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Original Research

Long-Term Outcomes of Reduced-Port Robotic Surgery (RPRS) for Uterine Myomectomy with the da Vinci Surgical System

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Abstract

Background: Reduced-Port Robotic Surgery (RPRS) for myomectomy is feasible alternate method to overcome disadvantages of multiport and single-site platforms of robotic surgery with better cosmetic results. We demonstrated operative outcomes and long-term outcomes after RPRS. **Methods**: This is analysis of a prospective, non-randomized study of 115 patients who underwent RPRS from April 2016 through July 2021. **Results**: Overall 115 patients were included for analysis. Patients' median age was 42 years (range, 28–52). The largest myoma was mostly located on the anterior uterine wall in 59 patients. The median myoma size and weight were 7.5 cm (range, 3–12) and 163 g (range, 42–753), respectively. The median myoma enucleation time and suture time were 10 minutes (range, 4–82) and 14 minutes (range, 5–63). Trend of shorter docking time and console time was shown with experience. The procedure was successfully performed via RPRS in 104 patients (91.5%); 10 patients required placement additional ports, conversion to open surgery was conducted in one case. There were 6 patients (5.2%) with postoperative complication with surgical wound infection (1.7%), bleeding (0.9%), peritonitis (1.7%), and pneumonia (0.9%). For long-term outcomes, 12 recurrences (10.4%) were observed in median follow-up of 25 months (range, 6–62 months). Total of 4 patients became pregnant after RPRS, and three patients had delivered with Caesarean section without complications. **Conclusions**: Our long-term results demonstrate the safety and feasibility of RPRS for uterine myomectomy as a valid treatment modality.

Keywords: robotic myomectomy; RPRS; uterine myomas; long-term outcomes; surgical outcomes

1. Introduction

Uterine myomas are the most common benign tumor of the female genital tract which affect 20 to 50% of women world-wide [1]. Symptoms of uterine myomas include menorrhagia, pelvic pain, dysmenorrhea, urinary symptoms, and infertility [2]. Hysterectomy is treatment option for symptomatic uterine myoma, but myomectomy is preferred surgical treatment for the women who desire to preserve fertility [3].

Laparoscopic surgery is known to have advantages of faster recovery, shorter hospital stay, reduced blood loss, and fewer complications compared to open surgery [4]. Laparoscopic myomectomy was first introduced in 1979 [5], and since then, laparoscopic myomectomy became popular surgical method due to many advantages. With advances in surgical instruments and surgeon's techniques, surgeons planned to reduce visible scars which led to development of single-port laparoscopic surgery [6]. Also, the demand for single-port laparoscopic myomectomy has increased in women who desire to reduced surgical scars through minimally invasive surgery. However, there are technical difficulties remaining associated with single-port laparoscopic myomectomy due to the collision of instruments, limited number of operating arms, and absence of an assistant arm for maintaining tension [7].

The da Vinci system (Intuitive Surgical, Sunnyvale, CA, USA) contributed to reduce the limitations of laparoscopic surgery, and robotic single-port surgery has been introduced to satisfy patients with less scars. However, robotic single-port surgery may have some disadvantages for myomectomy, with reduced extracorporeal triangulation, a complex docking process, and non-articulated semi-rigid instruments [8,9].

In order to overcome these limitations with better cosmetic results, we have been performed a Reduced-Port Robotic Surgery (RPRS) as alternate surgical method. In RPRS, single-port using vertical umbilical incision (approximately 3 cm) reduces collision between the camera and left robotic instrument when moving simultaneously. In RPRS using a laparoscopic single-port platform with multiport robotic instruments, surgeons can use the articulation and dexterity of the robotic wrist of the left and right instruments, thereby facilitating suture of uterine defects with only two surgical port sites. Our previous reports have shown that RPRS resulted in similar short-term perioperative outcomes in contrast to multiport robotic myomectomy proving the technical feasibility of RPRS [10,11]. We also established a comparable level of safety with RPRS, and achieved shortened suturing time in RPRS compared to conventional 2-port laparoscopic myomectomy [12]. Here,

we aimed to demonstrate long-term outcomes of 115 cases of RPRS for myomectomy using da Vinci surgical system.

2. Materials and Methods

2.1 Study Design and Participants

This is a prospective, non-randomized study which analyzed the data of patients who underwent RPRS myomectomy from April 2016 through July 2021. During the study period, 115 patients underwent RPRS myomectomy using the da Vinci surgical system at Kangbuk Samsung Hospital (KBSMC) done by gynecologic surgeon with more than 15 years of experience (Dr. W.Y. Kim). The inclusion criteria of this study were as follows: women with symptomatic myomas, such as menorrhagia, dysmenorrhea, or increased size; appropriate medical status for robotic surgery; and women between 18 and 55 years old. The exclusion criteria were as follows; women who needed additional surgical procedures at the time of myomectomy, such as severe adhesiolysis due to endometriosis or other previous surgery; women with suspected malignant uterine or adnexal disease; women with major medical comorbidities or psychiatric illness; and women who refused to participate or give consent to the procedures. The study protocol was approved in accordance with the ethical standards of the Declaration of Helsinki (IRB: 2016-04-083).

2.2 Data Collection

Information regarding participant demographics was obtained from the KBSMC benign gynecologic disease database and included data regarding age, body mass index (BMI) (kg/m^2), parity, chief complaint, previous abdominal surgery, and myoma characteristics (location, largest diameter, number of myoma, and weight of removed myoma). The myoma location was categorized according to the International Federation of Gynecology and Obstetrics (FIGO) classification system. Perioperative and postoperative details included docking time, myoma enucleation time, suture time, estimated blood loss during surgery, lengths of hospital days, surgical method conversion (additional port, conversion to open surgery), and any postoperative complications. Regarding surgical procedure time, surgeon measured the time for each part during surgery, recorded it on the surgical record, and reviewed the recorded video if necessary. Additionally, long-term recurrence and pregnancy outcomes of patients were investigated. Pre-operative evaluation of the size and location of the myomas was performed using pelvic magnetic resonance imaging or transvaginal sonography. The largest myoma was categorized based on the greatest diameter of the largest myoma reported during pre-operative imaging. During the long-term follow-up, patients were routinely evaluated via ultrasonography every 6 months after RPRS. Myoma recurrence was confirmed when a new myoma measuring 1 cm or more was detected on ultrasonography. Patients were also asked if they attempted for pregnancy, and all of the obstetric data were collected during the follow-up. The definition of long-term outcomes used in this study refers to outcomes observed in a follow-up period of 6 months or more in addition to the immediate surgical outcomes and complications.

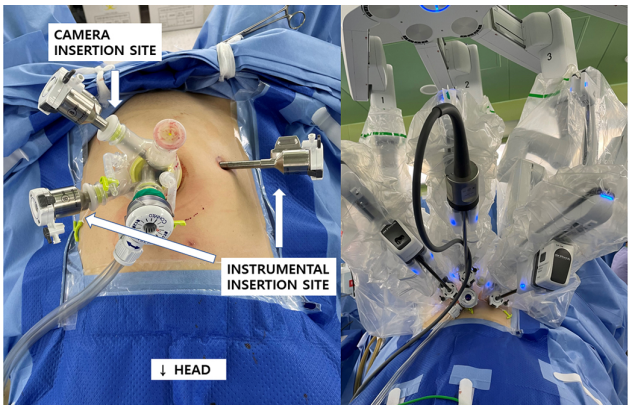

Fig. 1. Instrumental setting for RPRS. RPRS, Reduced-Port Robotic Surgery.

2.3 Surgical Procedures

In all cases, a vertical umbilical incision of approximately 3 cm was made via an open Hasson approach. In the RPRS, a laparoscopic cannula of 12 mm was introduced through the channels of the single-port device after the cap component was removed before the single-port device was positioned at the incision. During this process, an iodine-impregnated incision drape (Ioban 1) was used to cover the cannula and channel, to prevent CO_2 gas leakage. After achieving pneumoperitoneum via insufflation of CO_2 to 14 mmHg, the patient was placed in the Trendelenburg position at 20 degree. An 8.5-mm or 12-mm da Vinci endoscope with a 0 degree-angled view was then inserted. An 8-mm conventional robotic port was inserted into the 12-mm channel of the single-site platform. An additional 8 mm conventional robotic port was inserted into a usual robotic port site on the patient's right abdomen (Fig. 1). Since the da Vinci endoscope and arm 1 are using as the same umbilical site during surgery, it is important to reduce the interference between the two. It is necessary to maintain the angle of entry of the da Vinci endoscope and arm 1 as much as possible. A detailed description of the RPRS method was included in the previous study [11]. During RPRS myomectomy we used fenestrated bipolar forceps, robotic tenaculum forceps and Hot Shears Monopolar Curved Scissors (Intuitive Surgical, Sunnyvale, CA, USA). Before initiating the uterine incision, a dilute solution of vasopressin was injected into the base of the uterine myoma to reduce blood loss. After a layer-by-layer dissection, the myoma was enucleated. Once removed, myomas were placed in the posterior cul-de-sac or in the paracolic gutter for retrieval and

morcellation at the end of the surgery. The uterine incision was repaired in two layers using polyglyconate unidirectional barbed sutures with a 37 mm half circle taper-point needle (V-Loc; Covidien, Dublin, Ireland). Prior to myoma extraction from the abdomen, the robot-assisted devices were undocked. The myomas, which were placed into the specimen retrieval endobag, were removed transumbilically with knife morcellation. Next, all operative sites were irrigated, and any clots that had formed were removed. Once hemostasis was confirmed, an adhesion barrier was placed over the uterine incision site.

3. Results

A total of 115 patients underwent RPRS myomectomy from during April 2016 through July 2021. The detailed patients' demographic data and characteristics of myomas are shown in Table 1. Median age of patients was 42 years (range, 28–52), and most patients were nulliparous (66.9%). Most common cause of RPRS was menorrhagia (33.9%), followed by increased size of myoma (29.6%). Most myoma was located in anterior part (51.3%) with FIGO type 4 (23.5%). Median number of removed myoma and size of largest myoma were 3 (range, 1–15) and 7.5 cm (range, 3–12), respectively.

Perioperative and postoperative outcomes are described in Table 2. Median enucleation time and suture time were 10 minutes (range, 4–82) and 14 minutes (range, 5–63), respectively. Additionally, trend of significant progress with shorter docking time and console time was shown with experience (Fig. 2). Median estimated blood loss was 100 mL (range, 10–700), and most patients (64.3%) stayed in hospital for 4 days. The procedure was successfully performed via RPRS in 104 patients (91.5%). In 10 cases (8.7%), trocars were added to multiport surgery, and conversion to open surgery was conducted in one case (0.8%). Total 6 cases (5.2%) of postoperative complications were shown with surgical wound infection (2, 1.7%), postoperative bleeding (1, 0.9%), peritonitis (2, 1.7%), and pneumonia (1, 0.9%).

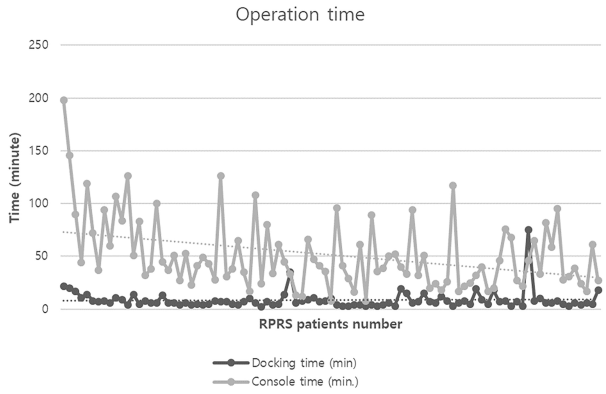

Fig. 2. Trend of operation time with increased experience.

Table 1. Baseline characteristics (n = 115).

Characteristic	Values
Age, years, median (range)	42 (28–52)
BMI, kg/m^2, median (range)	21.9 (16.2–34.2)
Parity, n (%)	
Nulliparous	77 (66.9)
Multiparous	38 (33.1)
Indication of surgery, n (%)	
Menorrhagia	39 (33.9)
Dysmenorrhea	16 (13.9)
Increased size of myoma	34 (29.6)
Others	26 (22.6)
Previous abdominal surgery, n (%)	
Yes	54 (47.0)
No	61 (53.0)
Location of the largest myoma, n (%)	
Anterior	59 (51.3)
Posterior	47 (40.9)
Lateral	9 (7.8)
Size of largest myoma, cm, median (range)	7.5 (3–12)
Number of myoma removed, median (range)	3 (1–15)
Weight of myoma, g, median (range)	163 (42–753)
FIGO type, n (%)	
0	4 (3.5)
1	12 (10.4)
2	11 (9.6)
3	16 (13.9)
4	27 (23.5)
5	10 (8.7)
6	25 (21.7)
7	10 (8.7)

Data are expressed as median (range), frequencies (percentages), as appropriate.
BMI, body mass index; FIGO, International Federation of Gynecology and Obstetrics.

Recurrence of myoma was detected in 12 patients (10.4%) in median follow-up of 25 months (range, 6–62 months), and characteristics of myoma recurrence are shown in Table 3. Multiple recurrence was shown in 7 patients (58.2%), and median size of recurred myoma was 1.6 cm (range, 1.0–2.8). FIGO type 4 (50.0%) and anterior location (41.7%) were most common.

We investigated pregnancy outcomes in 37 patients under 40 years of age during follow-up period. Of those, 24 patients were not planning for pregnancy, and 8 patients did not answer. Total of 5 patients tried to become pregnant, and pregnancy outcomes after RPRS are shown in Table 4. Three patients had delivered with Caesarean section without complications, and one patient was in first trimester pregnancy at the time of follow-up.

4. Discussion

We have previously demonstrated the safety and feasibility of RPRS by comparing RPRS with multiport robot-assisted laparoscopy [10,11] and conventional 2-port la-

Table 2. Perioperative and postoperative outcomes in patient with RPRS (n = 115).

Outcomes	Values
Docking time, minute, median (range)	7 (5–35)
Enucleation time, minute, median (range)	10 (4–82)
Suture time, minute, median (range)	14 (5–63)
Estimated blood loss, mL, median (range)	100 (10–700)
Hemoglobin change, mg/dL, median (range)	2.5 (0.1–6.5)
Length of hospital days, n (%)	
4	24 (20.9)
5	74 (64.3)
6	12 (10.4)
≥7	5 (4.3)
Surgical method conversion, n (%)	
Conventional multiport	10 (8.7)
Open surgery	1 (0.8)
Postoperative complications within 30 days, n (%)	
Surgical wound infection	2 (1.7)
Postoperative bleeding	1 (0.9)
Peritonitis	2 (1.7)
Pneumonia	1 (0.9)
Recurrence, n (%)	
Yes	12 (10.4)
No	103 (89.6)

Data are expressed as median (range), frequencies (percentages), as appropriate.
RPRS, Reduced-Port Robotic Surgery.

Table 3. Characteristics of recurrence after RPRS (n = 12).

Characteristics	Values
Number of recurrent myoma, n (%)	
Single	5 (41.8)
Multiple	7 (58.2)
Size of recurrent myoma, cm, median (range)	1.6 (1.0 2.8)
Location of the largest myoma, n (%)	
Anterior	5 (41.7)
Posterior	4 (33.3)
Lateral	3 (25.0)
FIGO type, n (%)	
2	1 (8.3)
4	6 (50.0)
5	5 (41.7)

Data are expressed as median (range), frequencies (percentages), as appropriate.
FIGO, International Federation of Gynecology and Obstetrics; RPRS, Reduced-Port Robotic Surgery.

paroscopic myomectomy [12]. In this study, we showed additional long-term outcomes of RPRS with 115 patients. The RPRS had success rate of 91.5% (104 cases); Additional trocar insertion was performed in 10 cases (8.7%), and conversion to open surgery was conducted in one case (0.8%). Recurrence of myoma was detected in 12 patients (10.4%) in median follow-up of 25 months (range, 6–62 months). Total of 5 patients tried to become pregnant after RPRS, and three patients had delivered with Cesearean section without complications. Trend of shorter operation time was shown with experience. These results demonstrated that RPRS can be valid surgical modality for myomectomy.

There are number of research results showing that MIS and single-site robotic surgery are useful in various surgeries related to gynecological cancer [13,14]. However, in uterine myomectomy, the application of MIS is particularly difficult because firm grasp and strong pulling are required during surgery. The multiport robot-assisted myomectomy may be related to worse cosmetic outcomes with trocar-related complications and complaints. To improve these disadvantages, single-port robotic system was developed for less blood loss and better cosmetic results [15]. Robotic single-site platforms have limitations such as restrictive range of motions with non-articulating instruments and limited electrosurgical instrument options. Especially for myomectomy, it is challenging to enucleate myomas and suturing uterus with semi-curved, non-articulating instruments. The instruments designed for robotic single-site platforms are relatively more flexible than conventional robotic instruments. Therefore, it is more difficult to use for surgeries where a firm grasp is required, such as pulling and providing traction during myoma enucleation.

RPRS for myomectomy can be alternate method to overcome these disadvantages of multiport and single-site platforms of robotic surgery. In RPRS, single-port using vertical umbilical incision (approximately 3 cm) reduces collision between the camera and left robotic instrument when moving simultaneously. In RPRS using a laparoscopic single-port platform with multiport robotic instruments, surgeons can use the articulation and dexterity of the robotic wrist of the left and right instruments, thereby facilitating suture of uterine defects with only two surgical port sites.

The present study demonstrated surgical and long-term outcomes of RPRS. Previously, we presented comparison results of RPRS and other surgical methods [11,12]. The present study is intended to show additional patients' data with long term outcomes including recurrence and pregnancy outcomes of RPRS which is advantage of this study. The limitations of this study are as follows. It is difficult to generalize because it is a study result from a single institution with not large size number of patients' data. Our results are not randomized for analysis and have no comparison group. It can be criticized that criteria for myoma recurrence are non-generalized and applicable only in our study. Also, regarding pregnancy-related outcomes, the number of patients who attempted pregnancy was too small to show sufficient results. In our institution, some of our treatment protocols may be different from other general guidelines, because minimally invasive surgery, which can reduce the recovery period of the patient, was consid-

Table 4. Pregnancy outcomes after RPRS (n = 5).

Case number	Age at RPRS	RPRS to pregnant time, months	Gestational age at delivery, weeks	Complication during pregnancy	Abnormal finding at Ceserean section
1	34	22	NA	-	-
2	35	7	38+6	non specific	non specific
3	37	5	38+3	non specific	non specific
4	36	7	In first trimester pregnancy at the time of follow-up	-	-
5	34	9	37+3	non specific	adhesion

RPRS, Reduced-Port Robotic Surgery. NA, not available (the exact gestational age was not available if delivered at other hospital).

ered as the main priority when deciding on the surgical method in our institution's treatment protocols. As each factor, the number and size of myomas were not simply limited for robotic surgery, but the size, location, and number of myomas were comprehensively evaluated in the preoperative imaging test to determine the surgical methods. In the case of large sized G0 and G1 myomas, it may be difficult to remove surgically with resectoscopy, so it was performed with a robotic surgery according to the doctor's decision. Unfortunately, in this study, data that measured patient's cosmetic satisfaction was not shown. However, we have experienced an increasing number of patients preferring RPRS in clinical field, and we are expecting further increasing numbers of RPRS for myomectomy in institutions in Korea.

5. Conclusions

Despite some limitations, this study demonstrated safety and feasibility of RPRS for myomectomy with surgical outcomes and long-term outcomes. We believe that the RPRS is surgical method for myomectomy which overcame some of the disadvantages of robotic single-site surgery with better cosmetic result than multiport surgery.

Data Availability Statements

The datasets for this manuscript are not publicly available because the Institutional Review Board (IRB) of Kangbuk Samsung Hospital restricted providing raw data of this study to public for privacy issues. Requests to access the datasets should be directed to Review Committee of Research Data under IRB in Kangbuk Samsung Hospital.

Author Contributions

JWS, WYK and ESP contributed conception and design of the study; JWS and GPL organized the database; ESP performed the statistical analysis; ESP, JWS wrote the first draft of the manuscript; WYK, GPL, JWS and ESP wrote sections of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

Ethics Approval and Consent to Participate

The studies involving human participants were reviewed and approved by the institutional review boards (IRB) Kangbuk Samsung Hospital (IRB: 2016-04-083) in accordance with the Declaration of Helsinki and the International Conference on Harmonization Good Clinical Practice guidelines. The patients/participants provided their written informed consent to participate in this study.

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Conflict of Interest

The authors declare no conflict of interest.

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