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AAGL Position Statement: Robotic-Assisted Laparoscopic Surgery in Benign Gynecology

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Introduction

The AAGL publishes Position Statements on the state of minimally invasive gynecology to improve the overall quality of women's gynecologic care. The AAGL follows a process to assure that any conflicts of interest are disclosed and appropriately addressed and that relationships with manufacturers and other third parties do not influence the development process.

The Board of Trustees of the AAGL proposed that a Position Statement be developed by leaders in the field of minimally invasive surgery to provide the members of the society a document outlining the current status of robotic surgery and its application in the management of patients with benign gynecologic diseases. The Position Statement has been developed by a group of individuals with experience and interest in the assessment of minimally invasive gynecologic surgery. The goal of this document is to present an unbiased view, informed by the available literature, of the critical aspects of robotic surgery that impact the management of patients with gynecologic conditions.

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Background

Robotic-assisted laparoscopic surgery is a relatively new innovation in the field of gynecologic surgery. The available evidence demonstrates the feasibility and safety of robotic-assisted laparoscopic surgery in benign gynecologic disease, but more high quality research is needed to further define the role of robotic surgical systems in this field. This Position Statement aims to outline the current status of robotic-assisted laparoscopic surgery and its application in the management of patients undergoing benign gynecologic surgery based on currently available published evidence.

Robotic-assisted laparoscopic surgery was developed to overcome the difficulties encountered with conventional laparoscopic technology, but evaluation in randomized controlled trials comparing it with conventional laparoscopy is limited [1]. Two hundred eighty-five citations about robotic laparoscopic surgery for benign gynecologic disease were obtained for a 2012 Cochrane Review, yet only 2 were randomized controlled trials [2]. The goal of this Position Statement is to provide an assessment based on the current literature. The Position Statement is not meant to be a standard of care document or replace an individual's clinical judgment regarding the use of robotic technology in gynecologic surgery.

Clinical Considerations

Hysterectomy

Hysterectomy is the most common gynecologic surgical procedure performed in the United States, with approximately 600 000 cases per year, accounting for more than $5 billion health care dollars [3]. Analysis of US surgical

data in 2003 showed that abdominal hysterectomy is performed in 66% of cases, vaginal hysterectomy in 22% of cases, and laparoscopic hysterectomy in 12% of cases [4]. The feasibility and safety of the robotic-assisted laparoscopic hysterectomy has been demonstrated in multiple retrospective case series. Diaz-Arrastia [5] reported the first case series of 11 patients who underwent robotic-assisted laparoscopic hysterectomy in 2002. A few years later in 2006, Nezhat et al [6] described their initial experience with robotic-assisted laparoscopic gynecologic procedures including robotic-assisted hysterectomy. Reynolds and Advincula [7] later reported a case series of 16 consecutive patients who underwent robotic hysterectomy in 2006, and Kho et al [8] reported a similar study in 2007 that included 91 patients. In all the studies, there were no conversions to laparotomy, intraoperative and postoperative complications were similar to those previously reported by similar case series for conventional laparoscopic hysterectomy, and all authors concluded that robotic-assisted laparoscopy was safe and effective for hysterectomy in their initial experiences.

Since these initial case series, there have been several published retrospective studies that directly compare conventional laparoscopic hysterectomy with robotic-assisted laparoscopic hysterectomy. The largest published retrospective cohort study compared 100 patients scheduled for conventional laparoscopic hysterectomy prior to the acquisition of a robotic surgical system vs 100 patients scheduled for robotic-assisted laparoscopic hysterectomy after acquisition [9]. The mean operating time (skin-to-skin) for conventional laparoscopic hysterectomy was 27 minutes longer than for the robotic-assisted approach ($p < .001$) when comparing all subjects. Nezhat et al [10] compared 26 robotic-assisted laparoscopic hysterectomies with 50 matched control conventional laparoscopic hysterectomies. Mean surgical time for the robotic-assisted laparoscopic hysterectomy was 276 minutes compared with 206 minutes for the conventional laparoscopic hysterectomy. Blood loss, length of stay, and postoperative complications were not significantly different. No conversion to laparotomy was reported in either group.

Sarlos et al [11] prospectively compared the first 40 robotic-assisted laparoscopic hysterectomies with 40 case-matched conventional laparoscopic controls at their institution. No conversions to laparotomy or severe perioperative complications occurred in either group. Mean operating times were 109 minutes for the robotic-assisted laparoscopic group and 83 minutes for the conventional laparoscopic group ($p < .05$). The authors did not see a decrease in operative time for the last 10 cases performed compared with the first 10 cases. Mean length of stay was higher for the conventional laparoscopy group (3.9 vs 3.3 days). However, average cost of the robotic-assisted laparoscopic group was €4067 ($5410 US dollars) compared with €2151 ($2861 US dollars) for the conventional laparoscopic group, not accounting for acquisition and amortization of the robotic surgical system. Surgeons were also surveyed on the perceived advantages and disadvantages of the robotic surgical system. Surgeons reported that they enjoyed the better ergonomics and wider range of motion of robotic instruments, and did not find lack of haptic feedback to be a disadvantage. Surgeons found the lack of direct access to the patient to be a significant disadvantage compared with conventional laparoscopy.

Sarlos et al [12] also recently reported on the results of a randomized trial comparing robotic-assisted vs conventional laparoscopic hysterectomy that included 95 patients. In all cases, 2 surgeons expert in conventional laparoscopic and robotic-assisted surgery performed the procedures. Operating times were longer for the robotic-assisted laparoscopic group (106 vs 75 minutes), with no differences in blood loss or surgical complications. Although there was a greater improvement in postoperative quality of life 6 weeks following robotic-assisted laparoscopic hysterectomy relative to conventional laparoscopic hysterectomy, there was no difference in postoperative analgesic use or return to normal activities.

Two other randomized controlled trials comparing robotic-assisted laparoscopic hysterectomy and conventional laparoscopic hysterectomy are currently under way by Kho (Clinicaltrials.gov identifier: NCT00895284) and Paraiso (Clinicaltrials.gov identifier: NCT00485355). Preliminary results of the Paraiso trial have been presented in abstract form [13]. In this preliminary report, 53 women were randomized to either a conventional total laparoscopic hysterectomy ($n = 27$) or a robotic-assisted laparoscopic hysterectomy ($n = 26$). Compared with conventional laparoscopic hysterectomy, operative time (skin-to-skin) was significantly longer in the robotic-assisted laparoscopic group (77 minutes longer), as was total surgical time defined by the time from entry into the operating room to exit, which was 72 minutes longer. There were no significant differences between groups in estimated blood loss, preoperative and postoperative hematocrit change, and length of stay. There were very few complications, with no difference in individual complication types or total complications between groups. There were also no differences in postoperative pain between groups on visual analog scales. A criticism of this abstract has been the fact that the authors were more experienced at conventional laparoscopy compared with robotic-assisted surgery during the randomization process.

One concern with all modes of laparoscopic hysterectomy is the higher risk of vaginal cuff dehiscence relative to open or vaginal hysterectomy. The reported incidence of this complication following laparoscopic hysterectomy varies widely, and has been reported to be between 0.2% and 7.5%. This variation likely reflects differences in surgical technique, surgeon experience, and sample size of individual publications. To clarify this variation, Ucella et al [14] recently published a pooled analysis of 13,030 laparoscopic hysterectomies, and found the overall incidence of vaginal cuff dehiscence to be 0.66%. Although this incidence of cuff dehiscence following laparoscopic hysterectomy remains significantly higher than that associated with

an abdominal or vaginal approach (0.21% and 0.13%, respectively), a systematic review by Ucella et al [15] indicates that robotic-assisted laparoscopic hysterectomy is associated with a higher incidence of cuff dehiscence relative to conventional laparoscopic hysterectomy (1.64% vs 0.64%). Additional risk factors for cuff dehiscence following laparoscopic hysterectomy appear to be malignancy and mode of cuff closure, with a significantly lower risk of dehiscence if the vaginal cuff is closed with transvaginal vs laparoscopic suturing. This latter finding has only been examined in conventional laparoscopic hysterectomy.

It has been suggested that certain subgroups may benefit from a robotic-assisted laparoscopic hysterectomy, such as those patients who are obese. A retrospective cohort study by Nawfal et al [16] examined the outcomes of 135 patients undergoing robotic-assisted total laparoscopic hysterectomy. Of these, 23.4% were of normal weight (body mass index [BMI] <25), 52.7% of women were obese (BMI >30), and 27.1% were morbidly obese (BMI ≥ 35). The authors found no association with BMI and blood loss, duration of surgery, length of stay, or complication rates. Similar findings have been reported with conventional laparoscopic hysterectomy in the obese women, and it is clear that any mode of laparoscopic surgery provides significant benefit relative to abdominal hysterectomy. It is unclear whether robotic-assisted laparoscopy has technical advantages for obese patients over conventional laparoscopy in the benign surgical population, as direct comparison of these 2 techniques has not been published.

Introduction of laparoscopic surgery has been shown to reduce the rate of abdominal hysterectomy significantly at a large academic institution [17]. Recent data also suggests a decline in the rate of abdominal hysterectomy following the introduction of robotic surgical system technology at specific institutions. Matthews et al [18] reported an overall decline in the rate of abdominal hysterectomy following the introduction of the robotic approach at their academic institution (52.3% vs 43.1%; $p = .052$). Similar findings were reported by Brenot and Goyert [19], who reported that the proportion of abdominal hysterectomies decreased significantly by 18% in the 18 months following the introduction of the robotic surgical system technology. A large-scale analysis of regional changes in surgical practice patterns for hysterectomy since the introduction of robotic surgical system technology in gynecologic surgery is urgently needed.

In summary, the number of abdominal hysterectomies has decreased, and this is due to an increase in the adoption of minimally invasive approaches, including conventional laparoscopic and robotic-assisted laparoscopic hysterectomies.

Myomectomy

Minimally invasive management of leiomyomas is one of the more challenging procedures in gynecology, considering the difficulties encountered in hysterotomy, enucleation, multilayer closure, and extraction of the myomas [20].

Advincula et al [1] performed a retrospective case-matched analysis of 58 patients who underwent robotic-assisted laparoscopic myomectomy vs myomectomy via laparotomy. Patients with robotic-assisted laparoscopic myomectomy had decreased estimated blood loss (195 vs 365 mL), length of stay (1.48 vs 3.62 days), and decreased complications when compared with the laparotomy group. There were no intraoperative complications in the laparotomy group and only 1 in the robotic group. Postoperative complication rates were higher in the laparotomy group (14 vs 3). Hospital charges were higher for the robotic group ($30,084 vs $13,400). Ascher-Walsh and Capes [21] found similar results in 125 women with 3 myomas or fewer who underwent robotic-assisted laparoscopic myomectomy or laparotomy. Blood loss, change in hematocrit, length of stay, and febrile morbidity were decreased in the robotic-assisted laparoscopic group, while operative time was increased compared with laparotomy.

Bedient et al [22] performed a retrospective review of 81 patients who underwent robotic-assisted or conventional laparoscopic myomectomies. Patients undergoing conventional laparoscopic myomectomy had a significantly larger mean uterine size, larger mean size of the largest myoma, and a greater number of myomas. When adjusted for uterine and myoma volume and number, no significant differences were noted between robotic-assisted vs conventional laparoscopic groups for mean operating time (141 vs 166 minutes), mean blood loss (100 vs 250 mL), intraoperative or postoperative complications (2% vs 20% and 11% vs 17%, respectively), hospital stay more than 2 days (12% vs 23%), readmissions, or symptom resolution. The authors concluded that short-term surgical outcomes were similar between conventional laparoscopic and robotic-assisted laparoscopic myomectomy.

Similarly, Nezhat et al [23] found that blood loss, hospitalization time, and postoperative complications were not significantly different between robotic-assisted and conventional laparoscopic myomectomies in a retrospective matched-control study of 50 patients performed by a single surgeon. However, the authors found that robotic-assisted laparoscopic cases consumed significantly more time than conventional laparoscopic cases (234 vs 203 minutes) and concluded that in the hands of a skilled laparoscopic surgeon, the robotic surgical system did not offer any major advantages. The average hospital charge at the author's institution for the robotic-assisted laparoscopic myomectomy was $56,000 vs $34,500 for the conventional laparoscopic myomectomy.

Gargiulo et al [24] performed a retrospective review of 115 patients undergoing laparoscopic myomectomy by conventional laparoscopy compared with 174 patients undergoing robotic-assisted laparoscopic myomectomy. Patient characteristics including tumor load and postoperative complications were similar, but operative time was significantly longer in the robotic-assisted laparoscopic group (195 vs 118 minutes). Conclusions on the significance of this time

difference may be limited by the fact that barbed suture was used in most patients in the conventional laparoscopic group, whereas nonbarbed suture was used in almost all of the patients in the robotic-assisted laparoscopic arm of the study. In spite of the above limitation, this is an important study because it compares laparoscopic and robotic techniques performed by expert high-volume teams with each respective modality.

In a retrospective review of 575 myomectomy procedures, Barakat et al [25] compared the outcomes between robotic-assisted, conventional laparoscopic, and open abdominal approaches. Robotic-assisted laparoscopic myomectomy was associated with decreased blood loss and hospital length of stay when compared with both conventional laparoscopic myomectomy and open abdominal myomectomy. No statistically significant difference was found between robotic-assisted and conventional laparoscopic myomectomy with respect to operative time (181 vs 155 minutes), in spite of the fact that a significantly higher tumor load was removed in the robotic-assisted group (223 [85.25, 391.50] g) compared with the laparoscopic group (96.65 [49.50, 227.25] g; $p < .001$).

A cost-minimization model performed with 2009 costs found that robotic-assisted laparoscopic myomectomy was consistently more costly than myomectomy performed via laparotomy or with conventional laparoscopic techniques, even when accounting for hospital stay but not for recovery time [26].

No data are currently available directly comparing the risk of uterine rupture in pregnancy after conventional laparoscopic vs robotic-assisted laparoscopic myomectomy as only 19 cases of uterine rupture following laparoscopic myomectomy are reported in the literature [27]. In a recent publication, Pitter et al [28] reported a large retrospective multicenter analysis of women who became pregnant after robotic-assisted laparoscopic myomectomy for symptomatic deeply infiltrating intramural myomas distorting the endometrial cavity and/or large submucosal myomas not amenable to a hysteroscopic approach. The study included 107 women who conceived after robotic-assisted laparoscopic myomectomy, which resulted in 127 pregnancies and 92 deliveries. One uterine rupture (1.1%; 95% CI, 0.3, 4.7) was reported. This is comparable with the reported incidence associated with conventional laparoscopic myomectomy [27].

Sacrocolpopexy

Pelvic organ prolapse is a prevalent condition, resulting in more than 200,000 surgical procedures yearly in the United States [29]. Abdominal sacrocolpopexy (SCP) is recognized as an excellent repair for advanced apical prolapse, with demonstrated long-term success [30]. However, with the high morbidity associated with a laparotomy and the difficulty in visualizing deep pelvic structures, a minimally invasive approach is preferred. Elliott et al [31] performed one of the first feasibility studies of 30 women undergoing robotic-assisted laparoscopic SCP. The authors used a conventional laparoscopic technique for the dissection, then docked the robot for attaching the mesh. One patient was converted to laparotomy. Mean operative time was 3.1 hours, and length of stay was 1 day for all but 1 patient. Two patients developed recurrent prolapse, and 2 patients had vaginal extrusion of the mesh over 24 months of follow-up. In a subsequent cost-minimization analysis of robotic vs open SCP, Elliott et al [32] reported a significantly shorter length of stay in the robotic-assisted laparoscopic group (1.0 vs 3.3 days) that corresponded with a 10% cost savings for the robotic-assisted laparoscopic ($10,178) vs abdominal group ($11,307). These costs have not been compared with conventional laparoscopic surgery.

Geller et al [33] performed a retrospective cohort study of 178 patients undergoing a robotic-assisted laparoscopic or abdominal SCP. The robotic-assisted laparoscopic group showed a slight improvement in the postoperative measurement of Pelvic Organ Prolapse Quantification System "C" point (-9 vs -8) when compared with open SCP and was associated with less blood loss (103 mL vs 255 mL), longer total operative time (328 minutes vs 225 minutes), and a shorter length of stay (1.3 days vs 2.7 days). There was a single cystotomy in each group, in each case identified and repaired at the time of the index surgery. The authors included all robotic-assisted laparoscopic cases, many of which comprised their early learning curve, which significantly lengthened the mean operative time in the robotic-assisted laparoscopic group. An analysis of operative performance times from the same group several years later reported a reduction in mean procedure time from 341 minutes for the first 10 cases to 255 minutes for the remaining 171 cases [34].

Tan-Kim et al [35] compared robotic-assisted laparoscopic with conventional laparoscopic SCP in a retrospective cohort study of 104 patients. They also found a longer total operative time in their early robotic-assisted laparoscopic experience vs conventional laparoscopic SCP (281 vs 206 minutes) and noted that setup time accounted for only 9 minutes of the difference. Length of stay, blood loss, complications, and objective cure did not differ between the 2 procedures. Because of the increase in operative time, surgical costs were higher for the robotic group ($2724 vs $2295).

One randomized controlled trial exists comparing robotic-assisted laparoscopic vs conventional laparoscopic SCP in which 38 patients were randomized to conventional laparoscopic and 40 to robotic-assisted laparoscopic SCP [36]. Total operative time was longer in the robotic group (265 minutes) compared with the conventional laparoscopic group (199 minutes). Anesthesia time, total time in the operating room, total SCP, and total suturing time were all significantly longer in the robotic-assisted laparoscopic group. Participants in the robotic-assisted laparoscopic group also had significantly higher pain at rest and with activity during

weeks 3 through 5 after surgery and required longer use of nonsteroidal anti-inflammatory drugs. At 6 weeks, pain was equivalent. The mean direct costs for the robotic-assisted laparoscopic group were $1936 more than those for the laparoscopic group. Both groups demonstrated significant improvement in vaginal support and functional outcomes 1 year after surgery, with no differences between groups. The authors noted that in an institution such as their own, where skills for conventional laparoscopic SCP had already been developed, the robot added no benefit, though it may accelerate the learning curve for less experienced surgeons interested in offering patients a minimally invasive SCP. This study was criticized for the fact that surgeons experienced with conventional laparoscopy performed all of the cases in the study instead of surgeons experienced with robotic-assisted laparoscopy, with less than 10 robotic cases reported for 2 of the principal surgeons.

Operative time has been shown to decrease quite rapidly with increased robotic-assisted laparoscopic volume. In a retrospective review of 80 patients undergoing robotic-assisted SCP, Akl et al [37] reported a 25% decrease in total time after completion of the first 10 cases, with a sequential decline to approximately 160 minutes after 50 cases, when a plateau was reached. A cost-minimization model performed with 2008 costs found robotic-assisted SCP ($8508) to be more expensive than laparoscopic SCP ($7353) and abdominal SCP ($5792) [38]. Length of stay was included in the analysis, but not recovery time.

Long-term outcomes for robotic SCP have been reported. Both anatomic support and pelvic floor function were maintained at 44 months after surgery when compared with both preoperative data and long-term outcomes for abdominal SCP [39].

Adnexal Surgery

The only published study to date that compares robotic-assisted laparoscopic with conventional laparoscopic adnexal surgery was performed by Magrina et al [40] in 2009. They retrospectively examined all patients who underwent adnexal surgery from 2003 to 2008 at their institution. Eighty-five patients underwent robotic-assisted laparoscopic adnexectomy (90% for adnexal mass and 10% for prophylactic bilateral salpingo-oophorectomy), and 91 patients underwent conventional laparoscopic adnexectomy (97% for adnexal mass, 3% for prophylactic bilateral salpingo-oophorectomy). Operative time was higher for the robotic group (77 vs 62 minutes). Blood loss, complication rates, and hospital stays were similar, with no blood transfusions or conversions. The authors noted that large adnexal masses were preferably approached by conventional laparoscopy because of the restrictions of port placement with the robotic-assisted laparoscopy system as well as the increased ability to drain large benign cysts with conventional laparoscopic instruments compared with instruments used with the robotic-assisted laparoscopic system.

Endometriosis

Laparoscopy, considered the gold standard for diagnosis of endometriosis, is also recognized as subsequent management when conservative therapy fails. Recently, the robot was theorized to aid in the management of endometriosis by allowing the operator to see more endometriosis, though this has not been shown in any published reports.

One retrospective cohort study by Nezhat et al [41] compared robotic-assisted laparoscopic with conventional laparoscopic surgery for the treatment of endometriosis in 78 patients. Operative time was longer for the robotic-assisted laparoscopy compared with conventional laparoscopy (191 vs 159 minutes). There were no significant differences in blood loss, hospitalization, or intraoperative and postoperative complications. There were no conversions to laparotomy. To date, there are no studies showing the differences in outcomes for endometriosis and course of the disease between robotic-assisted and conventional laparoscopic surgery.

Tubal Reanastomosis

Surgery has an important role in the management of regret of tubal sterilization [42]. The first feasibility study for tubal reanastomosis on the da Vinci surgical system was published by Degueldre et al [43]. Two case series compared robotic-assisted laparoscopic tubal reanastomosis performed with the robotic surgical system with conventional microsurgical reanastomosis through minilaparotomy. The case-control study by Rodgers et al [44] compared 26 robotic-assisted tubal reanastomosis cases with 41 reanastomoses performed by outpatient minilaparotomy. Surgical times were significantly longer for the robot compared with open surgery. Robotic-assisted laparoscopic reanastomosis was also more costly, with a median cost differential of $1446 (cost analysis did not include the base cost of the surgical system and the annual maintenance fee). Hospitalization times, pregnancy (61% robotic vs 79% minilaparotomy), and ectopic pregnancy rates were not significantly different. Complications, however, occurred less frequently in the robotic group, and the return to normal activity was shorter in this group by 1 week.

The prospective cohort study by Dharia Patel et al [45] compared 18 robotic-assisted tubal reanastomosis cases and 10 open microsurgical tubal reanastomosis cases with hospital admission. Surgical times were again significantly longer for the robot compared with open surgery. This group did not perform outpatient minilaparotomy; hence, hospitalization times were significantly shorter in the robotic-assisted laparoscopic reanastomosis group. Time to recovery was also significantly shorter for the robotic-assisted laparoscopic reanastomosis group compared with the open surgery group (11.1 days [range, 2–28 days] and 28.1 days [range, 21–42 days, respectively). Pregnancy (62.5% robotic vs 50% open) and ectopic pregnancy rates were not significantly different. The hospital cost for robotic-assisted laparoscopic reanastomosis was $13,773 (vs $11,742 for the

open procedure). However, the cost per delivery was similar between the 2 procedures. The data seem to indicate that robotic-assisted laparoscopic tubal reanastomosis is safe and its final results are comparable with those obtained by classic tubal microsurgery performed by trained REI (Reproductive Endocrinology/Infertility) subspecialists, albeit at the cost of a longer recovery and a possibly longer hospital stay with the open technique. Cost analysis is controversial, but it would appear that even at the current high operating costs, open surgery is cost-effective only if patients are sent home within a few hours but not if they stay overnight.

Training Impact

Some laboratory simulation studies indicate that enabling benefit may pertain mostly to novice surgeons. When evaluating technically challenging tasks such as suturing, novice surgeons experienced an early and persistent enabling effect with robotic-assisted laparoscopy, while experienced laparoscopic surgeons demonstrated equal proficiency in both robotic and conventional laparoscopic surgery [46,47]. Robotic assistance for laparoscopy appears to eliminate the early learning curve for novices but may not provide advantages for experienced laparoscopic surgeons [12].

We are not aware of studies that compare the clinical learning curves of specific laparoscopic and robotic-assisted procedures. The number of cases required for surgical proficiency has yet to be established and is likely dependent on surgeon skill and type of procedure performed. Lenihan et al [48] evaluated the learning curve for benign gynecological procedures (mainly hysterectomy) in robotic-assisted laparoscopic surgery and found that operative times stabilized after approximately 50 cases. A significant improvement in operating time after 20 cases was found for the next 20 cases of hysterectomy and myomectomy [49]. Payne and Dauterive [9] found that operating time continued to decrease in the last 25 of 100 cases after acquisition of a robotic surgical system. Similar to laparoscopy, it is likely that surgical efficiency and proficiency continues to increase with number of cases performed. On the other end, Gargiulo et al [24] did not identify a significant learning curve for robotic-assisted laparoscopic myomectomy adopted in the context of an advanced minimally invasive surgery practice.

As it is true for conventional laparoscopy, the successful implementation of robotic-assisted laparoscopic surgery is more efficient with the establishment of a trained surgical team including bedside assistants, circulating nurses, and scrub technicians who are familiar with the set-up, use, and turnover of the specific equipment [3].

Cost Considerations

The issues surrounding the costs of robotic-assisted laparoscopic surgery are complex. One must take into account costs to the hospital, costs to the patient, and costs to society. These include direct and indirect costs of surgery including equipment, operating time, recovery room time, length of hospital stay, nursing, anesthesia, physician fee, outpatient care, and lost wages, for example.

Robotic surgical systems currently have a fixed cost ranging between $1.6 million and $2.5 million for each unit. Each robotic unit is required to have an annual maintenance contract priced at 10% of the cost of the unit, and disposable proprietary wristed instruments cost $2000 to $3000 each for 10 uses. As well, there are disposable drapes needed for the robotic arms in every procedure. In addition to high fixed equipment costs, longer operating room times result in higher costs to the patient and decreased productivity for the hospital and physician. Training operating room personnel and the effect of the learning curve are significant costs as well.

Estimates of the per-procedure cost of robotic-assisted laparoscopic surgery vary with assumptions about the frequency with which a robotic surgical system will be used. Barbash and Glied [50] examined data from the Healthcare Cost and Utilization Project across the full range of 20 types of surgery for which studies exist examining robotic-assisted laparoscopic surgery. They found that, on average, the additional variable cost of using a robotic surgical system was $1600 per procedure, and when the amortized cost of the robotic surgical system was included, the variable cost of using a robotic surgical system rose to $3200 per procedure.

These findings echo the cost differences found in many of the previously mentioned studies in this report. However, because of the shorter hospitalization for robotic-assisted laparoscopic surgery as compared with laparotomy, the robotic-assisted laparoscopic cost is similar or lower, and more so if the societal and indirect economic benefits of an earlier return to work are considered. Barbash and Glied [50] also noted that robotic technology might burden the health care system by encouraging more surgical procedures to be performed than are necessary, as in the case of prostate cancer. If the 600 000 hysterectomies performed in the United States were all done robotically, the reported cost increases would result in an extra $960 million to $1.9 billion burden on the health care system The AAGL has already issued a Position Statement on hysterectomy indicating that a minimally invasive approach is preferable to laparotomy [51].

Conclusion

The available evidence indicates that robotic-assisted and conventional laparoscopic techniques for benign gynecologic surgery are comparable regarding perioperative outcomes, intraoperative complications, length of hospital stay, and rate of conversion to open surgery. However, published reports demonstrate that robotic-assisted laparoscopic surgery has similar or longer operating times and higher associated costs [6]. Efforts should be focused on the proper credentialing and privileging of surgeons to utilize robotic surgical systems as a means to minimize cases otherwise

performed by laparotomy. Robotic-assisted laparoscopic surgery should not replace conventional laparoscopic or vaginal procedures for women who could otherwise undergo conventional laparoscopic or vaginal surgery for benign gynecologic diseases. This is congruent with the findings of a 2012 Cochrane Review [2].

Additional research comparing conventional laparoscopic and robotic-assisted laparoscopic surgery is needed to help characterize the advantages and disadvantages of robotic-assisted surgery and concurrently determine patient groups who would benefit from robotic-assisted laparoscopy over other methods. Pertinent research topics include the role of simulation, comparison of learning curves of robotic-assisted and conventional laparoscopic surgery, further cost analyses, practice trends, and additional studies focusing on short-term and long-term clinical outcomes for patients and surgeons.

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Position Statements are intended to be educational devices that provide information that may assist health care providers in caring for patients. This Position Statement is not a rule and should not be construed as establishing a legal standard of care or as encouraging, advocating, requiring, or discouraging any particular treatment. Position Statements are not intended to supplant the judgment of the health care provider with respect to particular patients or special clinical situations. Clinical decisions in any particular case involve a complex analysis of a patient's condition and available courses of action, with the ultimate determination to be made by the health care provider in light of each individual patient's circumstances. Therefore, clinical considerations may lead a health care provider to appropriately take a course of action that varies from this document.

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Appendix

Studies were reviewed and evaluated for quality according to a modified method outlined by the U.S. Preventive Services Task Force:

I Evidence obtained from at least one properly designed randomized controlled trial.

II Evidence obtained from non-randomized clinical evaluation.

- II-1 Evidence obtained from well-designed, controlled trials without randomization.
- II-2 Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one center or research center.
- II-3 Evidence obtained from multiple time series with or without the intervention.Dramatic results in uncontrolled experiments also could be regarded as this type of evidence.

III Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.