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Robotic Assisted Surgery for Endometriosis—"Is the Way Forward?"

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Abstract

Endometriosis is a chronic and progressive gynecologic disorder that affects 10% - 50% of women of reproductive age worldwide. Chronic pain and infertility are the most debilitating problems associated with it requiring both medical and surgical treatment. Laparoscopy is considered the gold standard for diagnosis and treatment. However, a 10% rate of conversion to laparotomy has been reported when performed by skilled laparoscopic surgeons and much higher in low volume less skilled surgeons. To improve surgical outcomes, robotic assistance is the logical next step in performing minimally invasive gynecological surgeries, especially in complex endometriosis cases. Enhanced 3D visualization and 10× magnification along with Endowrist instruments with seven degrees of freedom facilitates precise and careful dissection. Firefly technology using ICG green dye can improve detection of small and invisible lesions. Robotics is useful in deep infiltrating disease manifesting as lesions deeper than the superficial tissues of rectovaginal septum, vaginal fornix, pelvic sidewalls, parametrium, bowel or ureter and bladder. Trials show no increase in surgical time, blood loss, or intra- or postoperative complications and similar clinical outcome when robotics is compared with laparoscopy. At present, it is more appropriate to compare it with laparotomy rather than laparoscopy. Robotics can be used to manage recurrence of endometriosis after hysterectomy. Surgeons experienced in conventional laparoscopy can utilize robotic platform for deep infiltrating endometriosis for performing complex surgical dissection and achieving the surgical goals in mind and reduce conversions to open surgery. Robotic assistance can bridge the gap in performance of laparoscopic surgery in advanced endometriosis.

Keywords

Endometriosis, Advanced, Robotic Surgery, Laparoscopy, Deep Infiltrating Endometriosis, Hysterectomy, Recurrence

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1. Introduction

Endometriosis is a disease where the endometrial tissue is present outside the endometrial cavity, which grows over time under hormonal influence. It is a chronic and progressive gynecologic disorder that affects that affects 10% to 50% of women of reproductive age worldwide [1]. It is also estimated that more than 70 million women and adolescents worldwide suffer from this condition and probably affects them through their life [2]. The estimated prevalence of endometriosis is 5% - 15% among women of child-bearing age, 20% to 48% among women suffering from infertility however 70% of women with chronic pelvic pain not responding to hormonal therapy or to medical management [3].

Chronic pain and infertility are the most debilitating problems that often vex the women and their treating physicians alike. At present there are no clinical biomarkers that can help diagnose this condition at early stage. Endometriosis is a slow and progressive disease, takes years to develop lesions that can be picked up by traditional methods of diagnosis like USG or MRI. By the time these women require surgical therapy for overt clinical symptoms like dysmenorrhoea, chronic non cyclical pelvic pain, subfertility, heavy menstrual bleeding or abdominal gaseous bloating, they would be having advanced stage disease.

Laparoscopy is considered the gold standard for diagnosis and treatment of this condition. At present minimal access surgery to a large degree, has replaced laparotomy for the treatment of endometriosis for the obvious advantages [4]. However, still all women with endometriosis do not receive option of adequate minimal access surgery to improve their pain or fertility. Long learning curve with traditional laparoscopy and limited surgical skills leads to inadequate surgery or they are converted to open surgery. A 10% rate of conversion to laparotomy has been reported in patients with severe endometriosis managed with conventional laparoscopy when performed by high-volume, experienced laparoscopic surgeons [5]. This rate is much higher in low volume less skilled surgeons.

Since complete surgery for endometriosis is essential for good reproductive outcome, the inadequacy in endometriosis management with the conventional laparoscopy is where Robotic assisted surgery can be a game changer in women's health care. Robot-assisted laparoscopic surgery has seen rapid progression over the past one decade and has especially proven benefit complex procedures, such as the management of advanced endometriosis (**Figure 1**). Robotic surgery minimizes the restrictions that laparoscopy poses in treating cases of advanced endometriosis and may hold the key in the future ensuring success of improved fertility and pain outcomes. Other procedures that requiring extensive suturing such as myomectomy and sacrocolpopexy, which are at present still managed by laparotomy are also being increasingly being performed by robotic assistance.

The purpose of this article is to highlight the acceptance of robotic surgeries in endometriosis surgery especially the advance stage disease and review the current literature. A literature search was performed in Pubmeb with keys words—endometriosis, advanced, robotic surgery, laparoscopy, deep infiltrating endometriosis, hysterectomy and recurrence.

2. Why Robotics?

The surgical management of advanced stage endometriosis can often be challenging by conventional laparoscopy. Presence of altered tissue planes and dense adhesions due to infiltrative nature of this disease makes it difficult to do complete clearance by straight stick laparoscopic instruments. The da Vinci Robotic Surgical System (Intuitive Surgical) is an advanced laparoscopic-assisted surgical system that can address many of the current limitations of conventional laparoscopy. It is a logical next step in performing minimally invasive gynecological surgeries, especially in complex cases. This system provides enhanced 3D visualization with 10x magnification along with Endowrist instruments with seven degrees of freedom facilitates precise and careful dissection. It has basically 3 components. The first component is the vision cart, which provides 2-dimensional imaging through a 12-mm, dual optical endoscope. The endoscope has 2 telescopes with a 3D vision to the surgeon on the console. The second component of the da Vinci system is the patient-side cart with robotic arms and endowrist instruments. Whether to use two or three instruments will depend on the surgeon's decision depending on the case profile. The third component is the surgeon console that is located away from the patient bedside but in the same operating room. The surgeon seated at this console, with the help of masters can control instruments that are inserted via the 8 mm ports. This is aided by the surgeon's 3D view with the aide of a stereoscopic viewer. The surgeon console has additional foot pedals for energy sources, camera adjustment, and a swapping mechanism that helps the surgeon to control 3 instruments. Thus giving surgeon a near control of the surgical field without

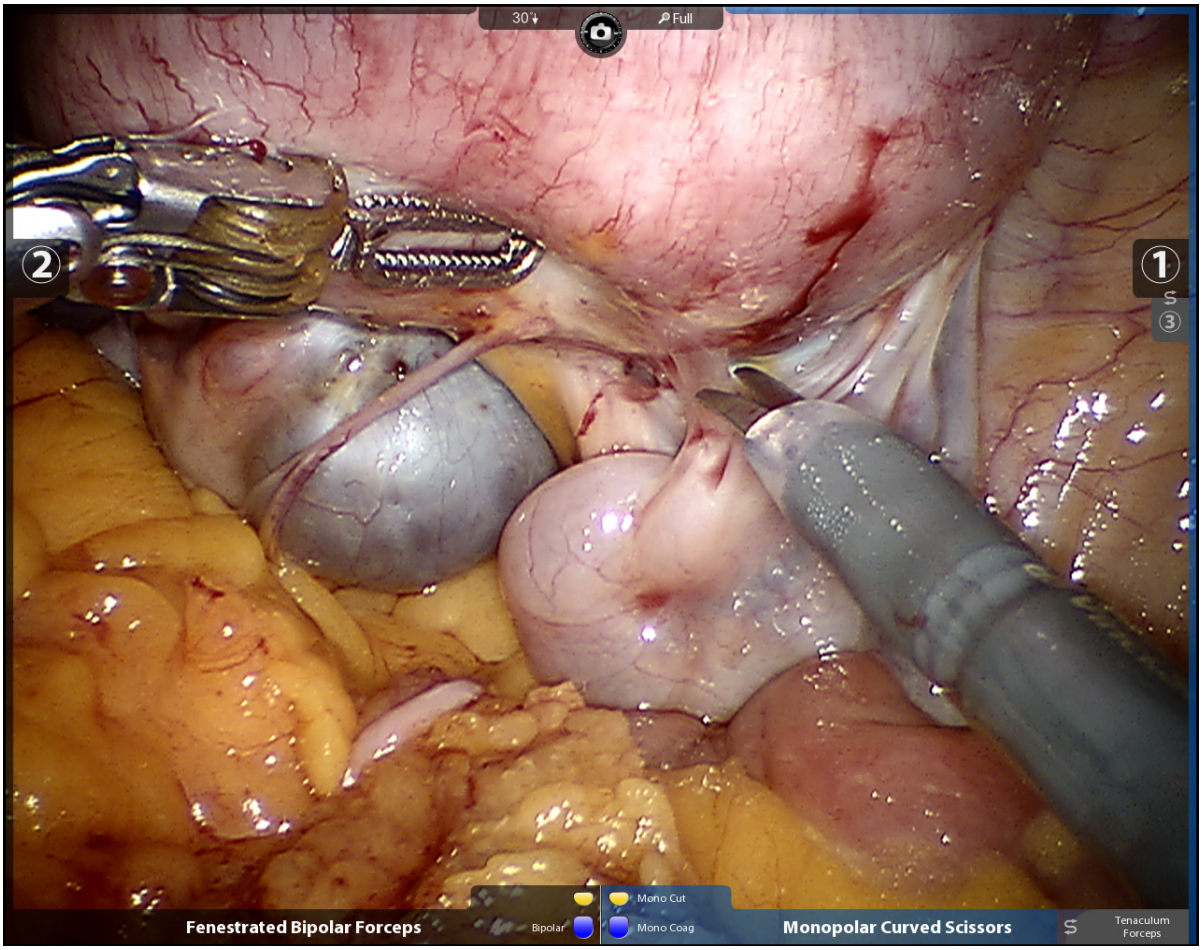

Figure 1. Endometriosis view through a robotic console.

dependency on the assistant as it happens in conventional laparoscopy. The better one sees the better diagnosis and surgery one can do in cases of endometriosis [6] (**Figure 2**). The robotic platform also enables the surgeon to do complicated dissection such clearance of the obliterated pouch of Doughlas, lateral pelvic wall dissection and resection of densely adherent endometriomas. Addition of firefly technology in the robotic platform can potentially help in increasing the removal of invisible endometriosis. As we know that full pain relief is not possible without complete resection of endometriosis. Some authors have used firefly technology with robotic single-incision laparoscopy. Indocyanine green (ICG) is a water-soluble dye that binds to plasma proteins. This is used with the infrared fluorescence imaging system integrated with the robotic platform. When injected the dye measures tissue perfusion and helps in selective vessel identification. Guan and colleagues found Firefly technology and (ICG) facilitated identification of endometriosis and were able to successfully perform single-site laparoscopic resection of advanced endometriosis nodules overlying the ureter and rectum with complete resolution of pelvic pain symptoms and excellent cosmetic results [7]. This method is being used by many centers to treat endometriosis as endometriosis is associated with increased neovascularization as ICG turns these endometriotic lesions dark green, enabling their detection easy [8]. These lesions are often subtle and are not visualizable with the naked eye, but when illuminated using Firefly technology, complete resection of the targeted affected tissue is possible.

3. Advanced Stage Endometriosis

3.1. Ovarian Cystectomy & Hysterectomy

Surgical management of advance stages (3 & 4) of endometriosis is a challenge. Complete removal of all

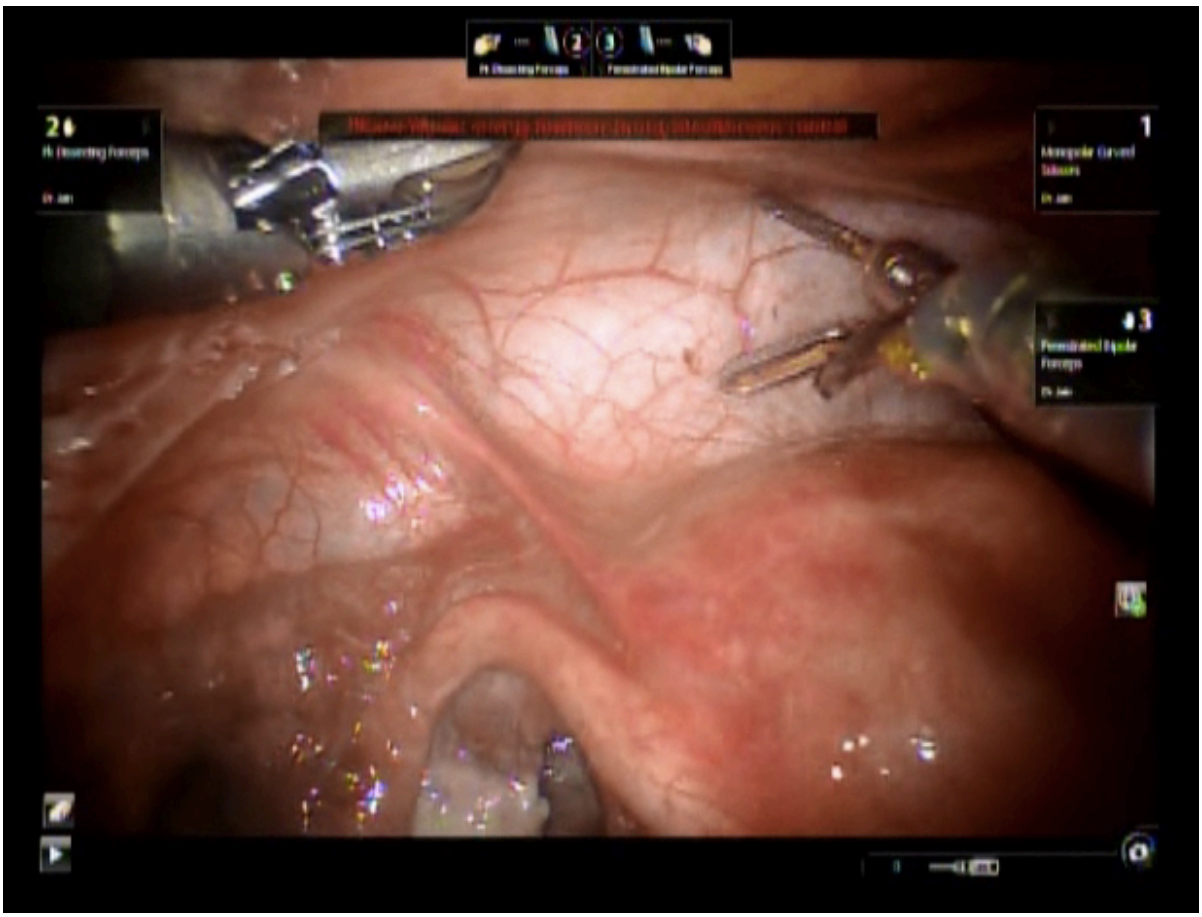

Figure 2. Early endometriosis lesion.

endometriosis implants has direct correlation to improvement of symptoms and fertility as well as risk of recurrence. Inadequate surgical clearance is the major hurdle today, in improving the outcomes in women with endometriosis. We believe this may be possible in future with the help of Robotic surgery. The computer aided robotic surgery with all its advantages enables the surgeon to perform complex resections of infiltrating endometriosis including endometriosis affecting recto-vaginal septum, bladder and bowel. Isolated reports have documented the use of robotics in patients with severe endometriosis involving the urinary and gastrointestinal systems either alone or in combination [9] [10]. Associated posterior vaginal resections are also necessary to perform in advanced disease.

In studies that compare the robotic versus laparoscopic approach, no special differences have been seen, except that as expected surgery time is longer in the former procedure. However, it is important to notice that no conversions are necessary, and the robotic approach may be more effective in cases of complex resections that have a significant organ compromise [11] [12]. Carman Nezhat and colleagues compared standard laparoscopy with Robotic assisted surgery for treatment of endometriosis and published in 2010. Their study suggests that Robotic assistance for the treatment of endometriosis is feasible without adding additional morbidity. However, their group did not show better outcomes robotic assisted surgery as compared to laparoscopic surgery possibly because majority of their patients had stage I or II disease. Thus the value of robotic assistance lies in the management of advanced cases of endometriosis and converting laparotomies to laparoscopies [13]. During fertility enhancing endometriosis surgery delicate pelvic structures such as nerves and reproductive organs need to be preserved for good functional outcome and the Da Vinci Robotic System with its several advantages represents a technical development of laparoscopic approach enabling one to reach these goals [14]. Adequate application of microsurgical principles reduces postoperative adhesions and conserve ovarian follicular reserve in the case of ovarian cyst excision. This is demonstrated during performance of cystectomy for endometrioma (**Figure 3**).

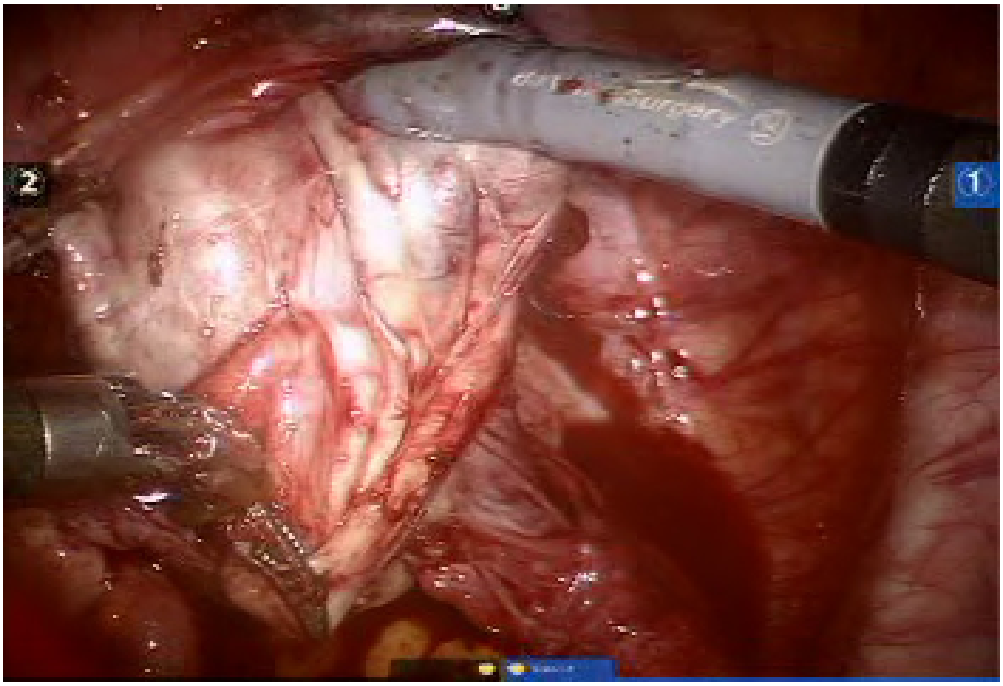

Figure 3. Ovarian cystectomy being performed by endowrist robotic instruments.

Retrospective analysis of robot-assisted versus standard laparoscopy in the treatment of pelvic pain indicative of endometriosis was reported by Dulemba in 2013 [15]. They compared feasibility of treating pelvic pain in patients with suspected endometriosis using robot-assisted laparoscopic techniques (n = 180) with conventional laparoscopy using CO_2 laser (n = 100). Differences were apparent in biopsies confirming endometriosis (80% robot-assisted vs. 56.8% traditional laparoscopy, $p < 0.001$). This result supports the fact that better visualization improves better diagnosis however at present perioperative outcomes were comparable in both groups. Further studies are needed to ascertain whether robotics provides better visual acuity and excision of endometriosis, as suggested by this study. Long-term prospective trials to evaluate resolution of symptoms and fertility outcomes comparing the two surgical approaches can establish the superiority of robotic assistance in endometriosis surgery. Prescaral neurectomy is an additional procedure for relief from chronic pain in advanced endometriosis. Nezhat and colleagues reported the feasibility of robot-assisted presacral neurectomy (RPSN) and compared the outcomes with laparoscopic presacral neurectomy (LPSN). Both groups had successful completion of the procedure by excising the hypogastric nervous plexus within the interiliac triangle. The experience of this group shows that the surgical robot provides a better angle and 3-dimensional visualization of the operating field, similar to laparotomy. Magnification and elimination of hand tremor by the robotic platform enables better surgical control during this procedure [16].

Advantages are 3D magnification of the operating field, smaller instruments, and tremor filtration are of benefit when hysterectomy is considered in cases of stage III and IV endometriosis. Bedaiwy *et al.* published the largest cohort of patients with advanced endometriosis managed with definitive surgery by robotic laparoscopy. A retrospective study of 43 patients with stage III and IV endometriosis, intraoperative complication rates were low and only 1 patient required conversion to laparotomy. One minor (self-limited ileus) and one major postoperative complication (vaginal cuff abscess) was reported which is a known complication irrespective of surgical route. There were no conversions to laparotomy because of an intraoperative complication. This data suggest both the feasibility and safety of hysterectomy in severe endometriosis. The advantages provided by the robotic platform become more indispensible when the surgical planes are dense and require complex pelvic dissection [17]. Introduction of robotic platform has seen increased rates of robotic hysterectomy with decrease in rates of abdominal hysterectomy. It is not surprising that in the last few years the adoption of robotic technique to perform gynecological surgeries especially hysterectomy is at a much faster rate that that was seen with acceptance of laparoscopic techniques [18].

3.2. Role in Deep Infiltrating Endomeriosis

When endometriosis manifests deeper than the superficial tissues of rectovaginal septum, vaginal fornix, pelvic sidewalls, parametrium, bowel or urinary bladder it is termed as deep infiltrating endometriosis (DIE). Presence of adhesions, fibrosis and smooth muscle metaplasia in DIE creates substantial distortion of anatomy and surgery for this stage of disease can be technically difficult. For years cases advanced endometriosis especially deep infiltrating endometriosis were managed by laparotomy. Women suffering from DIE are often young sexually active and desiring fertility. Chronicity and progression are two most distressing aspects of this condition. Currently the method of choice for treating this disorder is radical excision, which requires extensive adhesiolysis along with bladder or rectosigmoid resection. Laparoscopy became popular for both diagnosis and management for its obvious advantages, however remained of limited value in DIE. After introduction of the robotic platform, experience and evidence is slowly accumulating regarding its application in surgery for advanced endometriosis including DIE.

A prospective cohort study of 25 consecutive patients with DIE was conducted by Pellegrino A. *et al*. Robotic procedures was performed including removal of endometriotic nodules from the recto vaginal septum with rectal shaving alone or in combination with accessory procedures in patients who had stage 4 disease (rASRM > 40). All patients underwent successful surgery. Pathology confirmed the adequacy of the surgical specimen and the median largest endometriotic nodule was of 21 mm (range, 10 - 60 mm), with free margins in all cases. This series has a median long-term follow up of 22 months with an optimal operative time, demonstrating good long-term outcomes. The experience of this group recommends robotics as a safe and attractive alternative for comprehensive surgical treatment of DIE [19].

Neme RM reported a series of 10 women with colorectal endometriosis who underwent surgery with the da Vinci robotic surgical system in 2013. 80% of these women required extensive ureterolysis and 70% cystectomy. In addition to segmental colorectal resection in all cases, partial vaginal resection was necessary in 20% women. Six patients had infertility before surgery, 4 women conceived naturally and 2 underwent in vitro fertilization. This study shows that robotic-assisted laparoscopic surgery for the treatment of deep infiltrating bowel endometriosis is possible, effective, and safe. It also has good fertility results in the subsequent period [20]. A year later, Hassens & colleagues evaluated the perioperative results in robotic-assisted laparoscopy in DIE in a trial where eight centers participated. The patients were divided in 4 groups according to the localization of the nodules; rectum (n = 88), bladder (n = 23), ureter and uterosacral ligaments (n = 115) and those who underwent hysterectomy (n = 28). They evaluated the procedures performed, the duration of intervention, complications, recurrence and impact on fertility. One case in the rectum group was converted to laparotomy and 2 cases of rectal injuries required suturing. In the bladder group, there was one case of vesico-vaginal hematoma and a prolongated intermittent self-catheterization. In the ureter and uterosacral ligaments group, there were 2 ureteral fistulas. This multi centric and one of the largest series published on robotic-assisted laparoscopy for deep infiltrating endometriosis concluded that robotic-assisted laparoscopy in deep infiltrating endometriosis seems to be promising while no increase in surgical time, blood loss, and intra- and postoperative complications [21]. These results also emphasize that surgical corrections in DIE and advanced endometriosis are potential situations where robotics can reduce open surgery as it allows it allows access to narrow anatomical space such as in deep pelvis enhancing surgical outcome with comfort and precision. However in another large multi centric series stage 4 endometriosis managed by robot-assisted laparoscopy for DIE published by Collinet *et al.* in 2014 show no increase in surgical time, blood loss, or intra- or postoperative complications with the use of Robot [22]. Surgeons experienced in conventional laparoscopy can utilize robotic platform for deep infiltrating endometriosis for performing complex surgical dissection and achieving the surgical goals in mind. Although a longer operating time is needed, robotic surgery for DIE is feasible and safe. The interest in robot-assisted laparoscopy for deep infiltrating endometriosis seems to be promising.

3.3. Extra Genital Endometriosis

Also known as “endometriosis extragenitalis” this term describes presence of disease in areas other than genital organs and can be seen in appendix, bowel, urinary bladder, ureter, vagina, lung, liver and sometimes in extremely rare locations. However, endometriotic lesions in bladder, ureter or rectovaginal septum are common and require surgical intervention.

Bladder endometriosis presents as tough, nodular adenomatous fibrohyperplasia causing painful and ineffec-

tive bladder contractions as well as cyclical hematuria due to disturbances in the urothelium. These lesions cannot be removed completely by transurethral resection (TUR) because endometriosis infiltrates transmurally from the outside. Surgical correction requires bladder to be dissected free from the uterus and partial vesical resection either with laparotomy or laparoscopy. The first robotic-assisted laparoscopic partial cystectomy for infiltrating bladder endometriosis was reported by Connie Liu from Mount Sinai School of Medicine, New York [23]. Robotic-assisted (da Vinci) partial cystectomy with concomitant excision of endometrial nodules from the rectum and ovarian cyst was performed and reported by Chammas *et al.* in 2008 in a case of refractory endometriosis [24].

Endometriosis of the ureter is usually of extrinsic type where endometriosis tissue encompasses it from outside, typically seen in cases of bilateral ovarian endometriosis. Although rare, when multiple layers of the ureter are infiltrated with endomertiotic tissue it is described as intrinsic type. Infiltration of the rectum or sigmoid along with uterosacral ligaments can lead to partial or complete obliteration of pouch of Douglas's. Involvement of parametria causes ureteric obstruction requiring bilateral ureterolysis and surgical exposure of the ureters [25]. In intrinsic ureteric endometriosis, partial resection of the ureter with end-to-end anastomosis or direct ureteric neoimplantation is recommended [26]. Guan *et al.* reported the use of Firefly technology and ICG dye, which facilitated identification of endometriosis during robotic surgery. They were able to successfully perform resection of advanced endometriosis nodules overlying the ureter and rectum [7]. Ureterolysis is the surgery of choice and not segmental resection. It is seen that even if there is partial ureteral obstruction, both procedures have similar results with different morbidity and potential late sequelae [27].

In cases with endometriosis of the bowel, although intestinal mucosa is not infiltrated, abnormal microcirculation between the endometriosis nodule and the intestinal mucosa causes cyclical intestinal bleeding. Nezhat *et al.* have published 5 cases of successful robotically assisted laparoscopic management of extragenital endometriosis, specifically endometriosis of the bowel, bladder, and ureter [28]. When there is involvement of bowel especially recto-sigmoid region, extensive radical operations are needed for complete relief of symptoms. These surgeries although were performed by laparotomy in the past, they are now performed using minimally invasive techniques with the use of either laparoscopy or Robotics [27]. Reports have been published of a small number of patients undergoing robotic rectosigmoid resection. Ercoli *et al.* [29] have published data of 12 patients, with a median larger endometriotic nodule of 35 mm, who underwent robotic-assisted laparoscopic segmental resection for colorectal involvement and documented no complications when is was compared with patients undergoing the same procedure by laparoscopy and were reported to have with a higher surgical complication rates [30] [31]. Local excision or shaving of rectosigmoid lesions is preferable if lesion is not infiltrating the lumen or there is no stricture. Segmental bowel resection have higher morbidity as reported in several studies [30]-[32].

3.4. Post Hyst Endometriosis

A high recurrence rate of about 60% is reported in advanced stages of endometriosis where ovaries were conserved during hysterectomy having a 6 fold risk of recurrent pain and 8 folds risk of repeat surgery. Incomplete excision of endometriosis during hysterectomy is the most prominent reason in the literature for the recurrence of endometriosis. This is directly correlated to the surgical precision and removal of peritoneal and deeply infiltrated disease during the primary surgery. Drainage of endometrioma is associated with the highest rate of ovarian cyst reformation within three to six months after surgery. Hormonal replacement therapy is also associated with recurrence of pelvic pain. Surgical effort should always aim to eradicate the endometriotic lesions completely to keep the risk of recurrence as low as possible [33]. Authors have experience in management of recurrence of endometrioma after hysterectomy with ovarian conservation by robotic assisted surgery. These women present with cyclical pain and bleeding from vault and complete excision of endometrioma causes relief in symptoms (**Figure 4**).

4. Conclusion

Robotic assisted surgery has become a popular surgical approach for benign and malignant gynecologic conditions due of its technological advantages over conventional laparoscopy [34]. Conventional laparoscopy and robotic-assisted laparoscopy are both excellent methods for treatment of advanced stages of endometriosis. In the hands of experienced laparoscopic there is not much difference in the clinical outcome. However this can help to convert open surgeries for endometriosis into minimally invasive one as the learning curve with robotics is less.

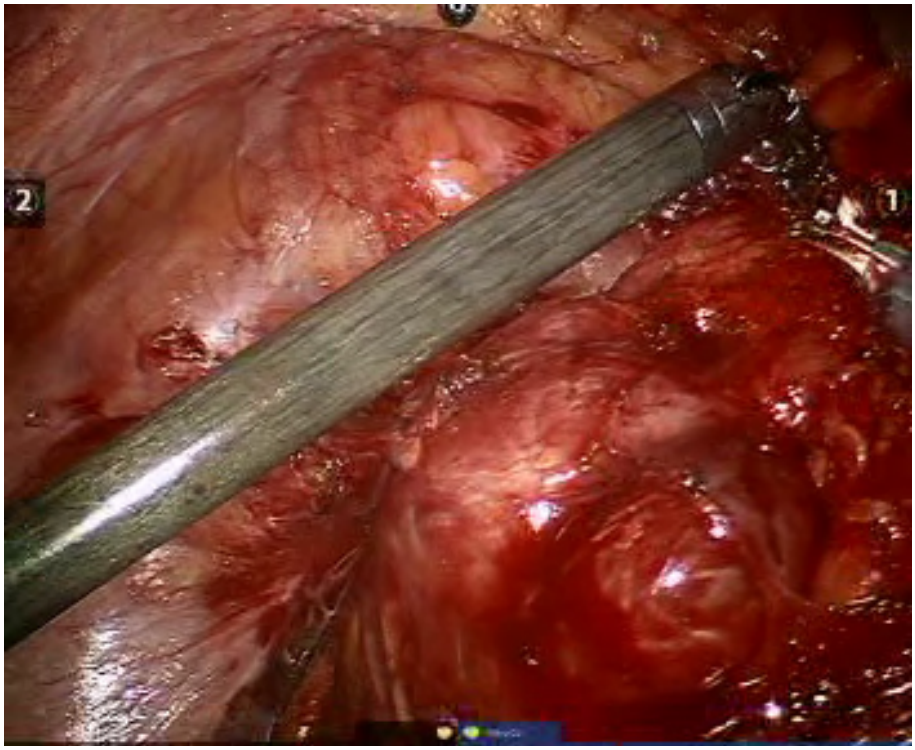

Figure 4. Post hysterectomy endometrioma in view after dissecting the of sigmoid away.

The robotic platform is a logical step forward to laparoscopy and if cost considerations are addressed may become popular among gynecological surgeons world over [18]. Currently robotic technology is far from perfect. The two main hurdles are the cost and bulkiness of the machine with lack of haptic feedback. Smaller, cheaper, and easier to use robots will be more popular. Since robotics is a form of minimally invasive surgery, it is more appropriate to compare it with laparotomy rather than laparoscopy. Robotic assistance can bridge the gap in performance of laparoscopic surgery in advanced endometriosis.

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