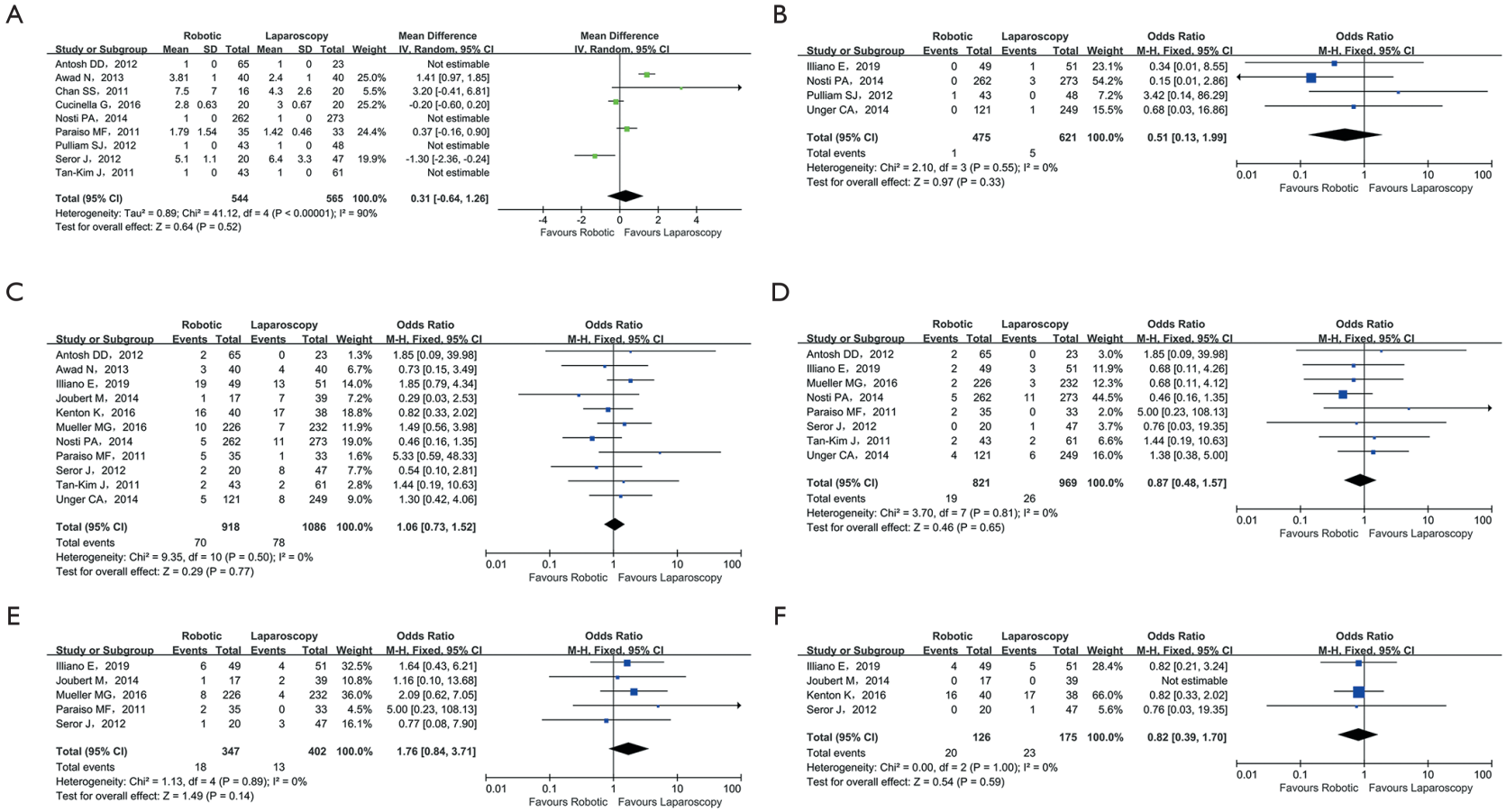

Figure 3 Meta-analysis of patients demographics. (A) Length of hospital stay; (B) perioperative transfusion rate; (C) postoperative complication; (D) mesh erosion; (E) postoperative anorectal dysfunction; (F) postoperative sexual disorder. CI, confidence interval.

to 1.26, P=0.52) with a high heterogeneity (P<0.00001, I^2=90%) (*Figure 3A*). Perioperative transfusion was reported in 4 (23,29,35,59) studies. Similarly, no significant differences were observed in perioperative transfusion between the RSC and the LSC (OR =0.51, 95% CI: 0.13 to 1.99, P=0.33) without significant heterogeneity (P=0.55, I^2=0%) (*Figure 3B*). A total of 11 (14,15,25,26,29,35,40,44,57-59) studies reported overall and major postoperative complications, and the results showed no statistically significant difference in the rate of postoperative complications between the RSC and LSC (OR =1.06, 95% CI: 0.73 to 1.52, P=0.77) without significant heterogeneity (P=0.5, I^2=0%) (*Figure 3C*). Of these, 8 (15,26,29,35,40,44,57,59) studies reported the rate of erosion of the mesh, 5 (15,26,35,57,58) reported postoperative anorectal dysfunction, and 4 (25,35,57,58) reported postoperative sexual disorders, respectively. Results of meta-analysis showed that there was no significant difference in the rate of erosion of the mesh (RSC 2.3% *vs.* LSC 2.7%, P=0.65), rate of postoperative anorectal dysfunction (RSC 5.2% *vs.* LSC 3.2%, P=0.14), and the rate of postoperative sexual disorders (RSC 15.9% *vs.* LSC 13.1%, P=0.59) (*Figure 3D,E,F*).

Cure and recurrence

The cure and recurrence outcomes are summarized in *Figure 4* and Table S3. A total of 5 (14-16,35,58) studies reported the cure rate of POP (POP ≤1 grade), and the results showed that the difference between RSC and LSC in a cure rate of POP was not statistically significant (OR =1.30, 95% CI: 0.55 to 3.05, P=0.55) without significant heterogeneity (P=0.77, I^2=0%) (*Figure 4A*). Objective recurrence was reported in 8 (15,26,36,40,44,57-59) studies. There was no significant difference in the rate of objective recurrence between RSC and LSC (OR =1.20, 95% CI: 0.83 to 1.73, P=0.34) without significant heterogeneity (I^2=33%, P=0.16) (*Figure 4B*). A total of 5 (16,26,36,44,58) studies reported the reoperation rate, showing that the difference between RSC and LSC in reoperation rate was not statistically significant (OR =0.66, 95% CI: 0.27 to 1.61, P=0.36) without significant heterogeneity (P=0.9, I^2=0%) (*Figure 4C*).

Publications bias

Egger's test was used to assess the publication bias for four outcomes. The P values for operative time, intraoperative blood loss, postoperative complication, conversion rate, and objective recurrence (24 months) were 0.206, 0.765, 0.865, 0.309, and 0.327, respectively. No significant publication bias was discovered among the studies.

Discussion

In this systematic review and meta-analysis of 49 articles, including 3,014 patients, 18 were comparative studies on LSC *vs.* RSC, and 31 were non-comparative single-arm studies on RSC. For RSC, the median operative time was 226 [90–604] minutes, estimated blood loss was 56 [5–1,500] mL, and hospital stay was 1.55 [1–16] days. Intraoperative complications and postoperative complications occurred in 74 (2.7%) and 360 (13.0%) patients, respectively. Out of 2,768 RSC patients, 40 had been converted from a robot-assisted approach to other approaches, 134 of 1,852 patients (7.2%) had recurred prolapses of any compartment. Compared with LSC, RSC was associated with significantly lower blood loss (WMD =–58.48 mL, 95% CI: –100.58 to –16.39, P=0.006) and lower conversion rate (OR =0.35, 95% CI: 0.15 to 0.79, P=0.01). However, longer operative time (WMD =37.35 minutes, 95% CI: 24.46 to 50.24, P<0.00001) and no significant difference in perioperative transfusion, intraoperative and postoperative complications, and objective recurrence were observed between RSC and LSC.

Sacrocolpopexy is the "gold standard" procedure for the treatment of POP patients with apical defects. Different surgical approaches have emerged successively over recent years, including traditional laparoscopy, single-hole laparoscopy, robot-assisted laparoscopy, vaginal-assisted laparoscopy, and transvaginal approaches, with different surgical approaches having different respective advantages (60). The LSC has become the current mainstream approach of this operation due to its advantages of minimal trauma, high cure rate, and low recurrence rate (3). However, from analysis of the anatomical structure, the anterior longitudinal ligament on the pelvic surface of S1 vertebra in the presacral region is a relatively safe suture area for sacral fixation (the upper boundary is 10 mm below the promontory, the lower boundary is 40 mm below the promontory, and the horizontal width is 15 mm) (61). LSC operation is mainly performed in this area, but the sacrococcygeal curvature in this area is concave backward, which is a relatively "blind area" for laparoscopic surgery. Besides, the presacral region's anatomy is complex, rich in blood vessels, and has high anatomical variability. Considering that the right internal iliac vein is a large vessel nearby and the presacral venous plexus is interwoven into a mesh, it is challenging to arrest bleeding following injury to the presacral vessels and bleeding can easily occur during

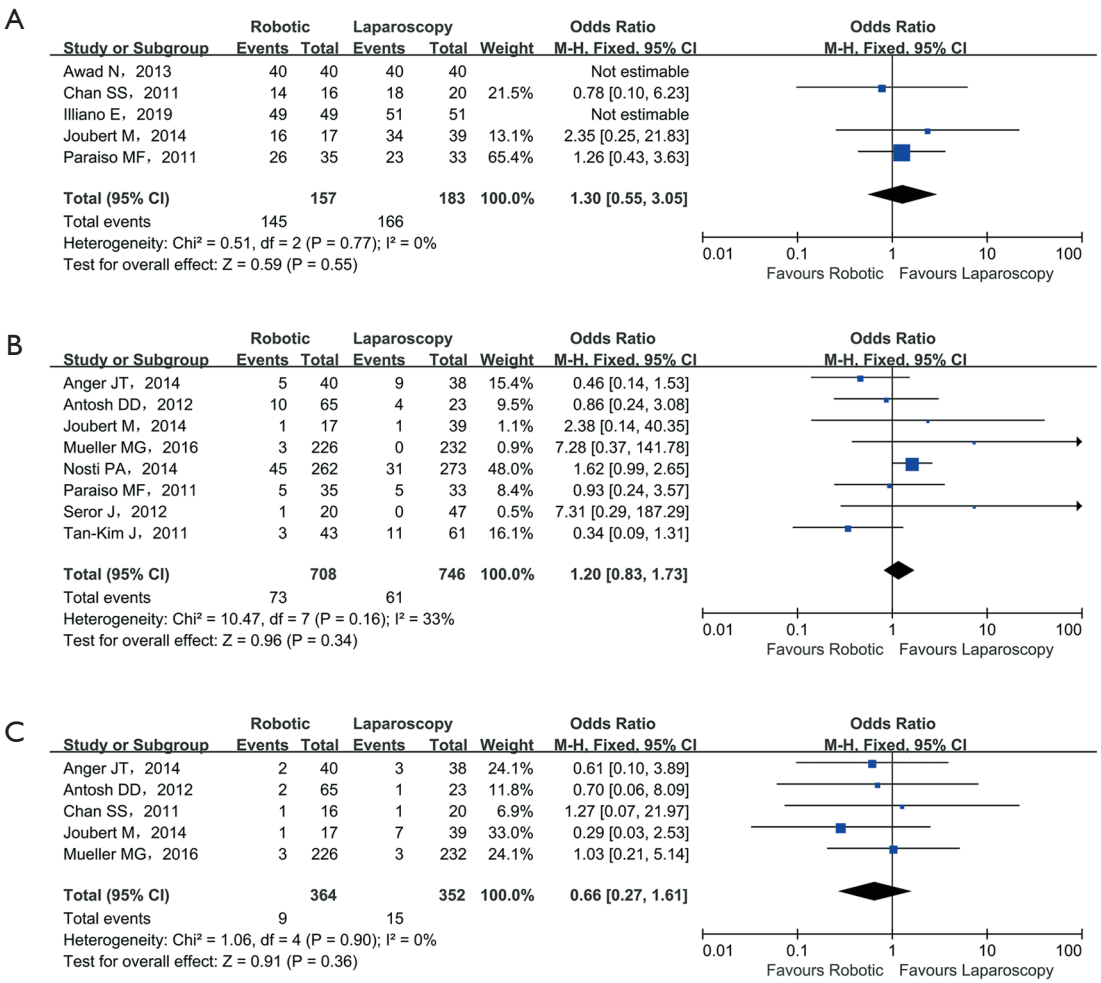

Figure 4 Meta-analysis of patients demographics. (A) Cure rate of POP; (B) objective recurrence (24-month); (C) reoperation rate. POP, pelvic organ prolapse; CI, confidence interval.

the operation. In addition, the pelvic cavity is occupied by uterus, ovaries, bladder, rectum, and other organs, and the ureter travels on both sides; thus, it is difficult to surgically separate and suture (62,63). Consequently, the principal limitations of traditional LSC are the difficulty of suturing and the risk of vascular injury provoked by the chopstick effect of two-dimensional (2D) vision and instruments.

The RSC has attracted increasing attention as an emerging surgical technique with unique advantages (64). Firstly, the robotic surgery system's camera has a dual-lens structure, which provides doctors with a super-clear, high-fold surgical field, and 3D visualization of the pelvis. Secondly, its mechanical arm has "7 degrees of freedom" and installs a flutter filter device, enabling the simulated wrist to rotate 540°, with the unique properties of high precision, flexibility, and stability. Thirdly, the console is designed according to the mechanical characteristics of the human body. By controlling the handle and pedal, the operator can realize the precise real-time movement of the wrist, hand, and fingers through the sensing system, allowing operator comfort and diminishing operator fatigue. Fourthly, it circumvents the disadvantage of poor cooperation between the operator and assistant that inevitably appears during LSC (64). Da Vinci robotic surgery was successfully applied in gynecological surgery for the first time in 2004, and it was officially approved by the Food and Drug Administration (FDA) for use in the gynecological clinic in 2005.

Intraoperative bleeding volume is a crucial parameter to evaluate the quality of surgery, and it is significantly

related to the recovery of patients after surgery. Our results demonstrated that the intraoperative bleeding volume of the RSC group was significantly lower than that of LSC; the maximum median blood loss of RSC was 131 mL, in comparison, that of LSC was 280 mL; there were 5 out of 621 LSC series that required transfusion, and just 1 out of 475 participants in RSC, which indicated that robotic surgery had apparent advantages in meticulous and precise operation. The RSC also revealed significant advantages in avoiding conversion of laparoscopic surgery. In essence, RSC's conversion rate was 0.76% (7/794), mainly due to severe pelvic and abdominal adhesions, while the conversion rate of LSC was 2.8% (27/951); besides adhesions, bladder and bowel injury were the main reasons leading to conversion. In comparing the operation time, that of the RSC group was longer while a broad range of operation time was seen among different institutions, which may be generated by the following reasons. First, there was no uniform criterion to measure operation time. Some hospitals had included the docking time of the robot surgical system, which adds an extra 3–60 mins (15). Besides, some data were collected during the early adoption phase for RSC at numerous institutions. Additionally, surgeons' experience always has an inverse correlation with the duration of surgery. Akl and Awad *et al*. reported that operative time decreased >25% after the execution of the first 10 cases, which was primarily attributed to the shortening of console time (14,43). Also, Geller *et al*. described that time of cuff closure, anterior and posterior sacral dissection, sacral mesh attachment, peritoneal closure, total docked time, and total incision time decreased after the first 20 procedures of RSC, which suggested that the learning curve of RSC is an influential factor on operative time (7). In comparing perioperative complications, average hospitalization days, post-operative cure rate, and objective recurrence rate, there were no significant differences between the two surgical methods, indicating that both methods had the characteristics of high cure rate and low recurrence rate in terms of clinical efficacy.

The principal disadvantage of the robotic surgery system is the inherent cost and high maintenance cost. However, advantages such as the "simulated wrist" mechanical arm and high-definition 3D visual field effectively overcome the problem of "blind area" of vision and operation in LSC surgery, which provides a positive guarantee for surgical operation. They can effectively reduce the risk of vascular injury, bleeding, and endoscopic transfer in the presacral area.

Conclusions

The RSC appears to offer some advantages compared to conventional laparoscopic surgery, although both approaches appear to offer equivalent clinical outcomes. It is crucial to note that heterogeneity among studies may have affected this study's outcome, and a high-quality and large-sample randomized trial comparing both techniques is required.

Acknowledgments

We gratefully acknowledge the contributions of numerous investigators that we were unable to include in this review, owing to space limitations. This research was sponsored by Hubei Province's Outstanding Medical Academic Leader Program. Part of the funds was used to gain access to the database.

Funding: This research is supported by Hubei Province's Outstanding Medical Academic Leader Program.

Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at http://dx.doi.org/10.21037/atm-20-4347

Peer Review File: Available at http://dx.doi.org/10.21037/atm-20-4347

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/atm-20-4347). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Yang J, He Y, Zhang X, Wang Z, Zuo X, Gao L, Hong L. Robotic and laparoscopic sacrocolpopexy for pelvic organ prolapse: a systematic review and meta-analysis. Ann Transl Med 2021;9(6):449. doi: 10.21037/atm-20-4347