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SCIENTIFIC REVIEW

Robotic Single-Port Platform in General, Urologic, and Gynecologic Surgeries: A Systematic Review of the Literature and Meta-analysis

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Abstract

Background Robotic platforms have recently acquired progressive importance in different surgical fields, such as urology, gynecology, and general surgery. Through the years, new surgical robots have become available as single-port robotic platform. The study is aimed to value the single-port robotic platform characteristics in different surgical specialties.

Methods The terms “LESS” OR “single port” OR “single site” AND “robot” OR “robotic” were systematically used to search the PubMed and Scopus databases. A total of 57 studies were considered eligible for the present review. The articles included were divided according to the surgical field in which the study was conducted: General surgery (29 articles), Gynecology (18 articles), Urology (10 articles).

Results Most part of the articles showed the feasibility of robotic single-port surgical procedures and described advantages in terms of cosmetic, hospital stay, and in some series even cost reduction. A meta-analysis was conducted, showing a significant increment of complications using RSP if compared with SLPS and a trend ($P = 0.008$) when RSP was compared with LESS. The comparison of different techniques in terms of conversion to laparotomy did not show any significant difference.

Conclusion Robotic single port potentially furnishes an important surgical and post-operatory improvement; however, some limits still prolong the surgical time and complication rate.

Introduction

The benefits of endoscopic procedures have been well demonstrated in the literature. The advantages are mainly related to reduced hospitalization, postoperative pain, complications rate, and consequently a consistent improvement in patients’ quality of life [1]. In the last years, the concept of ultra-minimally invasive surgery (U-MIS) took place with the effort to minimize the number of trocars used and the size of instruments. The decrease in the size of the ports was obtained with the innovation of 3 mm and percutaneous instruments, while the reduction in the number of trocars was achieved with the use of single-port devices [2–11].

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Since their approval and marketing in 2005, robotic platforms acquired progressive importance in different surgical fields, such as urology, gynecology, and general surgery. Through the years, new surgical robots [12–14] have become available and others are in an experimental phase. Of note, also in the field of robotic surgery, one of the directions for innovation and technology improvement has been the reduction in the instrument size [15] and the use of single port. Regarding this latter aspect, robotic single-site surgery has been extremely useful to overcome the ergonomic limitations and the long learning curve of standard single-port laparoscopic surgery.

The objective of this article is to present the existing clinical evidence on the use of single-port robotic-assisted platforms in different surgical fields such as general surgery, gynecology and urology. When data were available, we also reported the cost analysis of these procedures.

Materials and methods

The present review was designed to incorporate population criteria, surgical interventions, and outcomes. The systematic search was modeled in agreement with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [16, 17], and it was registered in the International Prospective Register of Systematic Reviews (available at http://www.crd.york.ac.uk/PROSPERO; CRD 42018108068). The terms "LESS" OR "single port" OR "single site" AND "robot" OR "robotic" were systematically used to search the PubMed and Scopus databases. A hand search of the references of both potentially relevant articles and articles qualifying for inclusion was also performed. Original reports in English language were identified, with the purpose of including all relevant papers regarding robotic single-site surgery in three of the main possible applications of this technique (i.e., general surgery, urology and gynecology). Exclusion criteria included duplicate publications, non-English language literature, case series including less than 10 single-site robotic procedures, letters, editorials, different fields of application and then general surgery, urology and gynecology and reviews to avoid repetition of studies results. The flow diagram of the detailed process of selection of articles for inclusion in the review is reported in Fig. 1.

The principal findings considered in the present review were: the study design, the number of patients included in each study, operative time, estimated blood loss (EBL), conversion rate to multiport robotic or standard laparoscopy or laparotomy, postoperative complications, postoperative hospital stay, costs analysis (when provided by the studies), and the possible advantages and disadvantages reported by the authors of the studies.

Statistic analysis

A meta-analysis of the comparative studies was performed using the Cochrane Review software (Review Manager version 5.3 for Windows; Cochrane Community, London, UK), in order to assess the rate of complications and conversions to laparotomy of single-site robotic surgery, compared to conventional standard techniques (standard robotics, LESS and standard laparoscopy). No meta-analysis was conducted regarding operative time, estimated blood loss and hospital stay, due to the large heterogeneity of the studies included. A Chi-square test for heterogeneity among proportions was used to determine the presence of statistical heterogeneity between studies in terms of surgical-related complications and success rate.

Random effect model was used. Forest and funnel plots were created for each comparison; P values < 0.05 were considered statistically significant.

Results

A total of 57 studies were considered eligible for the present review (flow diagram Fig. 1). The articles included were divided according to the surgical field in which the study was conducted: General surgery (29 articles), Gynecology (18 articles), Urology (10 articles).

General surgery

We selected 29 studies published between 2011 and 2018, consisting of 14 case–control and 15 case series.

Perioperative data, rate of conversion, complications, and authors comment are reported in Table 1.

General surgery procedures represent the largest application of robotic single port (RSP) described in the literature. Five studies with more then 200 patients have been reported [18, 40, 41, 43, 46]. The most frequent procedure performed with RSP is cholecystectomy, but also bowel resections and adrenalectomies have been reported. Most of the studies describe that the operative time for RSP cholecystectomy ranges approximately between 60 and 120 min. Instead for adrenalectomy and colectomy, the time required is mainly between 100 and 230 min.

In some studies, the operative time was significantly increased for RSP if compared with standard laparoscopy (SLPS) or laparo-endoscopic single site (LESS) [20, 36, 44, 45]. A shorter operative time is reported in case of RSP-reverse [23]. Other studies do not confirm the disadvantages in terms of operative time using RSP [18, 22, 26, 34, 44, 46]. The authors attribute the different results obtained to the variable experience of the surgeons involved. In a study by Svoboda et al. [41], the population

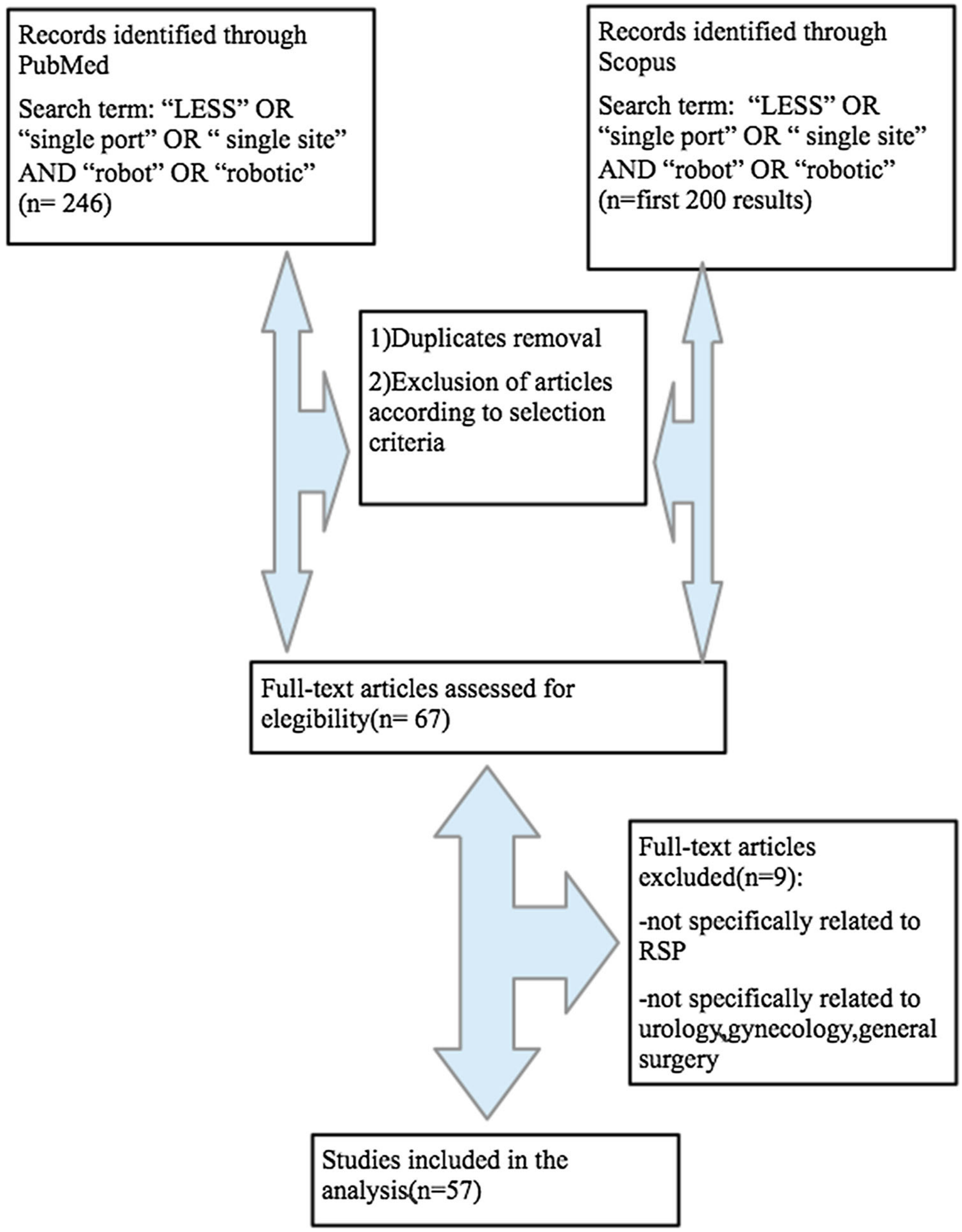

Fig. 1 Flow diagram of the detailed process of selection of articles for inclusion in the review

was stratified on patients' BMI. The results of this report showed that patients with BMI $\geq$ 30 have a significantly prolonged operative time.

All studies report minimal EBL for RSP cholecystectomy, while adrenalectomies were more frequently related with major EBL, although no studies reported statistically significant differences with other techniques. The conversion rate, especially for cholecystectomies, is acceptable. Balachandra et al. [18] reported a large series of 678 cases (415 RSP, 263 SLPS) in which the rate of conversions from RSP to SLPS and from RSP to laparotomy (LPT) was 2.9% and 3.2%, respectively. No significant differences in terms of conversions were detected when comparing different surgical approaches. Hospital stay ranges between 1 and 4 days in the majority of the studies selected, although series including complex procedures such as colectomy and adrenalectomy describe a tendentially longer average hospital stay. Some comparative studies [18, 23, 36, 40] report that RSP is associated with a shorter hospitalization, compared to SLPS and LESS. However, other studies such as Kudsi et al. [20] and Arghami et al. [26] did not report significant differences between RSP and other techniques.

The majority of the complications reported in the studies included were minor (grade 1–2). Umbilical wound infections and umbilical incisional hernias represent the most frequently reported adverse events.

Table 1 Studies referring to robotic single port in general surgery

References	Type of study	No. of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) Mean/median	Conversions (%)	Hospital stay (days) [P] mean/median	Postoperative complications [P]	Comments
Balachandran et al. [18]	Retrospective case–control	415 (RSP) 263 (SLPS)	CH	RSP 89.4 (SD 27.8) SLPS 92.6 (SD 31.9) $P = 0.169$	–	12 (2.9%) RSP to SLPS $P = 0.551$ 13 (3.2%) RSP to LPT 13 (4.9%) SLPS to LPT $P = 0.232$	RSP 1.9 (SD 3.1) SLPS 2.4 (SD 2.3) $P = 0.012$	–	Less pain control with RSP $P = 0.032$ More wound infection with RSP $P = 0.037$ More umbilical incisional hernias with RSP $P = 0.006$
Rosales-Velderrain et al. [19]	Retrospective case series	14	CH	82 (range 64–169)	Mean: 2 (range 2–25)	–	1 (range 0–2)	1 (7.1%)[a]	Feasible and safe approach with excellent cosmetic results
Kudsi et al. [20]	Prospective randomized case–control	83(RSP) 53 (SLPS)	CH	RSP 61 (SD 27.5) SLPS 44 (SD 19.9) $P < 0.0001$	RSP 13.06 SLPS 15.83 $P = 0.45$	–	RSP 0.69 SLPS 0.58 $P = 0.32$	4 (4.8%)[a] RSP 2(3.7%)[a] SLPS	Better cosmesis with RSP Safe procedure
van der Linden et al. [21]	Prospective case series	27	CH	81 (range 81–115)	–	1 (3.7%) to RMP 2 (7.4%) to LPT	1 (range 1–10)	4 (14.8%)[a]	5 (18.5%) trocar site hernias Higher costs than SLPS.
Pietrabissa et al. [22]	Prospective randomized case–control	30 (RSP) 30 (SLPS)	CH	RSP 98 (SD 34) SLPS 87 (SD 30) $P = 0.19$	–	RSP 0 SLPS 0	RSP 1.2 (range 1–3) SLPS 1.2 (range 1–3)	RSP 2 (6.6%)[a] SLPS 0 (0%) $P = 0.49$	Better cosmesis with RSP $P < 0.001$ Increased risk of incisional hernias with RSP
Jung et al. [23]	Retrospective case–control	5 (RSP) 50 (RSP-R)	CH	RSP 132.6 RSP-R 99.12 $P = 0.009$	RSP 20 RSP-R 12.4 $P = 0.467$	1 (2%) RSP-R to LPT	RSP 2.16 RSP–R 1.91 $P = 0.036$	–	–
Lee et al. [24]	Retrospective case series	33	AD	234.4 (SD 100.4)	392.6 (SD 1075.6)	5 (15%) to SLPS 2 (6%) to LPT	2.8 (SD 1.5)	6 (12%)[a]	RSP is comparable to other existing minimally invasive techniques
Jones et al. [25]	Retrospective case series	17	CH	94 (range 65–127)	–	1 (5.8%) to SLPS	1 (range 1–5)	1 (5.8%)[a]	Feasible technique and easier compared to LESS

Table 1 continued

References	Type of study	No. of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) Mean/median	Conversions (%)	Hospital stay (days) [P] mean/median	Postoperative complications [P]	Comments
Arghami et al. [26]	Retrospective case–control	16 (RSP) 16 (SLPS)	AD	RSP 183 (SD 33) SLPS 173 (SD 40) $P = 0.63$	576 (SD 377) SLPS 618 (SD 372) $P = 0.68$	2 (12%) RSP to SLPS 1 (6%) RSP to LPT 1 (6%) SLPS to LPT	RSP 2.3 (SD 0.5) SLPS 3.1 (SD 0.9) $P = 0.23$	–	Increased narcotic use with SLPS $P < 0.001$
Ayloo et al. [27]	Retrospective case series	31	CH	81.96 (range 4–127)	8.3 (range 5–15)	2 (6.4%) to RMP	0.3 (range 0–2)	1 (3.2%)[a]	Feasible and safe technique
Juo et al. [28]	Retrospective case series	59	CO	188 (range n.r.)	100 (range n.r.)	3(5.1%) to RMP 1 (1.7%) to SLPS 4 (6.8%) to LPT	4 (range n.r.)	10 (16.9%)[a] 5 (8.4%)[b] 1 (1.6%) grade 5	Feasible and safe technique
Uras et al. [29]	Retrospective case series	36	CH	61.8 (range 34–110)	–	1 (2.8%) to RMP	1.05 (range 1–2)	–	The dexterity of instruments and the 3D view facilitate the movements
Lim et al. [30]	Retrospective case series	22	AR	167.5 (range 112–251)	24.5 (range 5–230)	–	6 (range 5–9).	–	Feasible and safe technique Better cosmesis
Pietrabissa et al. [31]	Prospective case series	100	CH	71 (SD 19)	–	2 (2%) to LPT	–	–	More complex than SLPS but easier than LESS
Konstantinidis et al. [32]	Retrospective case series	45	CH	84.5 (SD 25.5)	–	3 (6.7%) to RMP	1	1 (2.2%)[a]	Improved cosmetic result and less postoperative pain Increased costs
Morel et al. [33]	Retrospective case series	28	CH	80 (range 45–195)	5 (range 0–50)	–	–	–	Feasible and safe technique
Wren et al. [34]	Retrospective case–control	10 (RSP) 10 (RMP)	CH	RSP 105.3 (range 82–139) SLPS 106.1 (range 70–142) $P = 0.93$	–	1 (10%) RSP to LPT	–	SLPS 1 (10%)[a]	–
Kroh et al. [35]	Case series	13	CH	107 (range 48–205)	38 (range 0–150)	1 (7.7%) to RMP	0.9 (range 0.2–4.9)	1 (7.7%)[a]	Improved cosmesis and pain control
Mattei et al. [36]	Retrospective case–control	20 (RSP) 20 (SLPS)	CH	RSP 77.4 (SD 20.7) SLPS 48.4 (SD 16.4) $P < 0.00001$	–	–	RSP 1.01 (SD 0.22) SLPS 2.48 (SD 2.51) $P < 0.0004$	RSP 4(20%)[a]	Improved cosmesis but longer operative times with RSP

Table 1 continued

References	Type of study	No. of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) Mean/median	Conversions (%)	Hospital stay (days) [P] mean/median	Postoperative complications [P]	Comments
Lim et al. [37]	Retrospective case–control	37 (RSP) 60 (SLPS)	CH	RSP 132 (SD 36) SLPS 53 (SD 20) p(n.r.)	–	–	RSP 1 (SD 0) SLPS 1.70 (SD 0.8) p(n.r.)	5 (13.5%)[a] RSP	Higher wound infection rate
Lee et al. [38]	Retrospective case series	30 (RSP)	CH	53.80 (SD 15.20) (range 32–80)	–	–	1.30 (SD 0.54) (range 1–3)	–	–
Su et al. [39]	Retrospective case–control	51 (RSP) 63 (LESS)	CH	RSP 71.30(SD 48.88) LESS 74.70(SD 30.16) $P = 0.772$	–	2 (3.17%) LESS to LPT	RSP 4.21 (SD 0.72) LESS 4.13 (SD 0.93) $P = 0.823$	–	Pain reduction with RSP $P = 0.001$ Increased costs with RSP $P = 0.001$
Gonzalez et al. [40]	Prospective case series	465 (RSP)	CH	52 (range 29–221)	–	– 6 (1.2%) to MPR – 4 (0.8%) to SLPS	0.68 (range 0.12–0.95)	11 (2.3%)[a]	Triangulation eliminate Instruments fighting
Svoboda et al. [41]	Retrospective case series	200 RSP 88 BMI < 30, 112 BMI > 30	CH	59.2 (19.7%) (BMI < 30) 69.8 (26%) (BMI > 30) $P = 0.0012$	–	–	–	1 (0.5%)[b]	RSP is safe and feasible in obese patients
Morel et al. [42]	Prospective case series	82	CH	91.05 (SD 29.92)	10.60 (SD 14.23)	2 (2.44%) to RMP – 1(1.22%) to LPT	2.42 (SD 5.96)	2 (2.44%)[a] 2(2.44%)[b]	Longer operative time in obese patients $P = 0.010$
Gonzalez et al. [43]	Prospective case–control	166 (RSP) 166 (LESS) 166 (RSP spider)	CH	LESS 37.1 (SD 13.3) (range 17–103) RSP 63.0 (SD 25.2) (range 33–221) RSP spider 52.8 (SD 18.7) (range 24–121) $P < 0.001$	–	– 3 (1.8%) RSP to RMP – 3 (1.8%) RSP spider to RMP	LESS 1.3 (SD 5.3) (range 0.5–65) RSP 1.2 (SD 2.2) (range 0.5–25) RSP spider 1.5 (SD 2.6) (range 0.5–24) $P < 0.001$	LESS 3 (1.8%) RSP 3(1.8%) RSP spider 2 (1.2%) $P = 0.897$	Triangulation avoid instruments fighting with RSP and RSP spider Longer operative time with RSP and RSP spider

Table 1 continued

References	Type of study	No. of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) Mean/median	Conversions (%)	Hospital stay (days) [P] mean/median	Postoperative complications [P]	Comments
Buzad et al. [44]	Prospective case–control	20 (RSP) 10 (LESS)	CH	RSP 84.6 (SD 20.5) LESS 85.5 (SD 11.8) $P = 0.8737$	RSP 13.06 LESS 15.83 $P = 0.45$	–	–	1 (5%)[a] RSP	–
Spinoglio et al. [45]	Retrospective case–control	25 (RSP) 25 (LESS)	CH	RSP 62.7 (SD 16.6) (range 40–105) LESS 83.2 (SD 21.1) (range 40–135) $P = 0.0006$	–	–	RSP 1.1 (SD 0.3) (range 1–2) LESS 1.2 (SD 0.7) (range 0.6–3) $P = 0.2854$	–	Reduction in operative time and learning curve with RSP
Hagen et al. [46]	Retrospective case–control	99 (RSP) 99 (MLPS)	CH	RSP 97.0 (SD 39.0) SLPS 93.5 (SD 32.5) $P = 0.4935$	–	4 (4.0%) RSP to LPT 1 (1.0%) SLPS to LPT $P = 0.3689$	1.9 ± 1.7 (RSP) 1.7 ± 1.6 (SLPS) $P = 0.3950$	RSP)7 (7%)[a] SLPS 3 (3%)[a] RSP 7 (7.1%)[b] $P = 0.0140$	–

RSP robotic single port, *RSP-R* robotic single port reverse, *RMP* robotic multiport, *SLPS* standard laparoscopic, *LESS* single-port laparoscopy, *LPT* laparotomy, *CH* cholecystectomy, *AD* adrenalectomy, *CO* colectomy, *AR* anterior resection

[a]Grade I–II

[b]Grade III–IV

In the study by Juo et al. [28] is reported a G5 complication consisting of a stroke in a patient died during post-operatory.

Urology

We selected ten studies published between 2010 and 2016, consisting of four case–control studies and six case series.

Only in three studies, there were more than 50 patients enrolled. The procedures performed consisted of pyeloplasty, prostatectomy, partial/radical nephrectomy, and cystectomy.

Perioperative data, rate of conversion, complications and authors' comments are reported in Table 2.

Regarding operative time, Law et al. and White et al. [47, 50] reported no significant differences between RSP and RMP and SLPS, respectively. Instead, Shin et al. [52] reported a prolonged operative time for (RSP) ($P = 0.03$) compared with robotic multiport (RMP); these data were confirmed by Olweny et al. [54] that compared RSP with LESS ($P = 0.007$). The estimated blood loss reported in the different studies is very variable, between 50 and 550 ml. These data are probably due to the different procedures performed and the different surgeons' experiences. However, it is noteworthy that in the case–control studies no significant differences were reported.

We distinguished conversions to multiport technique robotic or standard laparoscopy (SLPS) (approximately between 5 and 30% in the different studies included) and laparotomy (LPT) (reported in four studies [51, 53, 55, 56] between 1 and 6%). The hospital stay was similar across the different studies (between 2 and 6 days), depending on the surgical procedure performed. Of note, in case–control studies, no significant difference was recorded excluding the study by White et al. [51] in favor of RSP (although in that study the sample was 10 patients per arm).

Postoperative minor complications grade 1–2 were rare, and in case–control studies no significant differences were registered when comparing RSP to other techniques. Four studies [60, 62, 64, 66] report grade 3–4, ranging between 3 and 20%. The most frequent major complications (grade 3) were related to the umbilical incisional site (i.e., dehiscence, hernia, or infection).

Gynecology

We selected 18 studies published between 2013 and 2018 consisting of 11 case series and 7 case–control studies.

Perioperative data, rate of conversion, complications, and authors' comments are reported in Table 3.

The majority of the studies on gynecologic procedures included less than 100 patients, and most of them have no control group.

The most frequently reported procedure was hysterectomy, but also adnexal surgery, myomectomy, and sacrocolpopexy have been described. The operative time is extremely variable due to the inclusion of different procedures; the mean average operative time for hysterectomy was between 100 and 150 min. Most of the case–control studies [62–64, 67, 70] compared RSP with RMP and LESS. While some studies reported a similar operative time when comparing RSP and LESS [59, 62, 67, 73], others [64, 65, 70] described an advantage of standard single-site laparoscopy over RSP.

In the majority of the studies, the mean EBL reported is minimal (< 100 mL). One series of myomectomies [68] reports a mean EBL of 135 mL. In the studies by Bogliolo et al. and Paek et al. [64, 65], a significant difference in terms of EBL was reported in favor of RSP, respectively, compared with RMP and LESS. Only in one study by Fagotti et al. [67], the difference in terms of EBL between RSP and LESS was significant in favor of LESS, while in the rest of the case–control studies no significant differences were recorded [59, 63, 70, 73].

The rate of conversion ranged between 0 and 5% and case–control studies did not identify any significant difference between RSP and other minimally invasive techniques. Several studies have reported the use of a supplementary ancillary port, in addition to the single-port trocar or conversion to SLPS or RMP. In one study by Vizza et al. [74], a conversion to vaginal surgery was reported.

The hospital stay varied between 1 and 6 days, depending on the type of procedure performed. Both Bogliolo et al. and Fagotti et al. [65, 67] reported a significant reduction in hospital stay in favor of RSP. The other case–control studies did not confirm these results.

The complication rate reported in the studies is very low, being < 10%, except for one prospective study by Vizza et al. [74] where, in a series of 20 patients, a 20% rate of major complications is described (pelvic abscess, bowel perforation, and vaginal dehiscence).

Among the major complications reported in the gynecologic literature, hemoperitoneum, ureteral injury, and vaginal vault dehiscence have been described.

Meta-analysis

Considering all the data available (irrespective of the surgical branch of application), we performed a meta-analysis to compare the RSP with the principal three reference procedures: SLPS, RMP, and LESS. We focused our analysis on two principal factors: conversion rate and complications.

Regarding conversion rate, Fig. 2 shows that there is no significant difference in terms of conversion to laparotomy

Table 2 Studies referring to robotic single port in urology

References	Type of study	N° of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) median/mean	Conversions (%)	Hospital stay (days) [P] median/mean	Complications [P]	Comments
Law et al. [47]	Prospective case–control	16 (RSP) 14(RMP)	PL	RSP 225.2 (SD 42.2) RMP 198.9 (SD 57.8) $P = 0.33$	RSP 115.3 (SD 101.2) RMP 115 (SD 74) $P = 0.71$	–	RSP 3.6 (SD 1.9) RSP 3.6 (SD 1.9) $P = 0.76$	RSP 5 (31.2)[a] RMP 4 (25%)[a] $P = 0.76$	Lack of EndoWrist articulation Safe technique
Kaouk et al. [48]	Prospective series	19 (RSP)	11 (PR) 4 (PN) 2(RN) 2(SN)	PR 239 (range 173–326) PN 232 (range 182–292) RN 157 (range 156–157) SN 165 (range 135–195)	PR 350 (range 100–650) PN 550 (range 300–2500) RN 105 (range 10–200) SN 100 (range 100–100)	–	PR 5 (range 3–9) PN 5.8 (range 4–8) RN 4 (range 3–5) SN 4 (range 4–4)	5 (26.3%)[a] 2 (10.5%)[b]	Safe technique
White et al. [49]	Retrospective case series	50	PN, RN, SN, NU, PR, C, SC, UR	207 (SD 74)	140 (SD 111)	8 (16%) to RMP 2 (4%) to LESS	2.9 (SD 1.7)	5 (10%)[a] 1 (2%)[b]	Safe technique
White et al. [50]	Retrospective case–control	10 (RSP) 10 (SLPS)	RN	RSP 167.5 (range 150–210) SLPS 150 (range 150–173) $P = 0.28$	RSP 100 (range 50–100) SLPS 100 (81–150) $P = 0.39$	–	RSP 2.5 (range 2–3) SLPS 3 (range 3–4) $P = 0.03$	1 (10%)[b] (RSP) 1 (10%)[a] (LESS)	Shorter hospital stay with RSP Less pain killers with RSP $P = 0.049$
White et al. [51]	Retrospective case series	20	PR	187.6 (range 120–300)	128.8 (range 50–350)	2 (10%) to RMP	2.5 (range 1–6)	3 (15%)[a] 1 (5%)[b]	Less challenging compared with LESS Excellent cosmesis
Shin et al. [52]	Retrospective case–control	79 (RSP) 80 (RMP)	PN	RSP 210.3 (SD 83.4) RMP 183.1 (SD 76.1) $P = 0.033$	RSP 334.9 (SD 30–1550) RMP 313.0 (SD 30–1600) $P = 0.669$	1 (1.72%) RSP to LPT 2 (2.5%) RMP to LPT	RSP 4.6 (SD 2.1) RMP 4.8 (SD 2.2) $P = 0.645$	10 (12.6%)[a] (RSP) 12 (15%)[a] 3 (3.75%)[b] (RMP) $P = 0.279$	Pain score reduction with RSP $P = 0.048$

Table 2 continued

References	Type of study	N° of patients	Type of surgery	Operative time (min) [P] mean/median	EBL (ml) median/mean	Conversions (%)	Hospital stay (days) [P] median/mean	Complications [P]	Comments
Tiu et al. [53]	Retrospective case series	67	PN (20 tumor > 4 cm, 47 tumor < 4 cm)	Tumor > 4 cm 197 (range 123–264); tumor < 4 cm 178 (range 105–273) [NS]	Tumor > 4 cm 408 (range 50–1150); Tumor < 4 cm 271 (range 50–1550) [NS]	1 (5%) tumor > 4 cm to LPT [NS]	Tumor > 4 cm 5.3 (range 3–11); Tumor < 4 cm 4 (range 2–8) $P = 0.046$	3 (15%)[a] (Tumor > 4 cm) 5 (10.6%)[a] 2 (4.2%)[b] (tumor < 4 cm) [NS]	Safe technique
Olweny et al. [54]	Retrospective case–control	10 (RSP) 10 (LESS)	PL	RSP 226 (SD 36.7) LESS 188 (SD 12.4) $P = 0.007$	RSP 56 (SD 21) LESS 42 (SD 35) $P = 0.38$	2 (20%) SLPS to SLPS $P = 0.14$	RSP 2.6 (SD 1.0) LESS 2.6 (SD 1.3) $P = 0.99$	1 (10%)[b] (RSP) 2 (20%)[b] (LESS) $P = 0.53$	Reduced learning curve for RSP Greater maneuverability with EndoWrist
Lee et al. [55]	Retrospective case series	68	51(PN) 12(NU) 2 (RN) 2 (AD) 1 (SN)	219 (range 109–382)	319 (range 50–1550)	3 (4.4%) RSP to LPT	4.5 (range 1–16)	–	Safe technique Increased dexterity with EndoWrist
Buffi et al. [56]	Prospective case series	30	PL	160 (range 101–300)	–	2 (6.7%) RSP to SLPS	5 (range 3–13)	7 (23%)[a] 1 (3%)[b]	Good cosmesis Low postoperative pain

RSP robotic single port, *RMP* robotic multiport, *SLPS* standard laparoscopy, *LESS* single-port laparoscopy, *LPT* laparotomy, *PL* pyeloplasty, *PR* prostatectomy, *PN* partial nephrectomy, *RN* radical nephrectomy, *SN* simple nephrectomy, *NU* nephroureterectomy, *C* cystectomy, *SC* sacrocolpopexy, *UR* ureteral reimplantation, *AD* adrenalectomy

[a]Grade I–II

[b]Grade III–IV

Table 3 Studies referring to robotic single port in gynecology

References	Type of study	No. of patients	Surgery	Median/mean operative time (min) [p]	EBL (ml)	Conversions	Hospital stay (days) [p]	Postoperative complication	Comments
Corrado et al. [57]	Prospective series	125 (RSP)	H ± PL	122 (range 35–282)	50 (range 10–250)	–	2 (range 1–3)	10 (8%)[a]	Costs reduction
Jayakumaran et al. [58]	Retrospective series	35 (RSP)	H ± SOB	142 (range 60–294)	75 (20–300)	2 (5.7%) RMP	0.95 (range 0.95–7)	–	Decreased postoperative pain Feasibility even in obese patients
Gungor et al. [59]	Retrospective case–control	20 (RSP) 25(LESS)	H	RSP 90 (range 70–165) LESS 90 (range 60–200) $P = 0.74$	RSP 40 (range 20–200) LESS 50 (range 20–250) $P = 0.77$	–	RSP 1 LESS 1 $P = 0.17$	–	Improved surgical precision and ergonomics but longer learning curve with RSP
Matanes et al. [60]	Retrospective series	25 (RSP)	SCP	190 (range 114–308)	30 (10–300)	–	2 (range 1–4)	1 (4%)[b]	Low complication rates Short hospitalization,
Gargiulo et al. [61]	Retrospective series	21 (RSP)	MY	152 (range 85–290)	50 (range 5–200)	–	1 (range 0–3)	2 (9.5%)[a]	Enhances the precision Feasibility even in obese patients
Bogliolo et al. [62]	Retrospective case–control	45 (RSP) 59 (RMP)	TH + BSO	RSP 144 (SD 41) (range 82–265) RMP 146 (SD 47) (range 80–244) $P = 0.840$	RSP 46 (SD 52) (range 10–200) RMP 150 (SD 151) (range 20–600) $P = 0.0008$	–	RSP 1.5 ± 1 RMP 2.5 ± 2 $P = 0.009$	RSP 1 (2.2%)[a] grade II RMP 2 (3.4%)[a]/[b] $P = 0.724$	Better postoperative pain and costs reduction with RSP
Paek et al. [63]	Retrospective case–control	20 (RSP) 228 (LESS)	CY-SO	RSP 91.1 ± (SD 31.4) LESS 68.7 (SD 34.0) $P = 0.005$	RSP 20 LESS 30 $P = 0.465$	LESS 3.5% to SLPS-RSP 0%	–	RSP/ LESS 2 (0.9%)[b] LESS 6 (2.6%)[a]	More precise dissection, improved hemostasis and reduced postoperative pain but longer operating time with RSP
Paek et al. [64]	Retrospective case–control	25 (RSP) 442 (LESS)	TH	RSP 170.9 (SD 65.5) LESS 88.3 (SD 38.4) $P = 0.0001$	RSP 20 LESS 50 $P = 0.040$	–	–	RSP 0 SLPS 6 (1.36%)[b] SLPS 5 (1.13%)[a]	Less postoperative pain but longer operative time with RSP

Table 3 continued

References	Type of study	No. of patients	Surgery	Median/mean operative time (min) [p]	EBL (ml)	Conversions	Hospital stay (days) [p]	Postoperative complication	Comments
Bogliolo et al. [65]	Retrospective series	45 (RSP)	H	134 (SD 36)	40 (SD 38)	1 (0.45%) SLPS	2.7 (SD 2)	1 (2.2%)[a] 1 (2.2%)[b]	Improved cosmetic results Feasibility even in obese patients Prolonged OT for enlarged uteri
Scheib et al. [66]	Prospective series	40	H, SOCY, H + CO	135 (range 84–11)	50 (range 25–300)	2 (0.8%) additional port 1 (0.4%) RMP	0.5	2.5%[b]	–
Fagotti et al. [67]	Retrospective case–control	19 (RSP) 38 (LESS)	TH + SOB	RSP 90 (range 60–147) LESS 107 (range 47–140) P = ns	RSP 75 (range 50–250) LESS 30 (range 10–300) $P = 0.005$	–	One-day disch. RSP 0 LESS 8 (21.1) $P = 0.041$	RSP 1 (5.9%)[b] LESS/ $P = 0.131$	Conflict reduction between the instruments with RSP
Choi et al. [68]	Retrospective series	61	MY	135.98 (SD 59.62) (range 60–295)	182.62 (SD 153.02) (range 10–600)	–	4.21 (SD 0.84) (range 3–6)	–	Improved cosmetic outcome Shorter hospitalization. Strong suture
De Meritens et al. [69]	Retrospective series	83	H, AS, PLND	128 (range 60–275) H 123(range 59–275) others	69 (range 10–200) H 43(range 0–200) others	1 (0.83%) RMP	0.5	(2.4%)[b]	Obesity makes RSP technically challenging
Akdemir et al. [70]	Retrospective case–control	24 (RSP) 34 (LESS)	H	RSP 98.5 (range 71–183) LESS 86 (range 59–140) $P = 0.013$	RSP 22.5 (range 40–61) LESS 25 (range 44–67) $P = 0.38$	–	RSP 1.6 (range 1–3) LESS 1.8 (range 1–4) $P = 0.92$	–	Improved surgeon dexterity, surgical precision with RSP
Sendag et al. [71]	Retrospective series	24	H	98.5 (range 71–183)	22 (range 7–120)	–	1	–	Less postoperative pain Limited range of motion Obesity and large uteri reduce the surgical performance
Vizza et al. [72]	Prospective cohort study	17	RH	90 (range 70–147)	75 (range 50–150)	1 (0.17) vaginal	2	–	Improved cosmetic results and less postoperative pain Semiflexible instruments not articulated

Table 3 continued

References	Type of study	No. of patients	Surgery	Median/mean operative time (min) [p]	EBL (ml)	Conversions	Hospital stay (days) [p]	Postoperative complication	Comments
Moukarze et al. [73]	Retrospective case–control	14 (RSP) 13 (RMP)	H + SLN	RSP 175 (range 150–230) RMP 184 (range 118–262) $P = 0.61$	RSP 50 (range 10–100) RMP 50 (range 10–500) $P = 0.50$	–	RSP 1 (100%) RMP 1 (100%) $P = 1.0$	–	Improved dexterity and surgeon ergonomics Costs reduction with RSP
Vizza et al. [74]	Prospective cohort study	20	RH + PL	190 (range 90–310)	75 (range 20–700)	–	6 (range 4–16)	4 (20%)[b]	Reduced hospital stay Better cosmesis Pain reduction Few electrosurgical options Longer learning curve

RSP robotic single port, *RMP* robotic multiport, *SLPS* multiport laparoscopic, *LESS* single-port laparoscopy, *LPT* laparotomy, *RH* radical hysterectomy, *SH* supracervical hysterectomy, *H* hysterectomy (non altrimenti specificata), *PL* pelvic lymphadenectomy, *SCP* sacrocolpopexy, *MY* myomectomy, *SO* salpingo-oophorectomy, *CY* cyst enucleation, *CO* cholecystectomy, *PLND* pelvic lymphadenectomy, *AS* adnexal surgery

[a]Grade I–II

[b]Grade III

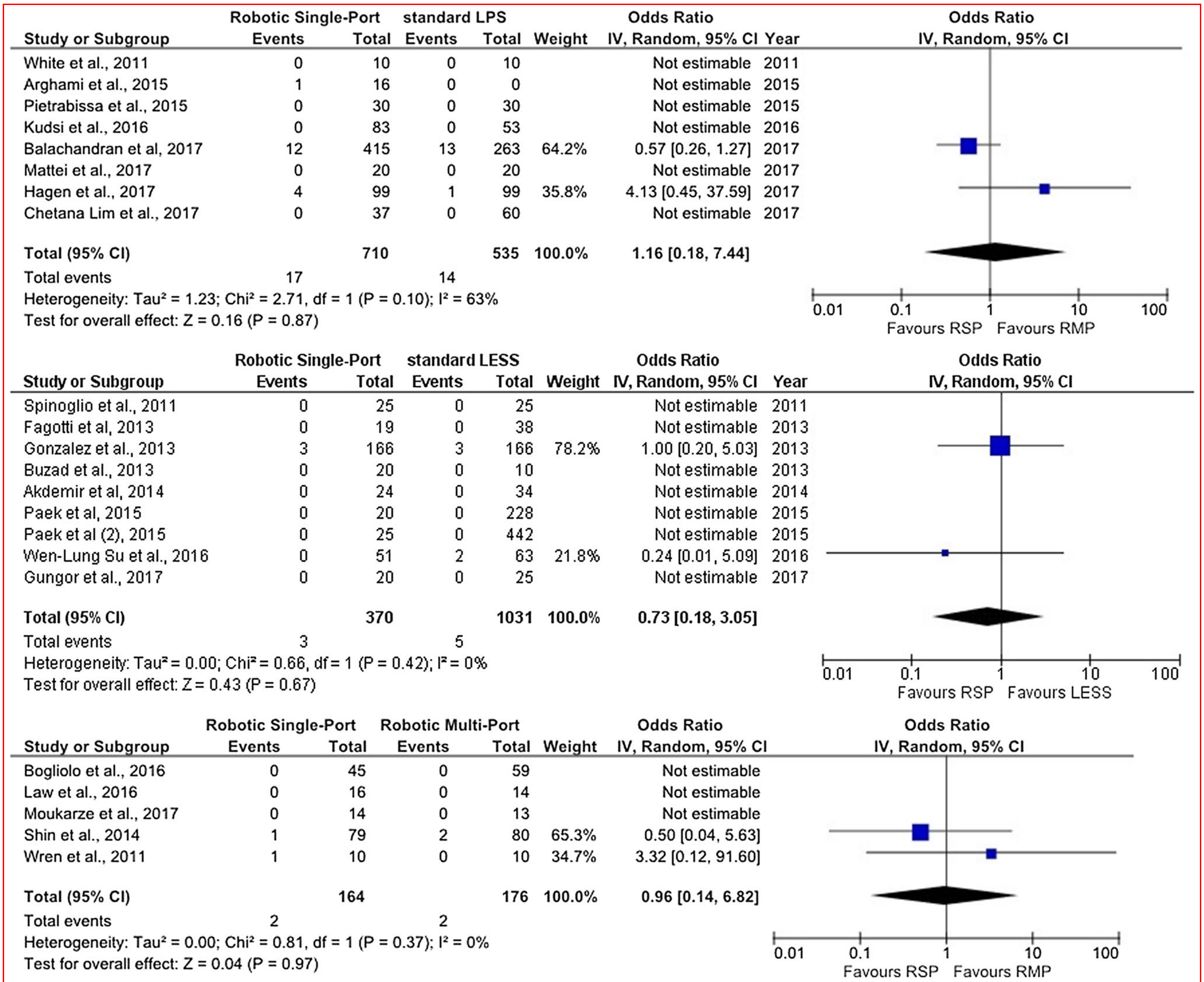

Fig. 2 Comparison of different techniques (RSP, RMP, LESS, SLPS) in conversion rate

when RSP is compared to SLPS ($P = 0.87$), LESS ($P = 0.67$) RMP (0.97).

When considering complications (Fig. 3), we found that RSP is associated with a significantly higher risk of any adverse event, compared to SLPS ($P = 0.002$). Also the comparison between RSP and LESS showed a tendency toward a higher risk of complications in the patients approached by RSP, although this did not reach statistical significance ($P = 0.08$). Conversely, when RSP is compared with RMP no difference in terms of complications has been recorded ($P = 0.60$).

Discussion

The present review provides a summary of the available studies on single-port robotic surgery. Of note, no randomized trial has been published on this issue and no good-quality evidence is available; as a consequence, we have to rely only on case series and few case–control studies.

LESS is a well-known procedure that was deeply investigated in the past [9, 10]. After an initial enthusiasm, especially related to a possible improvement in cosmetic outcomes, the procedures performed using this technique resulted to be more difficult and the learning curve was prolonged. In the literature, the principal criticism was the absence of triangulation (which represents a crucial point for every surgical procedure) and the instrument clashing. The results of these limits were a long operative time and a high difficulty in performing major procedures.

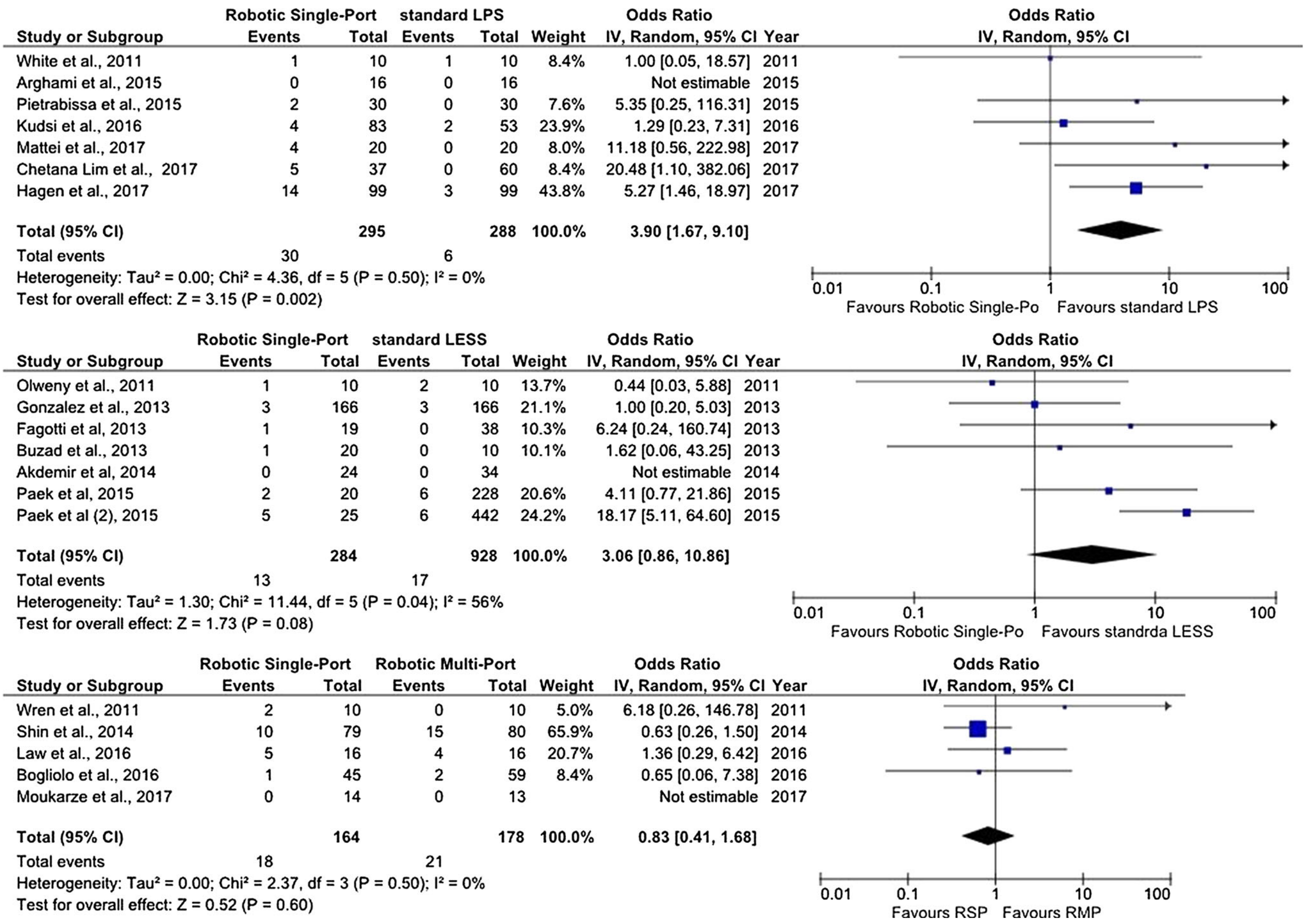

Fig. 3 Comparison of different techniques (RSP, RMP, LESS, SLPS) in complication rate

In this context, the implementation of robotic technology in single-site surgery represents a fundamental improvement in this field because it theoretically overcomes the ergonomic limits and the absence of triangulation, thanks to the robotic arms. Moreover, other advantages over conventional laparoscopy are greater dexterity, tremor filtration, and tridimensional vision [75].

More specifically, during LESS, as laparoscopic instruments are inserted into the abdominal cavity through a single incision, there can be a tendency to cross them just below the abdominal wall to obtain a separation between instrument tips without external collision of the hand-pieces. This crossing of the instruments allows a better range of motion, but the resultant reversal of handedness introduces a major mental challenge for the surgeon. Moreover, as reported in literature [47, 54, 55], in older RSP versions the absence of EndoWrist instruments reduce the possibility to obtain a correct traction on tissues and lifting up of organs, especially if the traction direction is parallel to the instruments. This aspect could influence the surgical outcome. Nevertheless, with the development of bent instruments and new port devices, triangulation can be restored in proximity of the target [75].

The robotic instruments cross at the abdominal wall to have the right instrument on the left side of the target and the left instrument on the right. To correct for the change in handedness, the robotic console was instructed to drive the left instrument with the right-hand effector and the right instrument with the left-hand effector. In this way, collision of the external robotic arms was prevented [75].

The next innovation step was made by Intuitive Surgical that furnished new dedicated software to RSP instruments described by Autorino et al. [75] and consists of a multi-channel access port with two curved cannulas for robotic instruments and other two straight cannulas. The curved cannulas are integrated with the system and allow the instruments to obtain triangulation.

Same-sided hand-eye control of the instruments is maintained through assignment of software of the Si system that enables the surgeon's right hand to control the screen right instrument even though the instrument is in the left robotic arm and, reciprocally, the left hand to control the screen left instrument even though the instrument is in the right robotic arm. The second part of the platform is composed by semirigid, non-wristed instruments. Using this setting, the instruments fighting is reduced because the curved cannulas angle the robotic arms away from each other. Internal collisions with the camera are avoided because the camera is designed to be placed in the middle of the curved cannula zone.

Specific comments by field of application

General surgery

In our analysis, we reported also the comments of the authors on the possible advantages and/or disadvantages of RSP. Some studies [20, 22, 36] evaluated patients' self-reported cosmesis following surgery: A better outcome was described following RSP, compared to SLPS.

Other authors [18, 26, 39] reported a statistically significant decrease in analgesic drugs use with RSP and reduction in painkillers. One study [39] performed a cost analysis of the different procedures, reporting a significant increased cost of RSP compared with SLPS, while Balachandra et al. [18] reported a higher incidence of umbilical incisional hernias and wound infections.

Urology

The more frequent advantages identified by the authors are represented by the reduction in instrument clashing and surgical advantages thanks to the 3D vision and the intuitive system of maneuver. Two studies [52, 53] are in accordance regarding the ergonomic advantages of RSP and the better cosmetic outcomes, compared with RMP. Some studies [50–52] reported a significant reduction in postoperative pain in favor of RSP, compared to standard technique ($P < 0.04$). Some authors [47, 54, 55] reported disadvantages related to the difficulty in tissue traction and instruments fighting, for procedures performed without EndoWrists.

Gynecology

A better cosmetic outcome and an enhanced learning curve were reported by several studies in favor of RSP, compared to RMP and LESS, respectively [62, 72, 74]. On the other hand, increased costs and longer operative time have been described using different techniques. When comparing RSP and RMP techniques, two authors [65, 73] described a cost reduction for procedures performed with RSP.

In accordance with other studies from other specialties, the most frequent disadvantages reported using RSP are prolonged operative time and a longer learning curve.

In an interesting study by Choy et al. [68], a better dexterity to gain stronger suture is reported using RSP. Considering that in procedures such as myomectomy this aspect is fundamental, it could be an important advantage in all surgeries requiring large number of sutures.

Vizza et al. [74] provided an insightful comment regarding the fact that there are still few electrosurgical options in RSP technology.

General considerations

At the end, considering the results of our meta-analysis, an interesting finding is the fact that we recorded a statistically significance increment of complications using RSP if compared with SLPS and a trend ($P = 0.008$) when RSP is compared with LESS. These data are probably related with the fact that RSP platforms represent a relatively new development and the surgeons have a higher experience with standard techniques instead of robotics. However, in our opinion the possibility to reduce the surgical invasiveness maintaining the same level of performance is crucial. The actual limits of RSP should not discourage surgeons but should represent a base in which further efforts will allow better operative outcomes.

In this context, apart from the technological innovations, the learning curve represents a fundamental step to overcome the RSP limits, including the increased complication rate. In a study by Spinoglio et al. [45] a comparative learning curve study was conducted, demonstrating the superiority of RSP over LESS. Considering the available literature, often reporting small series, it is clear that the RSP is in an initial phase, needing systematic practice to standardize the surgical procedures with the aim to obtain comparable outcomes with respect to RMP in terms of operative time and complication rate.

A possible effective way to reduce complications may be the addition of a supplementary port, in order to overcome possible issues related with triangulation and traction. Of course this suggestion deserves adequate investigation in the next future.

This opinion is supported by the fact that the comparison of two robotic platforms (RSP vs RMP) did not show any statistical differences in terms of complications ($P = 0.60$).

Instead, the comparison of different techniques in terms of conversion to laparotomy did not show any significant difference. In our opinion, this is probably related to the attention dedicated during robotic procedures and the consequent prolonged operative time.

Another important aspect is the costs analysis of RSP. In our study, we found two general surgery studies by Su et al.

and [39] Konstantinidis et al. [32], reporting an increase in costs when using RSP. On the other hand, two gynecologic studies by Corrado et al. [57] and Bogliolo et al. [62] did not confirm this difference. The discordance is probably related to the balance of operative time and hospital stay. Of course, increased operative time causes are associated with higher costs; however, a reduction in hospital stay may allow a profitable balance in favor of RSP. However, we have to acknowledge that costs are dependent on a large number of possible variables and further investigations about this aspect is needed to allow an exact estimate on this issue.

Future perspectives

In the next few months, new robots will be launched on the market, including single-port platforms. One of the most intriguing aspects of this new generation of robots is the fact that new fully articulated instruments and optical cameras with snake-like movements will become available. The obvious consequences will be the possibility to perform a more comfortable surgery, with potentially all the advantages of multiport approach, but requiring only a small incision in the umbilicus. This type of approach may allow the robotic system to enter in a new era with real and consistent advantages over traditional laparoscopic surgery.

Future platforms should incorporate a higher range of movements to improve dexterity, more effective electrosurgical (possibly multifunction) options, smaller caliber instruments to decrease the size of the umbilical incision, and possible complex articulating devices, allowing the maintenance of triangulation and an adequate traction and exposure of tissues.

In parallel to single-port robotic surgery, other forms of robotic platforms will be available, such as machines allowing hybrid procedures in which laparoscopy or open surgery will take an advantage from the use of dedicated robotic arms.

The strength of our study is the fact that it is a comprehensive picture of the present status of single-port robotic surgery, reporting its major applications.

At this moment, evidence does not support the use of single-port robotic surgery in clinical practice.

However, it is logical to hypothesize that new technological improvements will strongly enhance the utility of RSP in all the abdominal surgical fields.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Gueli Alletti S, Vizzielli G, Lafuenti L, Costantini B, Fagotti A, Fedele C, Cianci S, Perrone E, Gallotta V, Rossitto C, Scambia G (2018) Single-institution propensity-matched study to evaluate the psychological effect of minimally invasive interval debulking surgery versus standard laparotomic treatment: from body to mind and back. J Minim Invasive Gynecol 25:816–822
2. Rossitto C, Gueli Alletti S, Cianci S, Perrone E, Scambia G (2017) Reply. J Minim Invasive Gynecol 24(4):683–684
3. Gueli Alletti S, Rossitto C, Perrone E, Cianci S, De Blasis I, Fagotti A et al (2016) Needleoscopic conservative staging of borderline ovarian tumor. J Minim Invasive Gynecol 16:31151–31157. https://doi.org/10.1016/j.jmig.2016.10.009
4. Rossitto C, Gueli Alletti S, Rotolo S, Cianci S, Panico G, Scambia G (2016) Total laparoscopic hysterectomy using a percutaneous surgical system: a pilot study towards scarless surgery. Eur J Obstet Gynecol Reprod Biol 203:132–135
5. Uccella S, Cromi A, Casarin J, Bogani G, Serati M, Gisone B, Pinelli C, Fasola M, Ghezzi F (2015) Minilaparoscopic versus standard laparoscopic hysterectomy for uteri ≥ 16 weeks of gestation: surgical outcomes, postoperative quality of life, and cosmesis. J Laparoendosc Adv Surg Tech A 25(5):386–391
6. Cosentino F, Vizzielli G, Turco LC, Fagotti A, Cianci S, Vargiu V, Zannoni GF, Ferrandina G, Scambia G (2018) Near-infrared imaging with indocyanine green for detection of endometriosis lesions (Gre-Endo Trial): a pilot study. J Minim Invasive Gynecol 25:1249–1254
7. Gallotta V, Conte C, Giudice MT, Nero C, Vizzielli G, Gueli Alletti S, Cianci S, Lodoli C, Di Giorgio A, De Rose AM, Fagotti A, Scambia G, Ferrandina G (2018) Secondary laparoscopic cytoreduction in recurrent ovarian cancer: a large, single-institution experience. J Minim Invasive Gynecol 25(4):644–650
8. Uccella S, Buda A, Morosi C, Di Martino G, Delle Marchette M, Reato C, Casarin J, Ghezzi F (2018) Minilaparoscopy vs standard laparoscopy for sentinel node dissection: a pilot study. J Minim Invasive Gynecol 25(3):461.e1–466.e1
9. Wakasugi M, Tanemura M, Furukawa K, Tei M, Suzuki Y, Masuzawa T, Kishi K, Akamatsu H (2017) Feasibility and safety of single-incision laparoscopic cholecystectomy in elderly patients: a singleinstitution, retrospective case series. Ann Med Surg (Lond) 6(22):30–33
10. Rossitto C, Cianci S, Gueli Alletti S, Perrone E, Pizzacalla S, Scambia G (2017) Laparoscopic, minilaparoscopic, single-port and percutaneous hysterectomy: comparison of perioperative outcomes of minimally invasive approaches in gynecologic surgery. Eur J Obstet Gynecol Reprod Biol 216:125–129
11. Ghezzi F, Serati M, Casarin J, Uccella S (2015) Minilaparoscopic single-site total hysterectomy. Obstet Gynecol 126(1):151–154
12. Gueli Alletti S, Rossitto C, Cianci S, Restaino S, Costantini B, Fanfani F, Fagotti A, Cosentino F, Scambia G (2016) Telelap ALF-X vs standard laparoscopy for the treatment of early-stage endometrial cancer: a single-institution retrospective cohort study. J Minim Invasive Gynecol 23(3):378–383
13. Gueli Alletti S, Rossitto C, Cianci S, Scambia G (2016) Telelap ALF-X total hysterectomy for early stage endometrial cancer: new frontier of robotic gynecological surgery. Gynecol Oncol 140(3):575–576
14. Gueli Alletti S, Rossitto C, Cianci S, Perrone E, Pizzacalla S, Monterossi G, Vizzielli G, Gidaro S, Scambia G (2018) The Senhance™ surgical robotic system ("Senhance") for total hysterectomy in obese patients: a pilot study. J Robot Surg. 12:229–234
15. Gueli Alletti S, Perrone E, Cianci S, Rossitto C, Monterossi G, Bernardini F, Scambia G (2018) 3 mm Senhance robotic

hysterectomy: a step towards future perspectives. J Robot Surg 12:575–577
16. Shamseer L, Moher D, Clarke M et al (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 349:g7647
17. Guyatt GH, Oxman AD, Vist GE et al (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 336:924–926
18. Balachandran B, Hufford TA, Mustafa T, Kochar K, Sulo S, Khorsand J (2017) A comparative study of outcomes between single-site robotic and multi-port laparoscopic cholecystectomy: an experience from a Tertiary Care Center. World J Surg 41(5):1246–1253. https://doi.org/10.1007/s00268-016-3799-0
19. Rosales-Velderrain A, Alkhoury F (2017) Single-port robotic cholecystectomy in pediatric patients: single institution experience. J Laparoendosc Adv Surg Tech A 27(4):434–437
20. Kudsi OY, Castellanos A, Kaza S, McCarty J, Dickens E, Martin D, Tiesenga FM, Konstantinidis K, Hirides P, Mehendale S, Gonzalez A (2017) Cosmesis, patient satisfaction, and quality of life after da vinci single-site cholecystectomy and multiport laparoscopic cholecystectomy: short-term results from a prospective, multicenter, randomized, controlled trial. Surg Endosc 31(8):3242–3250
21. van der Linden YT, Brenkman HJ, van der Horst S, van Grevenstein WM, van Hillegersberg R, Ruurda JP (2016) Robotic single-port laparoscopic cholecystectomy is safe but faces technical challenges. J Laparoendosc Adv Surg Tech A 26(11):857–861
22. Pietrabissa A, Pugliese L, Vinci A, Peri A, Tinozzi FP, Cavazzi E, Pellegrino E, Klersy C (2016) Short-term outcomes of single-site robotic cholecystectomy versus four-port laparoscopic cholecystectomy: a prospective, randomized, double-blind trial. Surg Endosc 30(7):3089–3097
23. Jung MJ, Lee SY, Lee SH, Kang CM, Lee WJ (2015) Single-site robotic cholecystectomy: reverse-port technique. Medicine (Baltimore) 94(42):e1871
24. Lee GS, Arghami A, Dy BM, McKenzie TJ, Thompson GB, Richards ML (2016) Robotic single-site adrenalectomy. Surg Endosc 30(8):3351–3356
25. Jones VS (2015) Robotic-assisted single-site cholecystectomy in children. J Pediatr Surg 50(11):1842–1845
26. Arghami A, Dy BM, Bingener J, Osborn J, Richards ML (2015) Single-port robotic-assisted adrenalectomy: feasibility, safety, and cost-effectiveness. JSLS 19(1):e2014.00218
27. Ayloo S, Choudhury N (2014) Single-site robotic cholecystectomy. JSLS 18(3). https://doi.org/10.4293/JSLS.2014.00266
28. Juo YY, Agarwal S, Luka S, Satey S, Obias V (2015) Single-Incision Robotic Colectomy (SIRC) case series: initial experience at a single center. Surg Endosc 29(7):1976–1981
29. Uras C, Böler DE, Ergüner I, Hamzaoğlu I (2014) Robotic single port cholecystectomy (R-LESS-C): experience in 36 patients. Asian J Surg 37(3):115–119
30. Lim MS, Melich G, Min BS (2013) Robotic single-incision anterior resection for sigmoid colon cancer: access port creation and operative technique. Surg Endosc 27(3):1021
31. Pietrabissa A, Sbrana F, Morelli L, Badessi F, Pugliese L, Vinci A, Klersy C, Spinoglio G (2012) Overcoming the challenges of single-incision cholecystectomy with robotic single-site technology. Arch Surg 147(8):709–714
32. Konstantinidis KM, Hirides P, Hirides S, Chrysocheris P, Georgiou M (2012) Cholecystectomy using a novel Single-Site robotic platform: early experience from 45 consecutive cases. Surg Endosc 26(9):2687–2694
33. Morel P, Hagen ME, Bucher P, Buchs NC, Pugin F (2011) Robotic single-port cholecystectomy using a new platform: initial clinical experience. J Gastrointest Surg 15(12):2182–2186
34. Wren SM, Curet MJ (2011) Single-port robotic cholecystectomy: results from a first human use clinical study of the new da Vinci single-site surgical platform. Arch Surg 146(10):1122–1127
35. Kroh M, El-Hayek K, Rosenblatt S, Chand B, Escobar P, Kaouk J, Chalikonda S (2011) First human surgery with a novel single-port robotic system: cholecystectomy using the da Vinci Single-Site platform. Surg Endosc 25(11):3566–3573
36. Mattei P (2018) Single-site robotic-assisted laparoscopic cholecystectomy in children and adolescents: a report of 20 cases. Surg Endosc 32(5):2402–2408
37. Lim C, Bou Nassif G, Lahat E, Hayek M, Osseis M, Gomez-Gavara C, Moussalem T, Azoulay D, Salloum C (2017) Single-incision robotic cholecystectomy is associated with a high rate of trocar-site infection. Int J Med Robot 13(4):e1856
38. Lee H, Lee DH, Kim H, Han Y, Kim SW, Jang JY (2017) Single-incision robotic cholecystectomy: a special emphasis on utilization of transparent glove ports to overcome limitations of single-site port. Int J Med Robot 13(3):e1789
39. Su WL, Huang JW, Wang SN, Lee KT (2017) Comparison study of clinical outcomes between single-site robotic cholecystectomy and single incision laparoscopic cholecystectomy. Asian J Surg 40(6):424–428
40. Gonzalez A, Murcia CH, Romero R, Escobar E, Garcia P, Walker G, Gallas M, Dickens E, McIntosh B, Norwood W, Kim K, Rabaza J, Parris D (2016) A multicenter study of initial experience with single-incision robotic cholecystectomies (SIRC) demonstrating a high success rate in 465 cases. Surg Endosc 30(7):2951–2960
41. Svoboda S, Qaqish TR, Wilson A, Park H, Youssef Y (2015) Robotic single-site cholecystectomy in the obese: outcomes from a single institution. Surg Obes Relat Dis 11(4):882–885
42. Morel P, Buchs NC, Iranmanesh P, Pugin F, Buehler L, Azagury DE, Jung M, Volonte F, Hagen ME (2014) Robotic single-site cholecystectomy. J Hepatobiliary Pancreat Sci 21(1):18–25
43. Gonzalez AM, Rabaza JR, Donkor C, Romero RJ, Kosanovic R, Verdeja JC (2013) Single-incision cholecystectomy: a comparative study of standard laparoscopic, robotic, and SPIDER platforms. Surg Endosc 27(12):4524–4531
44. Buzad FA, Corne LM, Brown TC, Fagin RS, Hebert AE, Kaczmarek CA, Pack AN, Payne TN (2013) Single-site robotic cholecystectomy: efficiency and cost analysis. Int J Med Robot 9(3):365–370
45. Spinoglio G, Lenti LM, Maglione V, Lucido FS, Priora F, Bianchi PP, Grosso F, Quarati R (2012) Single-site robotic cholecystectomy (SSRC) versus single-incision laparoscopic cholecystectomy (SILC): comparison of learning curves. First European experience. Surg Endosc 26(6):1648–1655
46. Hagen ME, Balaphas A, Podetta M, Rohner P, Jung MK, Buchs NC, Buehler L, Mendoza JM, Morel P (2018) Robotic single-site versus multiport laparoscopic cholecystectomy: a case-matched analysis of short- and long-term costs. Surg Endosc 32(3):1550–1555
47. Law J, Rowe N, Archambault J, Nastis S, Sener A, Luke PP (2016) First Canadian experience with robotic single-incision pyeloplasty: comparison with multi-incision technique. Can Urol Assoc J 10(3–4):83–88
48. Kaouk J, Haber GP, Autorino R, Crouzet S, Ouzzane A, Flamand V, Villers A (2014) A novel robotic system for single-port urologic surgery: first clinical investigation. Eur Urol 66(6):1033–1043
49. White MA, Autorino R, Spana G, Hillyer S, Stein RJ, Kaouk JH (2012) Robotic laparoendoscopic single site urological surgery: analysis of 50 consecutive cases. J Urol 187:1696–1701
50. White MA, Autorino R, Spana G, Laydner H, Hillyer SP, Khanna R, Yang B, Altunrende F, Isac W, Stein RJ, Haber GP, Kaouk JH (2011) Robotic laparoendoscopic single-site radical

nephrectomy: surgical technique and comparative outcomes. Eur Urol 59(5):815–822

51. White MA, Haber GP, Autorino R, Khanna R, Forest S, Yang B, Altunrende F, Stein RJ, Kaouk JH (2010) Robotic laparoendoscopic single-site radical prostatectomy: technique and early outcomes. Eur Urol 58(4):544–550
52. Shin TY, Lim SK, Komninos C, Kim DW, Han WK, Hong SJ, Jung BH, Rha KH (2014) Laparoendoscopic single-site (LESS) robot-assisted partial nephrectomy (RAPN) reduces postoperative wound pain without a rise in complication rates. BJU Int 114(4):555–561
53. Tiu A, Kim KH, Shin TY, Han WK, Han SW, Rha KH (2013) Feasibility of robotic laparoendoscopic single-site partial nephrectomy for renal tumors > 4 cm. Eur Urol 63(5):941–946
54. Olweny EO, Park SK, Tan YK, Gurbuz C, Cadeddu JA, Best SL (2012) Perioperative comparison of robotic assisted laparoendoscopic single-site (LESS) pyeloplasty versus conventional LESS pyeloplasty. Eur Urol 61(2):410–414
55. Won Lee J, Arkoncel FR, Rha KH, Choi KH, Yu HS, Chae Y, Han WK (2011) Urologic robot-assisted laparoendoscopic single-site surgery using a homemade single-port device: a single-center experience of 68 cases. J Endourol 25(9):1481–1485
56. Buffi NM, Lughezzani G, Fossati N, Lazzeri M, Guazzoni G, Lista G, Larcher A, Abrate A, Fiori C, Cestari A, Porpiglia F (2015) Robot-assisted, single-site, dismembered pyeloplasty for ureteropelvic junction obstruction with the new da Vinci platform: a stage 2a study. Eur Urol 67(1):151–156
57. Corrado G, Mereu L, Bogliolo S, Cela V, Freschi L, Carlin R, Gardella B, Mancini E, Tateo S, Spinillo A, Vizza E (2016) Robotic single site staging in endometrial cancer: a multi-institution study. Eur J Surg Oncol. 42(10):1506–1511
58. Jayakumaran J, Wiercinski K, Bungton CA (2018) Caceres robotic laparoendoscopic single-site benign gynecologic surgery: a single-center experience. J Robot Surg 12(3):447–454
59. Gungor M, Kahraman K, Dursun P, Ozbasli E (2018) Canan genim single-port hysterectomy: robotic versus laparoscopic. J Robot Surg 12(1):87–92
60. Matanes E, Lauterbach R, Mustafa-Mikhail S, Amit A, Wiener Z, Lior MHA (2017) Lowenstein single port robotic assisted sacrocolpopexy: our experience with the first 25 cases. Female Pelvic Med Reconstr Surg 23(3):e14–e18
61. Gargiulo AR, Choussein S, Srouji SS, Cedo LE, Pedro F (2017) Escobar coaxial robot-assisted laparoendoscopic single-site myomectomy. J Robot Surg 11(1):27–35
62. Bogliolo S, Ferrero S, Cassani C, Musacchi V, Zanellini F, Dominoni M, Spinillo A, Gardella B (2016) Single site versus multiport robotic hysterectomy in benign gynaecological diseases: a retrospective evaluation of surgical outcomes and cost analysis. J Minim Invasive Gynecol 23(4):603–609
63. Paek J, Lee J-D, Kong TW, Chang S-J, Ryu H-S (2016) Robotic single-site versus laparo-endoscopic single-site surgery for adnexal tumours: a propensity score-matching analysis. Int J Med Robot 12(4):694–700
64. Paek J, Lee J-D, Kong TW, Chang S-J, Ryu H-S (2016) Robotic single-site versus laparoendoscopic single-site hysterectomy: a propensity score matching study. Surg Endosc 30(3):1043–1050
65. Bogliolo S, Mereu L, Cassani C, Gardella B, Zanellini F, Dominoni M, Babilonti L, Delpezzo C, Tateo S (2015) Arsenio spinillo robotic single-site hysterectomy: two institutions' preliminary experience. Int J Med Robot 11(2):159–165
66. Scheib SA, Fader AN (2015) Gynecologic robotic laparoendoscopic single-site surgery: prospective analysis of feasibility, safety, and technique. Am J Obstet Gynecol 212(2):179.e1–179.e8
67. Fagotti A, Corrado G, Fanfani F, Mancini M, Paglia A, Vizzielli G, Sindico S, Scambia G, Vizza E (2013) Robotic single-site hysterectomy (RSS-H) vs. laparoendoscopic single-site hysterectomy (LESS-H) in early endometrial cancer: a double-institution case–control study. Gynecol Oncol 130(1):219–223
68. Choi EJ, Rho AM, Lee SR, Jeong K, Moon HS (2017) Robotic single-site myomectomy: clinical analysis of 61 consecutive cases. J Minim Invasive Gynecol 24(4):632–639
69. de Meritens AB, Kim J, Dinkelspiel H, Chapman-Davis E, Caputo T, Holcomb K (2017) Feasibility and learning curve of robotic laparo-endoscopic single site surgery in gynecology. J Minim Invasive Gynecol 24(2):323–328
70. Akdemir A, Yildirim N, Zeybek B, Karaman S (2015) Fatih sendag single incision trans-umbilical total hysterectomy: robotic or laparoscopic? Gynecol Obstet Invest 80(2):93–98
71. Sendag F, Akdemir A, Zeybek B, Ozdemir A, Gunusen I, Oztekin MK (2014) Single-site robotic total hysterectomy: standardization of technique and surgical outcomes. J Minim Invasive Gynecol 21(4):689–694
72. Vizza E, Corrado G, Mancini E, Baiocco E, Patrizi L, Fabrizi L, Colantonio L, Cimino M (2013) Stefano sindico and ester forastiere robotic single-site hysterectomy in low risk endometrial cancer: a pilot study. Ann Surg Oncol 20(8):2759–2764
73. Moukarzel LA, Sinno AK, Fader AN, Tanner EJ (2017) Comparing single-site and multiport robotic hysterectomy with sentinel lymph node mapping for endometrial cancer: surgical outcomes and cost analysis. J Minim Invasive Gynecol 24(6):977–983
74. Vizza E, Chiofalo B, Cutillo G, Mancini E, Baiocco E, Zampa A, Bufalo A, Corrado G (2018) Robotic single site radical hysterectomy plus pelvic lymphadenectomy in gynecological cancers. J Gynecol Oncol 29(1):e2
75. Autorino R, Kaouk JH, Stolzenburg JU, Gill IS, Mottrie A, Tewari A, Cadeddu JA (2013) Current status and future directions of robotic single-site surgery: a systematic review. Eur Urol 63(2):266–280