Taiwanese Journal of Obstetrics & Gynecology 60 (2021) 60–65

Contents lists available at ScienceDirect

Taiwanese Journal of Obstetrics & Gynecology

journal homepage: www.tjog-online.com

Original Article

First report comparing the two types of single-incision robotic sacrocolpopexy: Single site using the da Vinci Xi or Si system and single port using the da Vinci SP system

Sa Ra Lee [a,*], A-mi Roh [b], Kyungah Jeong [c], Sung Hoon Kim [a], Hee Dong Chae [a], Hye-sung Moon [c]

[a] *Department of Obstetrics and Gynecology, University of Ulsan College of Medicine, Seoul Asan Medical Center, Seoul, Republic of Korea*
[b] *Departments of Obstetrics and Gynecology, Songdo Herv Women Clinic, Incheon, Republic of Korea*
[c] *Department of Obstetrics and Gynecology, Robot Surgery Center, College of Medicine, Ewha Womans University, Seoul, Republic of Korea*

ARTICLE INFO

Article history:
Accepted 11 September 2020

Keywords:
Pelvic organ prolapse
Postmenopausal women
Robotic surgery
Sacrocolpopexy
Single incision

ABSTRACT

Objective: The gold standard procedure for treating patients with apical pelvic organ prolapse (POP) is sacrocolpopexy. However, no report comparing the two types of single-incision robotic sacrocolpopexy, namely, single-site robotic sacrocolpopexy (SS-RSC) and single-port robotic sacrocolpopexy (SP-RSC) exists. Therefore, we compared the safety and effectiveness of SS-RSC and SP-RSC.

Materials and methods: In this study, 48 patients who underwent single-incision RSC, 40 non-consecutive patients who underwent SS-RSC, and 8 consecutive patients who underwent SP-RSC for symptomatic POP quantification stage III–IV and were eligible for the 1-year follow-up (FU) were included. We compared the surgical time and operative outcomes of SS-RSC and SP-RSC. We also compared the data of the initial 8 cases in each group.

Results: The mean patient age was 59.2 ± 11.0 years and 66.1 ± 8.0 years in the SS-RSC (n = 40) and SP-RSC (n = 8) groups, respectively. The mean operative time (OT) and console time were comparable between the SS-RSC and SP-RSC groups (135.3 ± 31.6 min vs 141.8 ± 23.5 min; 94.6 ± 32.2 min vs 89 ± 9.5 min, respectively). The docking time and cervix suturing time were short in the SP-RSC group ($P < 0.05$). However, in the analysis of the initial 8 cases in each group, all surgical times except the cervix suturing time were shorter in the SP-RSC group ($P < 0.05$). Three cases had intraoperative bladder injury (two [5.0%] in the SS-RSC and one [12.5%] in the SP-RSC group). Two cases (5.0%) had umbilical incisional hernia in the SS-RSC group. Two cases had vaginal mesh erosion on the posterior vaginal wall, with 1 case in each group. One case (2.5%) experienced a recurrence of POP; an anterior compartment POP-Q stage 2 following SS-RSC at the 4-week FU.

Conclusion: Single-incision RSC, both SS-RSC and SP-RSC, is a feasible and effective surgical option for treating symptomatic apical POP with an aesthetic finish.

Introduction

Pelvic organ prolapse (POP) is a common condition in older women, with a prevalence of 41–50%. The probability that a woman will undergo surgery for POP until the age of 80 is estimated at 20% [1–5], with an incidence rate of 1.5–1.8 surgeries per 1000 women years [6,7].

Open sacrocolpopexy (OSC) has been the gold standard procedure for treating patients with apical POP. However, large abdominal incisions lead to postoperative pain, increasing the need for analgesics as well as decreased postoperative ambulation, long-term hospitalization, and increased morbidity [8]. Therefore, the need for minimally invasive sacrocolpopexy (MISC), laparoscopic sacrocolpopexy (LSC), and robotic sacrocolpopexy (RSC), has been increasing despite sacrocolpopexy requiring multiple intracorporeal suturing and deep tissue dissection, both of which are

* Corresponding author. Department of Obstetrics and Gynecology University of Ulsan College of Medicine, Seoul Asan Medical Center 88, Olympic-ro 43-gil, Songpa-gu, 05505, Seoul, Republic of Korea. Fax: +82 2 3010-3630.
E-mail address: leesr@amc.seoul.kr (S.R. Lee).

https://doi.org/10.1016/j.tjog.2020.10.007

difficult procedures in minimally invasive surgery. A total of 4362 patients underwent sacrocolpopexy during 2010–2016 in the United States, 73% of which underwent MISC, while the remaining 27% underwent OSC [9]. MISC was independently associated with a lower risk of 30-day minor and major complications, blood transfusion, prolonged hospitalization, and hospital readmission than OSC in a large nationwide study [9].

Early studies on MISC, comparing LSC with RSC, reported that RSC requires a longer surgical time and incurs higher costs than LSC albeit similar operative outcomes [10]. However, RSC has increased in popularity owing to easier suturing and deep tissue dissection with a higher magnification power than those in LSC. Recent studies have shown that robotic surgery has advantages over laparoscopic surgery such as shorter learning curves with difficult tasks, less blood loss, less postoperative pain, and faster recovery [11,12]. In terms of RSC, most reports do not pertain to single-incision RSC but to multi-port robotic sacrocolpopexy (MP-RSC) [13–16].

In terms of single-incision robotic surgery, robotic laparoendoscopic single site (R-LESS) using the da Vinci Xi or Si system (Intuitive Surgical, Sunnyvale, CA) or the single-port robotic surgery using the da Vinci SP system (Intuitive Surgical, Sunnyvale, CA) is available. The wristed needle driver facilitates suturing in R-LESS; however, multiple suturing continues to remain challenging because the movement angle of the single-site wristed needle driver is 45°, thus requiring a longer surgical time than that for the multi-port robotic surgery. The recently introduced da Vinci SP system offers both an aesthetic finish and increased versatility. A flexible 3-dimensional camera and three fully wristed, 6-mm double-jointed articulating robotic instruments are inserted into a specially designed single trocar. Surgeons can operate all three robotic instruments in a single trocar, which enables easier suturing and tying than that in R-LESS [17–20].

SS-RSC was first reported in 2016 with six cases demonstrating feasibility and safety [21]. Thereafter, only a few reports with smaller number of cases were published in 2017 (n = 25) [22], 2018 (n = 15) [23], and 2020 (n = 32) [24] because technical difficulties with respect to multiple suturing using semirigid instruments during SS-RSC compared with MP-RSC or OSC continue to exist. There are only three published reports regarding SP-RSC, and more information is needed for this new surgical system [17,19,20]. The surgical video of pure single-incision SP-RSC that included 8 cases was presented at AAGL 2019 [17], and data were also included in the case series on benign gynecologic surgery with the SP system [18]. Another study reported on a two-incision SP-RSC performed for 3 cases in 2020 [19]. They placed an additional 12-mm assistant port and used an external magnetic controller for bowel and bladder retraction [19]; the video article has also been published [20].

However, there are no reports on the comparison between the two types of single-incision RSC: SS-RSC and SP-RSC. The primary objective was to compare the operative time (OT) and perioperative outcomes of SS-RSC and SP-RSC. The secondary objectives were to compare the recurrence and complications postoperatively at the 1-year follow-up (FU). We also described our surgical experiences when we performed SS-RSC and SP-RSC, and we believe that this article can be helpful especially for surgeons who want to perform a single-incision RSC.

Materials and methods

Forty-eight patients who underwent single-incision RSC for symptomatic apical pelvic organ prolapse quantification (POP-Q) stage III–IV between November 2015 and September 2019 and completed the 1-year FU were included in this study. Forty non-consecutive patients who underwent SS-RSC between November 2015 and September 2019 and eight consecutive patients who underwent SP-RSC during January 2019 were also included. For more precise comparisons of the two groups, we also analyzed the data of the initial 8 cases in each group. Until 2018, only the da Vinci single-site robotic system was available in our hospital for single-incision robotic surgery. However, the da Vinci SP surgical system was available at our hospital from January 2019.

A retrospective chart review was performed on the prospectively collected data. Medical records including age; body mass index (BMI); detailed gynecologic, medical, and surgical histories; POP-Q stage; and surgical time were reviewed and collected for analysis. OT was defined as the time from the skin incision to skin closure for RSC and concomitant procedures. Docking time was defined as the time from the start of driving the robotic patient arm after completion of the port placement to the completion of robot docking. Mesh anchoring time was defined as the time taken for mesh anchoring suturing to the anterior and posterior vaginal walls as well as to the anterior longitudinal ligament (ALL) of the sacrum. Times for each intracorporeal surgical procedure in each case were re-checked by reviewing the completely recorded surgical videos.

The perioperative complications including estimated blood loss (EBL), intra- or postoperative adverse events, and recurrence of POP postoperatively at the 1-year FU were analyzed. The diagnosis of POP, POP-Q staging, operation, and postoperative FU were performed by a single urogynecologist (Lee SR). All surgical procedures were performed in the same manner with the same technical proficiency without interpersonal variations except the intrapersonal differences in surgical experiences during the 4 years of the study.

SS-RSC was performed using the da Vinci Si or Xi system; the surgical steps have been described in our previous report [20] except that the Glove port from December 2015 (Sejong Medical, Paju, Gyeonggi-do, South Korea) was used instead of the silicon port designed for the da Vinci single-site and the wound retractor (Applied Medical, Rancho Santa, Margarita, California, USA). In terms of semirigid robotic instruments, a monopolar hook bovie (permanent cautery) for the right robotic arm as well as fenestrated bipolar forceps for the left robotic arm were used for supracervical hysterectomy (SCH) and adnexectomy, and a wristed needle driver replaced the monopolar hook bovie for suturing procedures.

SP-RSC was performed using the da Vinci SP system. All working instruments, including the camera, monopolar scissors, fenestrated bipolar forceps, and a large needle driver were inserted into the single SP trocar. Monopolar scissors for the right (3 o'clock) robotic arm, fenestrated bipolar forceps for the left (9 o'clock) robotic arm, and a large needle driver for the centrally positioned (6 o'clock) robotic arm were used for SCH and adnexectomy. The arms of the monopolar scissors and the large needle driver were interchanged for suturing procedures.

All surgical cases were performed under general anesthesia and underwent standard operative care. The central docking type was chosen in all cases. The different surgical steps between the two groups were extracorporeal procedures; the length of skin incision, port placement, and robot docking procedures. A vertical incision of about 2.5–2.7 cm was made in the umbilicus, and the Glove port was used for SS-RCP. A vertical incision of approximately 2.7–3.0 cm was made in the umbilicus, and a GelPoint (Applied Medical, Rancho Santa Margarita, CA, USA) was used for SP-RSC. A metallic port specifically designed for the da Vinci SP system and a 5-mm auxiliary port were inserted into the pre-placed GelPoint. In terms of the number of robotic instruments that can be used simultaneously during surgery, two single-site robotic instruments for SS-RCP and three single-port robotic instruments for SP-RCP are available (Fig. 1).

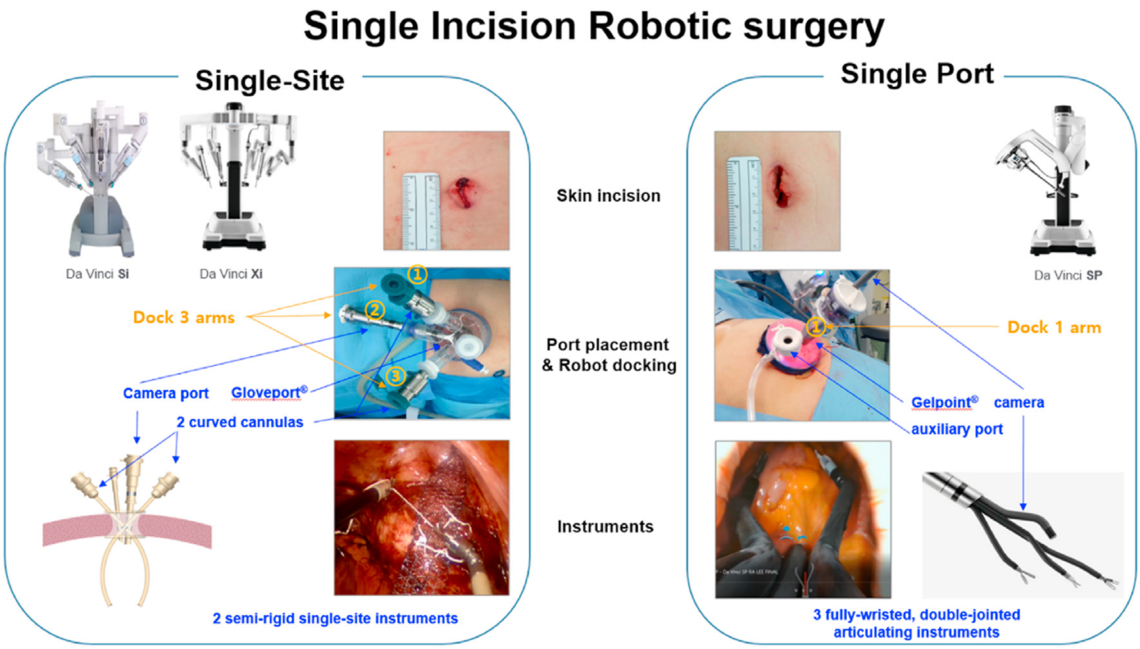

Fig. 1. Single incision robotic system, single-site single port. Picture of the da Vinci Si, Xi, SP systems © [2020] Intuitive Surgical, Inc. Used with permission.

The location of the incision, intraumbilical area, and lack of additional skin incisions were the same between the two types of single-incision robotic surgery, whereas the available number of instruments that can be used simultaneously during surgery (two for single-site surgery and three for single-port surgery) is different.

The surgical materials, including suture materials and mesh, were almost the same in all cases. Non-absorbable suture materials, 3-0 Goretex (WL Gore & Associates, Inc., Flagstaff, AZ, USA) or 2-0 Ethibond (Ethicon, Johnson & Johnson, New Brunswick, NJ, USA), and the absorbable suture material, 2-0 PDS (Ethicone, NJ, USA), were used for mesh anchoring sutures. Complete peritoneal closure was performed with absorbable barbed suture materials, 2-0 V-Loc (Covidien, Mansfield, MA, USA) or 2-0 Monofix PDO (Samyang, Daejeon, South Korea). A Y-shaped, partially absorbable macroporous polypropylene mesh (Seratex®PA B2 type, Serag-Wiessner KG, Naila, Germany) was used.

Most intracorporeal procedures were almost the same in all cases, with the only different surgical step being the use of the peritoneal tunneling method as Liu J et al. described [23]. Because we introduced the method in 2018, the peritoneal tunneling method was performed for all 8 cases (100%) in SP-RSC and for 25 cases (62.5%) except the initial 15 cases in SS-RSC. SCH with or without adnexectomy proceeded in a similar manner. The cervical stump was sutured with 1-0 V-Loc in a continuous running suture technique, and this step was omitted in the six cases of vault prolapse. Dissection of the avascular anterior vesicovaginal plane and the posterior rectovaginal plane was conducted. Dissection of the presacral area to expose the ALL of the sacrum approximately 3–4 cm was conducted. The presacral peritoneal incision was extended to the Cul-de-sac except for the caudal 1.5–2 cm for re-peritonealization when using the peritoneal tunneling method. Fixation of a Y-shaped mesh by multiple discrete sutures with both absorbable and non-absorbable suture materials on the anterior and posterior vaginal wall was performed. We inserted 3–4 anchoring sutures on the cervical stump, 12–16 anchoring sutures on the anterior and posterior vaginal wall (6–8 sutures each), and 3–4 anchoring sutures on the presacral ALL. The fixation of the cranial end of the Y-shaped mesh to the ALL was performed with non-absorbable suture materials after adjusting the mesh tension. Complete closure of the peritoneum with absorbable barbed suture materials to prevent mesh exposure, bowel adhesion, or bowel strangulation was performed. Removal of the retrieved uterus and adnexa with knife morcellation within an Endo-bag (Sejong Medical, Paju, Gyeonggi-do, South Korea) was performed.

The statistical analysis was performed using SPSS for windows version 20 (SPSS Inc, Chicago, Ill, USA), and the Wilcoxon rank-sum test and Fisher's exact test were used for comparing the continuous and categorical variables, respectively, between the groups. All tests were two-sided and considered significant at the 0.05 level. This study protocol was approved by the Asan Medical Center Institutional Review Board (approval No. 2020-0897).

Results

The mean age of the patients was 59.2 ± 11.0 and 66.1 ± 8.0 years in the SS-RSC and SP-RSC groups, respectively, and the median number of vaginal deliveries was two in both groups. The mean BMI was comparable between the two groups (23.0 ± 2.5 kg/m^2 vs 23.9 ± 2.5 kg/m^2). There were no differences in the distribution of the preoperative POP-Q stage, the proportion of vault prolapse cases, and previous abdominal surgery cases between the two groups (Table 1). Three patients with previous POP surgery (2 cases of anterior-posterior repair and 1 case of vaginal hysterectomy) were only in the SS-RSC group.

The surgical time for each procedure and concomitant procedures is listed in Table 2. In the analysis of times for each surgical procedure, significant differences were noted in the docking and cervix suturing times between the two groups ($P < 0.05$). These were longer in the SS-RSC group than in the SP-RSC group (5.0 ± 2.6 min vs 2.3 ± 1.3 min, $P < 0.001$; 4.5 ± 1.8 min vs 2.1 ± 1.9 min, $P < 0.01$, respectively) (Table 2).

In the analysis of the initial 8 cases in each group, the results were different. Interestingly, all surgical times except cervical suturing time were shorter in the SP-RSC group ($P < 0.05$). The OT of SP-RSC was 34 min shorter than that of SS-RSC (176.3 ± 20.2 min vs

141.9 ± 23.6 min, P = 0.02). The console time of SP-RSC was 53.5 min shorter than that of SS-RSC (142.5 ± 20.6 min vs 89 ± 9.5 min, P < 0.001). The mesh anchoring time of SP-RSC was 34.3 min shorter than that of SS-RSC (86.4 ± 10.2 min vs 52.1 ± 5.4 min, P < 0.001) (Table 3).

The mean specimen retrieval time was 1 min (range, 0.5–2 min) in both the groups because most cases were of postmenopausal women with an atrophied small uterus and adnexa. There was no difference in the rate of concomitant procedures, including adnexectomy, adhesiolysis, posterior repair, and trans-obturator tension free vaginal tape (TOT) between the two groups. The mean EBL was comparable and below 75.0 mL in the SS-RSC and SP-RSC groups (51.9 ± 33.7 mL vs 71.3 ± 41.2 mL) (Table 2).

In terms of operative adverse events, there was no transfusion or conversion to laparotomy or MP-RSC in either group; complication rates were not different between the two groups. There was no case of bowel obstruction, deep vein thrombosis, pulmonary embolism, sepsis, cardiac, respiratory, renal, or neurological complications. There were three cases of bladder injury (cystotomy) during the operation: two in the SS-RSC and one in the SP-RSC group. The intraoperative primary repair of the cystotomy site extended urinary drainage with indwelling urethral Foley catheter for 7 days. Removal of the Foley catheter after confirming no extravesical leakage of the dye on cystography resolved the issue.

The FU period was 24.8 ± 9.7 months (median, 24 months [range, 12–56]) in the SS-RSC and 17 months in the SP-RSC group. At the 4-week FU, all cases were POP-Q stage 0–I except one case of anterior compartment recurrence: POP-Q stage II in SS-RSC. The recurred POP case was also accompanied by an umbilical incisional hernia. There were two cases of umbilical incisional hernia in the SS-RSC group. Case 1 was of an 86-year-old woman who developed an umbilical incisional hernia at 3 months after the operation and who experienced the recurrence of POP. Therefore, a primary umbilical fascial closure and native tissue repair, anterior colporrhaphy, were performed concomitantly. Case 2 was of a 67-year-old women who had a wound infection and umbilical wound hernia and was diagnosed 2 months after the operation; a herniorrhaphy with artificial fascia was performed. These two patients were obese with BMIs 28.76 kg/m^2 and 27.07 kg/m^2, respectively.

There were two cases (2/48, 4.2%) of de-novo stress urinary incontinence in SS-RSC. One case underwent TOT and one case did not want to undergo an additional procedure for the mild symptom.

Two cases (2/48, 4.2%) had posterior vaginal wall mesh erosion: one (2.5%) in the SS-RSC and one (12.5%) in the SP-RSC group. Under local anesthesia, we removed the exposed mesh and surrounding vaginal wall. A primary vaginal wall closure with absorbable suture material, 2-0 Vicryl (Ethicon Inc, Somerville, NJ, USA), was performed; oral estradiol 2 mg once daily with 0.03 mg estriol vaginal tablet once daily for 4 weeks was administered. However, the mesh erosion recurred in the SS-RSC group patient, and she refused to undergo additional management because she did not have bothersome symptoms (Table 4).

Discussion

We compared the two types of single-incision robotic surgery systems, the da Vinci single-site system and the single-port system while performing RSC. The da Vinci SP system composed of a single metallic trocar, a flexible camera, and three double-jointed instruments enables single-incision robotic surgery with mechanisms of action different from the da Vinci single-site system with two curved trocars and semirigid instruments (Fig. 1). Additional studies elucidating the differences in performing single-incision robotic surgery with these two different robotic surgical systems in terms of the time required for each surgical procedure or the complications involved.

We demonstrated that the two types of single-incision RSC: SS-RSC and SP-RSC, are feasible and effective options for apical POP with an aesthetic finish. To the best of our knowledge, this is the first article comparing the two types of single-incision RSC: SS-RSC and SP-RSC.

The docking time and cervix suturing time were shorter in the SP-RSC group; however, the OT, console, mesh anchoring, reperitonealization times were comparable between the two groups. Interestingly, all surgical times except the cervix suturing time were significantly shorter in the comparison of the initial 8 cases in each group.

The mean OT in our study (135.3 min in SS-RSC and 141.8 min in SP-RSC) was similar to that of SS-RSC in a recent randomized controlled trial (RCT) (181 min, n = 32) [24] and a case series on SS-RSC (190 min, n = 25) [23]. Expectedly, the mean OT of our single-incision RSC was longer than MP-RSC in an RCT (157.5 min) [24] and while comparing with the recent data of a high-volume center (101 min) [25]. However, the OT of recent single-incision RSC, which was published in 2014 as the initial experience of Cleveland clinic [10], was shorter than LSC (235 min, n = 249) or MP-RSC (275 min, n = 121). Moreover, the OT of our single-incision RSC was also shorter than LSC (328 min vs 295.5 min) and comparable with OSC (225 min vs 222 min) in two RCTs comparing LSC and OSC [26,27].

A shorter OT is an important advantage especially for old and obese women, who are common among POP patients, for decreasing perioperative complications. Until recently, the

Table 1
Sociodemographic data and clinical history.

	SS-RSC (n = 40)	SP-RSC (n = 8)	*P* value
Age, years, Mean ± SD[a]	59.2 ± 11.0	66.1 ± 8.0	0.07
Vaginal parity, Median [range][a]	2 [0–5]	2 [1–3]	0.44
BMI, kg/m^2, Mean ± SD[a]	23.0 ± 2.5	23.9 ± 2.5	0.40
Overweight, n (%)[b]	7 (77.5%)	2 (25%)	1
Obesity, n (%)[b]	10 (23.2%)	3 (37.5%)	0.63
Premenopause, n (%)[b]	10 (25.0%)	0	0.18
Vault prolapse, n (%)[b]	5 (12.5%)	1 (12.5%)	1
Previous abdominal surgery, n (%)[b]	10 (25.0%)	5 (62.5%)	0.09
POP-Q stage, n (%)[b]			1
Stage III	30 (75.0%)	6 (75.0%)	
Stage IV	10 (25.0%)	2 (25.0%)	

SS, single site using the da Vinci Xi or Si platform; *RSC*, robotic sacrocolpopexy; *SP*, single port using the da Vinci SP platform; *BMI*, body mass index; *POP-Q*, Pelvic Organ Prolapse Quantification.
[a] *P* value calculated using the Wilcoxon rank-sum test.
[b] *P* value calculated using Fisher's exact test.

Table 2
Surgical data.

	SS-RSC (n = 40)		SP-RSC (n = 8)		Mean difference (95% CI)	*P* value
	Mean ± SD	Median [range]	Mean ± SD	Median [range]		
Operative time (min)[a]	135.3 ± 31.6	130 [76–200]	141.8 ± 23.5	145 [105–175]	6.5 (−14.5–27.5)	0.45
Docking time (min)	4.98 ± 2.55	4 [1.5–10]	2.31 ± 1.31	2 [0.5–5]	2.67 (1.39–3.95)	<0.001
Console time (min)[a]	94.6 ± 32.2	89.5 [43–174]	89 ± 9.53	89.5 [75–102]	5.65 (−6.72–18.02)	0.93
SCH ± adnexectomy, time (min)[a]	13.3 ± 5.3	13 [3–26]	15.7 ± 4.4	15.5 [10–24]	2.36 (−1.58–6.29)	0.13
Cervix suturing time[a] **(min)**	4.49 ± 1.82	4 [1–8]	2.12 ± 1.89	1 [1–6]	2.36 (0.73–3.99)	<0.05
Mesh anchoring time (min)[a]	51.45 ± 22.06	49 [20–100]	52.1 ± 5.38	50.5 [47–62]	0.67 (−7.33–8.68)	0.71
Peritoneum suturing time (min)[a]	11.8 ± 7.75	9 [3–36]	7 ± 1.77	6.5 [5–9]	4.8 (2.03–7.57)	0.11
EBL (ml)	51.88 ± 33.74	50 [10–150]	71.25 ± 41.21	50 [30–150]	19.38 (−15.74–54.49)	0.24
Concomitant procedures						
Bilateral adnexectomy, n (%)[b]	36 (90.0%)		8 (100%)			1
Adhesiolysis, n (%)[b]	7 (17.5%)		1 (12.5%)			1
Posterior repair, n (%)[b]	5 (12.5%)		1 (12.5%)			1
TOT, n (%)[b]	10 (25.0%)		2 (25.0%)			1

SS, single site using the da Vinci Xi or Si platform; *RSC*, robotic sacrocolpopexy; *SP*, single port using the da Vinci SP platform; *SCH*, supracervical hysterectomy; *EBL*, estimated blood loss; *TOT*, Trans-obturator tension free vaginal tape.
[a] *P* value calculated using the Wilcoxon rank-sum test.
[b] *P* value calculated using Fisher's exact test.

Table 3
Surgical time of initial eight cases in each group.

	SS-RSC (n = 8)		SP-RSC (n = 8)		Mean difference (95% CI)	*P* value
	Mean ± SD	Median [range]	Mean ± SD	Median [range]		
Operative time (min)[a]	176.25 ± 20.23	177.5 [140–200]	141.88 ± 23.59	145 [105–175]	34.38 (10.75–58)	0.02
Docking time (min)[a]	8.5 ± 1.07	8 [7–10]	2.31 ± 1.31	2 [0.5–5]	6.19 (4.9–7.47)	<0.001
Console time (min)[a]	142.5 ± 20.55	136.5 [114–174]	89 ± 9.53	89.5 [75–102]	53.5 (35.63–71.37)	<0.001
SCH ± adnexectomy, time (min)[a]	11.67 ± 5.01	10 [6–20]	15.75 ± 4.46	15.5 [10–24]	6.02 (4.66–7.38)	0.04
Cervix suturing time[a] **(min)**	6.67 ± 1.21	6.5 [5–8]	2.12 ± 1.89	1 [1–6]	4.54 (2.73–6.35)	0.15
Mesh anchoring time (min)[a]	86.38 ± 10.21	86 [70–100]	52.12 ± 5.38	50.5 [47–62]	34.25 (25.23–43.27)	<0.001
Peritoneum suturing time (min)[a]	21.75 ± 2.19	21 [20–25]	7 ± 1.77	6.5 [5–9]	14.75 (12.61–16.89)	<0.001
Concomitant procedures						
Bilateral adnexectomy, n (%)[b]	7 (87.5%)		8 (100%)			1
Adhesiolysis, n (%)[b]	0		1 (12.5%)			0.03
Posterior repair, n (%)[b]	0		1 (12.5%)			0.03
TOT, n (%)[b]	3 (37.5%)		2 (25.0%)			0.02

SS, single site using the da Vinci Xi or Si platform; *RSC*, robotic sacrocolpopexy; *SP*, single port using the da Vinci SP platform; *SCH*, supracervical hysterectomy.
[a] *P* value calculated using the Wilcoxon rank-sum test.
[b] *P* value calculated using Fisher's exact test.

Table 4
Intraoperative and postoperative adverse events (AEs).

	SS-RSC (n = 40)	SP-RSC (n = 8)	*P* value
Intraoperative AEs			
Bladder injury	2 (5.0%)	1 (12.5%)	1
Bowel injury	0	0	1
Blood loss requiring transfusion	0	0	1
Postoperative AEs			
Anemia	1 (2.5%)	0	1
Bowel obstruction	0	0	1
Wound infection	1 (2.5%)	0	1
Fever and readmission	0	1 (12.5%)	1
Urinary tract infection	0	0	1
Umbilical incisional hernia	2 (5.0%)	0	1
Vaginal wall -mesh erosion	1 (2.5%)	1 (12.5%)	1
De-novo stress urinary incontinence	2 (5.0%)	0	1
POP-Recurrence, anterior compartment	1 (2.32%)	0	1

AEs, adverse events; *POP*, Pelvic Organ Prolapse; *SS*, single site using the da Vinci Xi or Si platform; *SP*, single port using the da Vinci SP platform.
P value calculated using Fisher's exact test.

increased OT and cost had partially offset the advantages of RSC. However, surgical proficiency can help overcome longer OTs as demonstrated in recent publications, including our study [25–27].

The docking time was consistently shorter for SP-RSC than for SS-RSC, both in total cases and in the initial 8 cases. This is attributed to the one-step docking possible for the SP system and the 3 steps needed for the SS system (Fig. 1). Nevertheless, the experiences of the surgical team can shorten the docking time in robotic surgery [28]. Similarly, in our study, the docking time could be affected by the surgical experience. However, the main reason for the short docking time in SP-RSC is attributed to the fact that only one arm docking is needed in SP-RSC and three-arm docking is needed in SS-RSC. In terms of the cervix suturing time, because of the hard tissue nature of the uterine cervix, a surgeon needs instruments which are more powerful than the semirigid instruments for the SS system. However, the OT was the same, despite their initial experiences. All surgical times except the cervix suturing time were significantly shorter for SP-RSC in the comparison with the initial 8 cases in each group. For a beginning practitioner of single-incision RSC, SP-RSC might appear less challenging than SS-RSC.

In terms of complications, there were no differences between the two groups. Although a slightly larger skin incision of 2.7 cm was made in SP-RSC for the metallic trocar of the SP system, there was no case of incisional hernia in SP-RSC. The two cases of incisional hernia were only in SS-RSC, and both patients were obese. Our study showed that obese and overweight POP women can also undergo the single-incision RSC. However, obese women should be informed of the risk of postoperative incisional hernia, considering most POP patients are old aged women who are already at a high risk of umbilical hernia. A recent RCT comparing the MP-RSC ($n = 32$) and SS-RSC ($n = 32$) reported that 6.2% (2/32) of women in SS-RSC had postoperative incisional hernias compared with no case in MP-RSC [23]. Both the longer umbilical incision in SS-RSC (2.5 cm) than in MP-RSC (1.5 cm) and obesity could be risk factors for the occurrence of incisional hernia after the single-incision RSC.

The rate of intraoperative bladder injury (6.7%) was also comparable with that in the RCT (6.7%). However, the mesh erosion rate was higher in our study (4.4%) at 1 year of FU, and no case was reported in SS-RSC at the 6-month FU in the RCT [23]. A long-term FU is needed to conclude these findings as an increase in the mesh erosion rate is proportional to the FU period.

Among SS-RSC, SP-RSC, and MP-RSC, the most technically difficult operation was SS-RSC not only for intracorporeal procedures but also for robot docking and the easiest was MP-RSC. In terms of robot docking, except for the initial unexperienced cases, SP-RSC was the easiest, followed by MP-RSC.

The advantages of this study were as follows: 1) first study comparing the two types of single-incision RSC, i.e., SS-SCP and SP-SCP; 2) although there was a small number of cases in both the groups, this is the largest number regarding SS-SCP and SP-SCP cases in the literature; 3) the surgical time and details were checked once more with the completely recorded surgical videos; 4) this study excludes surgeons' interpersonal variations, as this is the experience of a single surgeon. The disadvantages of this study were as follows: 1) this was not an RCT; 2) relatively small number of cases in both the groups and relatively short-term FU data (12 months) precluded, thereby drawing conclusions about the long-term efficacy and safety of the single-incision RSC.

In conclusion, the two types of single-incision RSC: SS-RSC and SP-RSC, are more feasible and effective options for apical POP with an aesthetic finish than MP-RSC or OSC. The surgical time of a single-incision RSC could be shortened in SP-RSC.

Declaration of competing interest

The author(s) have no conflicts of interest relevant to this article.

Acknowledgments

This work was supported by the Institute for National IT Industry Promotion Agency (NIPA) grant funded by the Korea government (MSIT) (No. A0602-19-1032, Intelligent surgical guide system & service from surgery video data analytics).

References

[1] Lowenstein E, Ottesen B, Gimbel H. Incidence and lifetime risk of pelvic organ prolapse surgery in Denmark from 1977 to 2009. Int Urogynecol J 2015;26:49–55.
[2] Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. Obstet Gynecol 1997;89:501–6.
[3] Wu JM, Matthews CA, Conover MM, Pate V, Jonsson Funk M. Lifetime risk of stress urinary incontinence or pelvic organ prolapse surgery. Obstet Gynecol 2014;123:1201–6.
[4] Smith FJ, Holman CD, Moorin RE, Tsokos N. Lifetime risk of undergoing surgery for pelvic organ prolapse. Obstet Gynecol 2010;116:1096–100.
[5] Barber MD, Maher C. Epidemiology and outcome assessment of pelvic organ prolapse. Int Urogynecol J 2013;24:1783–90.
[6] Boyles SH, Weber AM, Meyn L. Procedures for pelvic organ prolapse in the United States, 1979-1997. Am J Obstet Gynecol 2003;188:108–15.
[7] Shah AD, Kohli N, Rajan SS, Hoyte L. The age distribution, rates, and types of surgery for pelvic organ prolapse in the USA. Int UrogynEcol J Pelvic Floor Dysfunct 2008;19:421–8.
[8] Jayakumaran J, Patel SD, Gangrade BK, Narasimhulu DM, Pandian SR, Silva C. Robotic-assisted laparoscopy in reproductive surgery: a contemporary review. J Robot Surg 2017;11:97–109.
[9] Linder BJ, Occhino JA, Habermann EB, Glasgow AE, Bews KA, Gershman B. A national contemporary analysis of perioperative outcomes of open versus minimally invasive sacrocolpopexy. J Urol 2018;200:862–7.
[10] Unger CA, Paraiso MF, Jelovsek JE, Barber MD, Ridgeway B. Perioperative adverse events after minimally invasive abdominal sacrocolpexy. Am J Obstet Gynecol 2014;211:547. e1-8.
[11] Holloway RW, Patel SD, Ahmad S. Robotic surgery in gynecology. Scand J Surg 2009;98:96–109.
[12] Gala RB, Margulies R, Steinberg A, Murphy M, Lukban J, Jeppson P, et al. Systematic review of robotic surgery in gynecology: robotic techniques compared with laparoscopy and laparotomy. J Minim Invasive Gynecol 2014;21:353–61.
[13] Geller EJ, Siddiqui NY, Wu JM, Visco AG. Short-term outcomes of robotic sacrocolpopexy compared with abdominal sacrocolpopexy. Obstet Gynecol 2008;112:1201–6.
[14] Elliott CS, Hsieh MH, Sokol ER, Comiter CV, Payne CK, Chen B. Robot-assisted versus open sacrocolpopexy: a costminimization analysis. J Urol 2012;187: 638–43.
[15] Geller EJ, Parnell BA, Dunivan GC. Robotic vs abdominal sacrocolpopexy: 44-month pelvic floor outcomes. Urology 2012;79:532–6.
[16] Hoyte L, Rabbanifard R, Mezzich J, Bassaly R, Downes K. Cost analysis of open versus robotic-assisted sacrocolpopexy. Female Pelvic Med Reconstr Surg 2012;18:335–9.
[17] Lee SR, Kim S, Chae H, Kang BM. Single-Port Robotic-Assisted Sacrocolpopexy Using the SP surgical system; first clinical experience. J Minim Invasive Gynecol 2019;26(7S):S74.
[18] Shin HJ, Yoo HK, Lee JH, Lee SR, Jeong K, Moon HS. Robotic single-port surgery using the da Vinci SP® surgical system for benign gynecologic disease: a preliminary report. Taiwan J Obstet Gynecol 2020;59:243–7.
[19] Ganesan V, Goueli R, Rodriguez D, Hess D, Carmel M. Single-port robotic-assisted laparoscopic sacrocolpopexy with magnetic retraction: first experience using the SP da Vinci platform. J Robot Surg 2020;8 [e-pub].
[20] Goueli R, Rodriguez D, Hess D, Ganesan V, Carmel M. Single-port robotic-assisted laparoscopic sacrocolpopexy with magnetic retraction: a video demonstration. Urology 2020;143:258–60.
[21] Lee SR. Robotic single-site® sacrocolpopexy: first report and technique using the single-site® wristed needle driver. Yonsei Med J 2016;57:1029–33.
[22] Matanes E, Lauterbach R, Mustafa-Mikhail S, Amit A, Wiener Z, Lowenstein L. Single port robotic assisted sacrocolpopexy: our experience with the first 25 cases. Female Pelvic Med Reconstr Surg 2017;23:e14–8.
[23] Liu J, Bardawil E, Zurawin RK, Wu J, Fu H, Orejuela F, et al. Robotic single-site sacrocolpopexy with retroperitoneal tunneling. J Soc Laparoendosc Surg 2018;22:e2018. 00009.
[24] Matanes E, Boulus S, Lauterbach R, Amit A, Weiner Z, Lowenstein L. Robotic laparoendoscopic single-site compared with robotic multi-port sacrocolpopexy for apical compartment prolapse. Am J Obstet Gynecol 2020;222: 358.e1–358.e11.
[25] Ploumidis A, Spinoit AF, De Naeyer G, Schatteman P, Gan M, Ficarra V, et al. Robot-assisted sacrocolpopexy for pelvic organ prolapse: surgical technique and outcomes at a single high-volume institution. Eur Urol 2014;65:138–45.
[26] De Gouveia, De Sa M, Claydon LS, Whitlow B, Dolcet Artahona MA. Laparoscopic versus open sacrocolpopexy for treatment of prolapse of the apical segment of the vagina: a systematic review and meta-analysis. Int Urogynecol J 2016;27:3–17.
[27] Nosti PA, Umoh AU, Kane S, White DE, Harvie HS, Lowenstein L, et al. Outcomes of abdominal and minimally invasive sacrocolpopexy: a retrospective cohort study. Female Pelvic Med Reconstr Surg 2014;20:33–7.
[28] Feng Z, Feng MP, Feng DP, Solórzano CC. Robotic-assisted adrenalectomy using da Vinci Xi vs. Si: are there differences? J Robot Surg 2020;14(2): 349–55.