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Current status on robotic assisted myomectomy

Imrich Kiss, Pavla Svobodova, Lubos Karasek, Bohuslav Svoboda

Department of Gynecology, 3rd Faculty of Medicine Charles University and Military University Hospital, Prague 16902, Czech Republic.

Correspondence to: Dr. Imrich Kiss, Department of Gynecology 3rd Faculty of Medicine, Charles University, Military University Hospital, U Vojenske nemocnice 1200, 169 02 Praha 6, Prague 16902, Czech Republic. E-mail: kiss.imrich@gmail.com

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Abstract
Uterine leiomyomas are common benign solid tumors of the uterus. While the presence of fibroids is rarely life threatening, they are associated with symptoms affecting quality of life and fertility. Myomectomy is a standard fertility-sparing surgery which should be considered for women suffering from fibroid-related symptoms who do not desire hysterectomy or any alternative treatment option. While open surgery is thought to be reserved for large and numerous myomas, mini-invasive methods as laparoscopy and robot-assisted surgery have evolved in the hands of experienced surgeons to also deal with these more complex cases. Robotic myomectomy has its advantages in lower blood loss, fewer complications, and shorter hospital stay over open surgery, whereas the comparison outcomes with laparoscopic myomectomy are still uncertain. Advantages of the wristed instruments, three-dimensional vision along with the incorporation of correct surgical techniques could emphasize the benefits of the robotic assisted approach in large and numerous myoma cases. Careful and detailed assessment should precede the surgery to recognize risks and steps to reduce operation time, which tends to be the most presented drawback of robotic myomectomy. As the tendency of robot-assisted surgeries is growing, many authors share their experience or publish comparison studies with other surgical methods. Our article describes the current status concerning robotic myomectomy, reviewing publications from the past five years (2016-2021).

Keywords: Robotic surgery, robotic myomectomy, robot-assisted myomectomy, surgical techniques

INTRODUCTION

Uterine leiomyomas (uterine fibroids) are a common benign smooth muscle tumors of the uterus that affects up to 70% of women until reaching menopause[1]. Risk factors include ethnicity, parity, early menarche, late menopause, family history, obesity, and hypertension[2]. While the presence of myomas are rarely life threatening, they are associated with symptoms affecting quality of life such as abnormal bleeding, pelvic pain, and urinary tract problems[3]. In addition, myomas might also be linked with adverse pregnancy outcomes such as infertility, preterm birth, or postpartum hemorrhage[4]. Diagnosis is made based on pelvic bimanual examination, ultrasonography, magnetic resonance imaging, or hysteroscopy. According to the localization of the lesion (submucosal, intramural, or subserous), myomas are further defined by the International Federation of Gynecology and Obstetrics (FIGO) subclassification system to better describe their relation to the uterus and help select the appropriate therapeutical approach alongside other factors such as size, number of lesions, reproductive plans, surgeons' skill, *etc.*[5]. Almost one third of women with myomas seek medical help and request treatment. The current medical strategies offer surgical interventions (myomectomy, hysterectomy, and occlusion of uterine arteries) or their alternatives (uterine artery embolization, high-frequency magnetic resonance-guided focused ultrasound, and ultrasound-guided radiofrequency ablation). Selective progesterone receptor modulators such as ulipristal acetate can be used as a preoperative option or as a pharmacological therapy to reduce symptomatology as an alternative to surgical treatment[6,7].

Myomectomy is a standard fertility sparing surgical method and should be considered for women with fibroid related symptoms who do not desire hysterectomy. While open surgery (laparotomy) is thought to be reserved for large and numerous myomas, mini-invasive methods as laparoscopy and robot-assisted surgery have evolved in the hands of experienced surgeons to also deal with these more complex cases. As the tendency of robot-assisted surgeries is growing, many authors share their experience or comparisons with other surgical methods. In our center, we specialize on all surgical modalities, although in the majority of cases preferring mini-invasive methods. While hysterectomy is still our leading procedure on a robotic system, in the past years, the number of robotic myomectomies is rapidly growing, mostly for complex cases. Our goal when writing this article was to research the current literature to support our shift from laparoscopic to robotic myomectomies. Articles indexed with "robotic myomectomy, robot-assisted myomectomy" and published from 2016 to October 2021 were retrieved from PubMed and reviewed for relevancy. Our article presents the reader up-to-date consolidated information concerning the quickly evolving technique of robotic myomectomy.

COMPARISON STUDIES

Robotic myomectomy is favorable in less complications, blood loss and hospital stay compared to open surgery, while it is becoming a preferred modality in more complex cases to conventional laparoscopy.

The meta-analysis conducted by Wang *et al.*[8] including 20 studies (2852 patients) compared robotic, laparoscopic, and open myomectomy. The results show that robotic myomectomy is associated with fewer complications and lower blood loss than the other modalities. It also showed lower conversion rate and less bleeding than laparoscopic myomectomy and lower postoperative pain score than open surgery. In a retrospective study by Ranes *et al.*[9], longer operation time is stated as the biggest drawback in comparison with open surgery, which could outweigh shorter hospital stay. A mean operative time difference of 84 min (95%CI: 60.41-109.29) in favor of open myomectomy against robotic assisted was observed in a meta-analysis by Iavazzo *et al.*[10]. On the other hand, robotic assisted myomectomy showed superiority in lower blood loss [92.78 mL/operation (95%CI: 47.26-138.29)], need for transfusion (981 patients; OR = 0.20; 95%CI: 0.09-0.43), total complications (1101 patients; OR = 0.31; 95%CI: 0.11-0.87), and length of hospital stay [1.84 days/patient (95%CI: 1.40-2.29)]. No significant difference was found in operating time, estimated blood loss, need for transfusion, number of complications, and length of hospital stay between robotic assisted and conventional laparoscopic myomectomy.

In a review study considering open or mini-invasive way of entrance in myoma enucleation, comparable outcomes in estimated blood loss, complications, and duration of hospital stay were reached between laparoscopy and robotic surgery[11]. The operative time of robotic myomectomy was stated as longer, as in previous studies. Demanding surgical skills for larger myomas and unfavorable localization and higher economic burden were stated as additional limiting factors for robotic myomectomy. The authors cited an older systematic review[12], in which short-term benefits such as blood loss, need of blood transfusion, and hospitalization were significantly lower in robotic assisted myomectomy, while open surgery showed to be preferable in operating time and costs. Gingold *et al.*[13] reviewed the myoma management in conventional *vs.* robotic assisted myomectomy. The outcomes of the reviewed studies show that robotic surgery was preferred in more complex cases, in which easier maneuverability of the wristed robotic instruments and three-dimensional visualization helped in better dissection, suturing, and application of hemostatic techniques. Nevertheless, these findings tend to be biased by surgeons' experience and inclination to select more difficult cases for robotic surgery and should not be considered as outcome-based evidence to prioritize robotic myomectomy.

When patients were questioned about their symptoms and health quality the morning before and one year after laparoscopic and robotic myomectomy, both groups showed a significant reduction in symptoms and improvement in quality of life without statistical difference between the two methods of surgery[14].

In the last few years, the dominant comparison studies are between multiport *vs.* single-site/single-port robotic myomectomies. The consensus is that multiport myomectomy is preferred for larger myomas, while single-site is feasible for selected patients with less complicated cases, and both methods are associated with low rates of intra- and post-operative complications[15,16]. In a very recent review, no significant differences were found in operating time, blood loss, and total complication rate[17].

OPERATING TIME

Generally, robot-assisted surgeries tend to be longer because of the necessary docking of the robotic arms before the actual surgery begins. For myomectomies, the use of the wristed instruments should speed up the suturing time, which, in comparison with laparoscopy, is a common obstacle even in experienced surgeons. This hypothesis was disproved, when robotic myomectomies showed similar operating time with laparoscopic ones regardless of the number of myomas removed[18]. It seems that the difficulty of docking and lack of tactile feedback during enucleation is compensated with easier and faster suturing in robotic myomectomy.

In a very recent study, factors related to the total operative time were body mass index (BMI), number of myomas, total myoma weight, location of dominant myoma, type of da Vinci robotic system (Xi *vs.* S), intraoperative uterine cavity exposure, blood loss, and total hospitalization period[19]. To the contrary, all of the above-mentioned factors, except for the location of dominant myoma and type of robotic system, are also associated with console time. Age, parity, previous surgeries, surgical indication, and size of the dominant myoma were not associated with total operating time. In the analysis of 242 cases, the number of myomas (5-9 *vs.* ≥10) and surgeon's experience were the only two factors that were positively correlated with operation time. Furthermore, the number of myomas and maximal myoma diameter were positively correlated with estimated blood loss[20].

Movilla *et al.*[21] proposed a preoperative calculator to predict the total operative time of myomectomies. Factors significantly associated with the length of surgery are age, diabetes mellitus, uterine volume, number of myomas generally and those more than 3 cm, diameter of the dominant myoma, and surgeons' experience. On the other hand, BMI, hypertension, previous surgeries, location, and classification of the myomas do not affect the operative time.

The significantly reduced time of single-site procedure can be acquired by combining the advantages of the laparoscopic enucleation and robotic assisted suturing called hybrid robotic single-site myomectomy[22,23].

The operating time also depends on the experience of the surgeon and the OR team. Robotic myomectomies have a steep learning curve, with the operating time significantly reducing after 10 cases[24].

LARGE/HEAVY/MULTIPLE MYOMAS

Several case studies show the enucleation of huge myomas (the biggest being 28 cm and 3.2 kg), while pushing the limits of robotic assisted techniques[25,26]. These cases confirm the efficiency, reliability, and safety of the robotic approach in well-selected cases regardless of the size of the fibroids. The major advantages of robotic surgery in comparison to abdominal is shorter hospital stay with faster recovery and less blood loss. Wristed instruments enabling a larger range of movements in a limited abdominal space blocked by the enlarged uterus and easier suturing of extensive uterine defects after enucleation are the assets of robotic surgery in contrast with laparoscopy resulting in lower conversion rate. A retrospective study of Lee *et al.*[27] compared robot-assisted myomectomies (RAM) with abdominal myomectomies (AM) in myomas larger than 10 cm and heavier than 250 g. While the operating time was significantly longer in RAM than AM (164 min *vs.* 108 min), hospital stays were shorter (2.68 RAM days *vs.* 4.13 AM days). Short-term postoperative complications such as fever or bleeding were lower in RAM than AM (26% *vs.* 54%). In a retrospective study, outcomes of robotic myomectomies of patients with large myomas (> 10 cm) were compared with myomas < 10 cm operated by a single surgeon[28]. While the largest myoma was 20 cm in diameter, operation time was the only significant difference between the two groups (263.4 ± 83.7 min *vs.* 219.1 ± 75.7 min, $P = 0.02$). Another comparison study between myoma size (≥ 9 cm *vs.* < 9 cm) showed significant increase in operation time (130 min *vs.* 92 min) and estimated blood loss (100 mL *vs.* 25 mL), while no major adverse outcomes were reported in either group[29]. Jansen *et al.*[30] retrospectively studied surgical approaches (abdominal, laparoscopic, or robotic) of myomectomies for extreme myoma burden (total specimen weight 436 g or ≤ 7 myomas). While the perioperative outcomes (estimated blood loss, blood transfusion, and complications) were similar in all modalities, mean operating time was the longest in robotic surgery (239 min) and mean hospital stay in abdominal surgery (2.2 days). Based on the analyses, the likelihood of complications increases in parallel with the myoma weight and number. The authors suggested preferring abdominal or laparoscopic approach in cases with extreme myoma weight and abdominal in cases of large number of myomas. On the other hand, Kim *et al.*[31] compared 30 robotic *vs.* 13 open surgeries for the removal of ≥ 10 myomas. Operating times were longer in the robotic approach (360 min *vs.* 180 min), while length of hospital stay was shorter (2.5 days *vs.* 3.5 days). Because there were no conversions to laparotomy or any major complication, the authors suggested robotic approach to be an alternative to open surgery in cases with more than 10 myomas. Lee *et al*.[32] recommended multiport robotic myomectomy with supraumbilical incisions in myomas larger than the umbilical level not only to ensure better cosmetic effect, but also to eliminate instrument and trocar collisions in single-port systems in a limited intrapelvic space.

FERTILITY AND OBSTETRICAL OUTCOMES AND RECURRENCE

Robotic surgery is a suitable myomectomy approach for infertile patients. In a retrospective study, more than half of the patients became pregnant with a 70% caesarean section rate without a report of uterine rupture[33]. Uterine rupture was also not reported in a comparison study, in which long-term pregnancy and miscarriage rates did not significantly differ after robotic assisted, laparoscopic, or abdominal myomectomy[34]. In a study where deep intramural myomas were enucleated, the pregnancy rate reached 75%[35]. The same pregnancy rate (70%) after robotic myomectomy was published in a Canadian cohort with 84% successful delivery or ongoing pregnancy at the time of data collection[36]. The risk of recurrence was 167% higher in laparoscopic myomectomy than in open surgery. The authors hypothesized that it is likely because of the extraction of small leiomyomas, which is less exhausting in manual removal than in the laparoscopic approach. The growth of residual myoma masses then results in newly diagnosed fibroids, which are considered recurrences[37]. Considering the better flexibility of robotic instruments, enucleation of small myomas should be more accessible, leading to lower recurrence. Another reason for higher recurrence was found to be associated with the preoperative use of GnRH agonists therapy to decrease the size of myomas[38].

SURGICAL TECHNIQUES

Safely extracting large and numerous myomas is often a challenge in minimal invasive surgery even for experienced surgeons. Moawad *et al.*[39] presented a reproducible technique enabling fast and safe tissue containment and extraction. It consists of stringing numerous fibroids together with a barbed suture, containment using a Endocatch bag, extraction through the extended umbilical incision using the Alexis Containment and Extraction System, and finally the so-called paper roll technique for specimen extraction. Suprapubic incision is a similar technique, which serves for initial abdomen insufflation, later assistant's easy access for retraction or needle entry, and finally large tissue extraction[40]. Contained manual morcellation is in comparison with electric power morcellation associated with shorter operation time but similar postoperative opioid pain relief treatment and length of hospital stay[41]. Additionally, with the cessation of power morcellation, wound complications with the necessary mini-laparotomy for tissue extraction has not increased[42].

Authors from South Korea proposed a new surgical technique called "locking suture on myoma (LSOM)" which replaces the tenaculum forceps, thus reducing the use of one instrument and lowering the total cost of surgery[43]. In this technique, a locking V-Loc suture is applied on the myoma after its exposure and traction can be easily performed by grasping the thread. Further locking sutures are applied as the dissection advances between the myoma and myometrium. The retrieved myomas are easily collected and extracted by grasping the threads. LSOM was also shown to be more feasible for larger, heavier, and a greater number of myomas than using the robotic tenaculum forceps, emphasizing its use especially in single-site surgery.

A very interesting technique of submucosal FIGO 2 classified myoma without endometrial injury was presented in a case study[44]. The authors recommended several steps to prevent penetration of to the uterine cavity. Proper preoperative and intraoperative imaging is crucial for planning the surgery and determining the correct site of myometrial incision. This is followed by cold cut careful preparation of the plane between the myoma and endometrium. Infusion of indigo carmine to dilatate the uterine cavity aids in delineating the endometrial cavity during dissection.

Blood loss can be lowered without compromising surgical morbidity by the vascular control technique[45]. This method uses vascular (bulldog) clamps to temporarily occlude the uterine arteries during the myomectomy. The maximal limit of occlusion time was set at 60 min with 5 min reperfusion intervals every 20 min.

One of the technical disadvantages of the robotic system is the lack of haptic feedback of the instruments. In myomectomy especially, the absence of tactile feedback can lead to longer operation time due to the necessary identification of intramural myomas with ultrasound and less accurate and destructive myometrial incisions above the myoma[13]. Giannini *et al.*[46] presented a device (wearable fabric yielding display) that can reproduce the stiffness of myomas *ex vivo*. When integrated into commercially available robotic systems, this device could lead to a better intraoperative identification of myomas with more precise surgery.

LEARNING CURVE AND ECONOMICS

Acquisition of a new robotic system and its maintenance cost are considered as the biggest drawback of faster expansion of robotic surgery worldwide. Despite the obligatory cost of purchasing the robotic system with its disposable instruments, implementation of correct strategies can reduce the costs of robotic surgery while maximizing its benefits. The most influential modifying factors which lead to the cost-effectiveness of robotic assisted surgeries are intraoperative and postoperative complications, length of surgery, and length of hospital stay, which are all related to surgeons' experience[47].

Even though there are no recent data on cost comparison of robotic *vs.* standard laparoscopic myomectomy, information could be related from benign hysterectomy surgeries. Interestingly, after adjusting patient-level covariates such as uterine weight, age, BMI, and previous abdominal or pelvic surgery, the cost of robotic surgery *vs.* laparoscopy was not significantly different in two separate hospitals. It is important to point out that the surgeries were performed by experienced surgeons past their learning curve[48]. Similar results were presented in a randomized trial[49], where comparable cost could be attained between the two modalities if a robot is already a pre-existing investment.

Data from single-center experience with robotic single-site myomectomy show a very rapid learning curve[50]. After 10 cases, port placement time and docking time significantly reduced, in addition to a higher number of retrieved myomas and lower hemoglobin decrease after surgery. When comparing with conventional laparoscopy, docking time needs to be assessed separately as it is an element that does not exist in laparoscopy. When looking at cases of robotic hysterectomies, console time has the most rapid learning curve followed by docking time. Even in the case of a well-experienced laparoscopic surgeon transferring to robotic surgery, suturing requires the greatest number of attempts to achieve stability[51].

Given that suturing is a major part of myomectomy, the surgeon's experience is a crucial variable in operation time resulting in cost effectiveness, as stated in previous studies.

Many resident and young surgeons struggle to keep up with the rapid advances in surgical techniques, mainly due to a lack of time spent in the operating room. Surgical simulators have an important role in helping to master these techniques outside the operation theatre. While computer simulators are often expensive and not realistic enough, live simulations are often very basic and life-like models cannot reproduce complex cases. Towner *et al.*[52] constructed a model of myomatosus uterus with artificial blood perfusion and secured it in a training box. In the post-simulation survey, residents stated higher confidence and comfort performing minimal invasive myomectomy which could have a positive impact on the learning curve in real-life surgeries.

CONCLUSION

The use of robotic systems enabled the implication of the advantages of mini-invasive surgery even in more complex cases. As the conclusions of studies are still not consistent, robotic myomectomy tends to show superiority in many factors over laparoscopy and open surgery. Operating time and higher cost seem to be the major drawback, but with the application of the presented surgical techniques and steep learning curve these could be rapidly minimized. Robotic single-site surgery seems to be a further step to reduce morbidity and pain and enhance cosmetic outcomes of minimal invasive techniques. This latest surgical access seems to be a feasible and safe procedure for myomectomy, which could replace conventional laparoscopy and robotic multiport surgeries even in complicated cases.

DECLARATIONS

Authors' contributions

Made substantial contributions to concept and design of the article: Kiss I, Svobodova P, Karasek L, Svoboda B

Drafted the article: Kiss I, Svobodova P

Critical revision of the article: Svobodova P, Karasek L, Svoboda B

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Ethical approval and consent to participate

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Consent for publication

Not applicable.

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