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REVIEW

Robotics in Gynecology: Why is this Technology Worth Pursuing?

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Abstract: Robotic laparoscopy in gynecology, which started in 2005 when the Da Vinci Surgical System (Intuitive Surgical Inc) was approved by the US Food and Drug Administration for use in gynecologic procedures, represents today a modern, safe, and precise approach to pathology in this field. Since then, a great deal of experience has accumulated, and it has been shown that there is almost no gynecological surgery that cannot be approached with this technology, namely hysterectomy, myomectomy, sacrocolpopexia, and surgery for the treatment of endometriosis. Albeit no advantages have been observed over conventional laparoscopy and some open surgical procedures, robotics do seem to be advantageous in highly complicated procedures when extensive dissection and proper anatomy reestablishment is required, as in the case of oncologic surgery. There is no doubt that implementation of better logistics in finance, training, design, and application will exert a positive effect upon robotics expansion in gynecological medicine. Contrary to expectations, we estimate that a special impact is to be seen in emerging countries where novel technologies have resulted in benefits in the organization of health care systems.

Keywords: robotics, gynecology, hysterectomy, myomectomy, laparoscopy

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Introduction

Centuries ago, the artificial doves described by Archytas[1] and the mechanical servants built by the Greek god Hephaestus were the first reference to automated machines that resembled living beings. In the 15th century, the great Leonardo da Vinci[2] designed elements of a humanoid robot. The word *robot* comes from the Czech that means labor, and it became a central subject on Karel Capek's play, *Rossum's Universal Robots,* in 1920,[3] which depicts android machines happy to serve their human masters. Modern day robots have found a place in various fields of the human task with capability to move in diverse environments and susceptible of being modified according to preset instructions. Activity deployed by these machines is prone to surpass that of humans in endurance, accuracy, strength, reproducibility, and time of work with unaltered quality in performance. The utilization of robots is now seen in industrial applications such as car assembly lines, for use in extreme conditions as in space, deep seas, and volcanoes, and for military purposes, mining, and health care.

Robotics have a notorious role in health sciences, especially in the field of surgery, supporting procedures that may be complex, requiring a great deal of effort and detail. The early conceptions for surgical robotics come from Scott Fisher, PhD, at the National Air and Space Administration (NASA) and J. Rossen, MD, at Stanford University, who in the 1980s integrated the concepts of virtual reality for development of surgical telepresence using a remote glove whose movements directed the robot's hands.[4,5] Almost simultaneously, Jacques Perrisat from France introduced the laparoscopic cholecystectomy.[6–8] Further advances were seen through the military when the United States Armed Forces sought to provide immediate surgical care for soldiers wounded in battle while preventing exsanguinations and other complications seen during hospital transfer. This gave rise to the Medical Forward Advanced Surgical Treatment (MEDFAST) and the Mobile Advanced Surgical Hospital (MASH), which relied on a entire robotic unit mounted upon a special military vehicle (Bradley) where medical assistance could be given forthwith.[9] Finally in the 1990s, commercial versions appeared, such as RoboDoc (1992), which consisted of a robotic arm for use in orthopedic surgery. This was followed by the automated endoscopic system for optimal positioning (AESOP),[10] designed for abdominal laparoscopic surgery. The da Vinci system (Intuitive Surgical Company) had significant improvements which included full 3-D vision, telepresence with a "wrist" joint in every instrument and a simple 2 opposing finger control emulating actions of the actual tweezer. The da Vinci robot was approved by the Food and Drug Administration (FDA) in the year 2000 for use in general laparoscopic surgery[4,11] (see Fig. 1).

In this work we attempt to delineate the purpose and advantages of robotics in surgical gynecology to expand use of this technology in emerging countries like Mexico, which have a wide organizational base for health care but are limited by serious drawbacks that can be relieved with robotic technology implementation.

Robotics Horizon in Gynecology

The da Vinci robot is the only one approved by the FDA for procedures in general surgery, heart and cardiothoracic surgery, head and neck, urology, and gynecology (see Fig. 1). Its use in the latter started in 2005, proving its usefulness for work within a compartment such as the female pelvis,[12] endometriosis and gynecologic neoplasias being the most successful targets.[13]

Hysterectomy

This procedure is the most common type of surgery around the world. Only the United States of America reports more than 600,000 hysterectomies per year, while in emerging countries (eg, Mexico and Brazil), this number might be greater than 200,000 surgeries per year. Robotic hysterectomy was developed based on the success endoscopic surgery had already achieved; still, by 2003, 66.1% of hysterectomies were being performed abdominally, 21.8%, vaginally, and only 11.8% through laparoscopy.[14] Greater interest was expected once robotics entered this surgical field, providing various advantages, especially to those surgeons without any laparoscopy experience. Among the parameters observed for robotic surgery versus conventional laparoscopic hysterectomy, we find total operative time being longer for the robotic procedure, the time difference ranging on average from 20 to 70 minutes among various studies, all of them with a significant difference ($P < .01$).[15–20] Blood loss is another important parameter. Initial studies showed great fluctuations (50–1500 mL).[15] Still, new information shows greater blood loss for the conventional

Figure 1. The Da Vinci Surgical System has an ergonomic console that remotely controls the various arms of the actual robotic unit performing the surgery.

approach (207.7 mL vs 131.5 mL),[17] and most studies concur with these findings. Although length of hospital stay may be influenced by institutional policy, clearly all studies favor robotic hysterectomy with an average of 1 less day of hospitalization, although some reports indicate no difference.[15,17,19–21] One study by Shashoua *et al* also evaluated narcotic usage and found that the robotic procedures required fewer units (1.2 vs 5.0 U, $P = .002$).[18] Most authors report a significantly diminished incidence in laparotomy conversions as well as complications, which if encountered, were quite similar to those found in conventional laparoscopy.[16,19,20,22,23] The precision movements and technology advantages were clear in cases with painful pelvic adhesions due to former surgeries, these patients experienced substantial relief. Also, larger uteruses were easier to manipulate and dissect. Surgeons praise ergonomics and vision, although most still look for haptic feedback and direct access to the patient.[19,20] The robotic hysterectomy tends to be double in cost when compared with the conventional laparoscopic procedure.

An important issue to address is vaginal cuff dehiscence. Although a concern in all variants of laparoscopic hysterectomy, the greatest incidence is reported in the robotic approach, which is reported to be 1.64% while conventional laparoscopy is reported to be 0.66%.[24] Risk factors associated with this complication are malignant lesions and the technique employed for vaginal cuff closure.[25]

Obese patients have been advanced as those with the greater benefits when operated on with robotics: however, studies with patients having a BMI > 30 kg/m^2 showed no significant differences compared with patients who had BMI < 25 kg/m^2; still, further studies are required.[26, 27]

Myomectomy

Robotic surgery for uterine myomas is an approach that shares the benefits of minimal invasive surgery and may simplify the procedure. Myomectomies are of concern because of uterine rupture in a subsequent pregnancy, a condition associated with poor closure of incisions or excessive use of diathermy.[28–29] Robotic myomectomy has shown a decrease in blood loss, length of hospital stay, and fewer complications when compared with laparotomies; when compared with

conventional laparoscopies, there is also less blood loss, shorter hospital stays, but a longer operative time (234 vs 204 min).[30] Overall complication rates were similar and costs usually doubled. Time of performance may be increased due to morselation, docking, draping, and trocar set up in contrast with regular procedures.[31,32] The robotic procedure improves fibroid enucleation and layered incision closure and reduces the number of incisions required. Inconveniences are a reduced field of movement when large fibroids are removed and inadequate countertraction due to insufficient torque during enucleation.[30–33] Reproductive outcomes in pregnancies and deliveries seem unaltered. Pitter *et al* studied these outcomes, reporting 92 deliveries out of 107 patients studied with only 1 uterine rupture.[33]

Sacrocolpopexy

Nearly 60 million women in the world are at risk or developing pelvic organ prolapse, and almost a third of all gynecological surgeries are related to this diagnosis. In the United States of America, 11% of females have a risk of having surgery to correct a pelvic organ prolapse or urinary incontinence.[34,35] Laparotomy, laparoscopy, and robotics seem to share qualities in safety, simplicity, and precise dissection.[36] Nonetheless, the increasing experience with robotics has shown benefits in reducing blood loss and shortening hospital stays. Costs and time performance as mentioned before are double with robotic procedures, albeit stable sexual function and improvement of pelvic support tend to be better under robotic manipulation.[33,38]

Endometriosis

Endometriosis is probably the most suited for robotic treatment. Due to its nature of slow and long implantation (7–8 years) and diagnosis relying upon laparoscopy and overt clinical symptoms (chronic pelvic pain, subfertility, intermenstrual bleeding, and abdominal bloating), experience has shown that many of the corrective surgeries performed in endometriosis require skill and proper equipment in order to restore the tissue affected in its anatomy and functionality while abnormal endometrium implantation is removed. Robotic surgery with vision enhancement (3-D) and ability to perform complex resections does seem to be the best option in most cases of endometriosis. In studies that compare the robotic versus laparoscopic approach, no special differences have been seen, except that as expected,[13,37] 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.[13,37]

Tubal reanastomosis

Among strategies designed for over population control, tubarian occlusion is a favored method in many countries because of its simplicity, low cost, and efficiency. However, plenty of women eventually desire to have their surgery reverted, and although artificial reproductive techniques (ART) are an alternative for such purpose, tubal reanastomosis obviates exposure to ovarian hyperestimulation and undesired twin gestations commonly seen with ART methodology. Success rates for tubal reanastomosis in open surgery is about 67.6%, with an incidence of ectopic pregnancy of 5.6%,[13,39] whereas robotic reanastomosis has a normal pregnancy rate of 71%, derived from adequate visualization of tissue components, precision in suturing, and a refined manipulation of salpinges. In this case, despite known limitations of cost and time duration compared with laparatomy, the time of recovery of patients is significantly shorter.[19]

Oncology

Oncology is a promising field for robotic intervention since it can rapidly assimilate the benefits seen with laparoscopy 20 years ago, such as staging treatment of cervical and endometrial cancer and in the management of ovarian tumors. Efficacy to perform robotic radical hysterectomies in patients with cervical cancer, for instance, is the same as laparoscopic procedures with known differences in time of elaboration (300 vs 241 minutes respectively).[40] Open, laparoscopic and robotic procedures disclosed similar data on blood loss and length of hospital stay with parallel complication rates to any of the approaches mentioned.

With respect to fertility preservation procedures such as traquelectomy, robotics exhibited a higher number of conversions derived from a smaller surgical field.[41] The treatment for early endometrial cancer is surgical; in this case, laparoscopy has not surpassed laparotomy, probably because of less experience among practitioners, limited skills gained by a long-term learning curve in the field, and other technical by stands that can be overcome with the robotic approach

by accelerating the learning curve of nonlaparoscopic surgeons for prevention of morbidity as in the case of obese women while providing minimal invasion.[42,43] In cases of ovarian cancer, robotics so far seemed more useful in the early stages or small volume disease than in advanced stages. Some of these cases may be solved by placing trocars higher in the abdomen.[13]

Obstacles and Potentiality

Experience is the mother of all knowledge, and, in this regard, robotics still has a long way to go, but through a very promising path. The most obvious problems now are length of time to perform, logistics, costs, and acceptance, which, once improved, will bring unsurpassed benefits to patients, organizations, and countries as well. The volume of patients and number of procedures are key elements for enhancement of use, which may pave the way for surgeons' increased participation while access to robotic technology is provided, regardless of its present limitations. Hence, more exposure is needed, and laparoscopic surgeons are the experts to be supported to gain widespread understanding among their peers and for diffusion of the technology.[13] Novice surgeons in endoscopic procedures benefit the most from robotic surgery, experiencing a shorter learning curve and a comfortable transition from open surgery technique to robot movements, naturaly without tremors and dexterity preserved as in open surgery by endowrist instrumentation with 7 degrees motion freedom of insertion, pitch, yaw, roll, and grip plus the 3-D field of vision.[37,44,45] Previous laparoscopic experience has proven extremely valuable and is, therefore, a requirement for the transition to robotics. Skilled movements, eye-hand coordination, and anatomy perception within an enclosed cavity are capacities that require experience and time to develop[13] (see Fig. 2). Satisfaction of patients still varies due to biases in

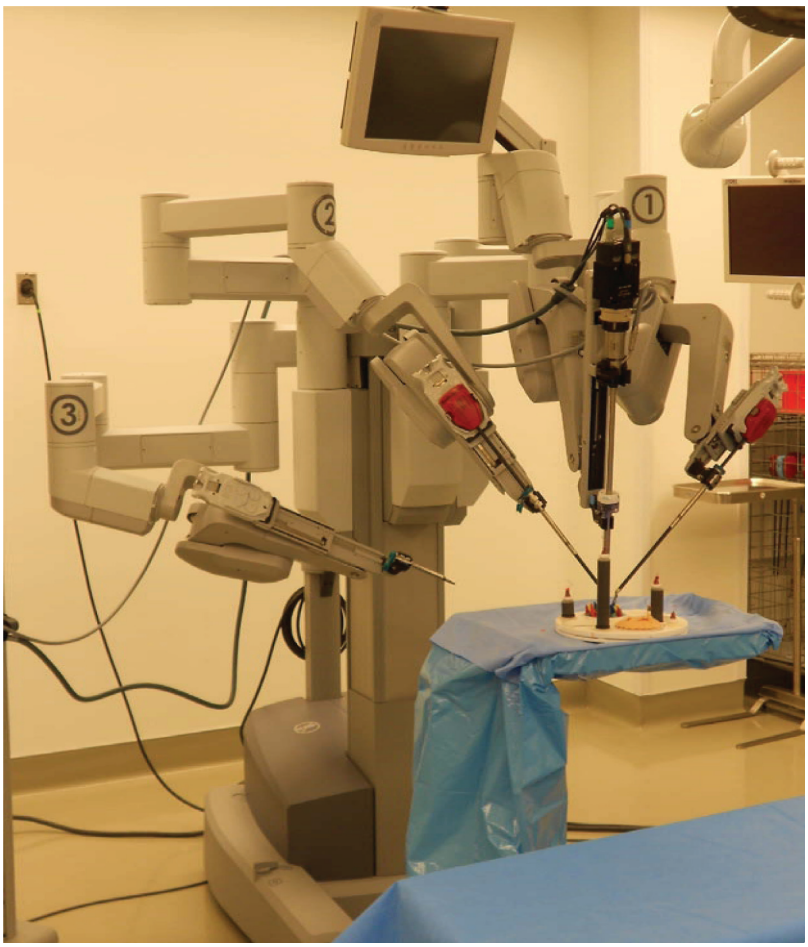

Figure 2. Training with models to enhance the abilities required for proper usage of this equipment is part of the course required to use the Da Vinci Surgical System. This robotic unit is being employed to move simple plastic models, requiring fine and precise movements.

selection, perceived information, and physician`s opinions along with esthetic inconveniences such as the number of scars (5 ports are utilized in robotics). In addition, training has to involve nurses, maintenance crews, or assistants and biomedical personnel to gain proficiency, optimal usage, and good results. Study of space for robot accommodation and characterization of expenses is highly relevant in a scenario where 1.5 to 2 million US dollars are invested just in the unit and a 10% annual maintenance contract must be signed and the surgical inserts must be replaced every 10 surgeries (at 2000–3000 US dollars per set).[46]

The amount of benefits expected speaks of potentiality. In our community of Mexico City, expenses to assist patients efficiently in public or county hospitals are high but associated with low proficiency levels. Incorporation of sophisticated methods like robotics in hospitals must give rise to a new culture in patients and health providers designing new avenues for a more judicious expense. Another important factor not to be underestimated is the amount of experience that may be stored in the robot's memory (future models) that will simplify procedures such as those mentioned here in and where emerging countries like ours could become a more favorable setting for a first successful mass and uninterrupted application.

Conclusions

Uncomplicated gynecological procedures performed by experienced surgeons through conventional laparoscopy have also been achieved by robotic technology despite limitations observed in costs and time of performance. An important asset, however, is that practically any gynecologic pathology is accessible for treatment through robotics. Taking into account that this specialty leads the number of surgeries performed in most medical centers, a prompt robotic leadership will become a reality. Paradoxically, emerging countries could become the first potential beneficiaries of such technology, since they are more prone to facilitate its use through improvement induction in organization, enthusiasm among young physicians, the volume of uncomplicated cases, and faster accrual of benefits.

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Author Contributions

Analyzed the data: RAY, EJOG. Wrote the first draft of the manuscript: RAY, EJOG. Contributed to the writing of the manuscript: RAY, EJOG, JHA. Agree with manuscript results and conclusions: RAY, EJOG, JHA. Jointly developed the structure and arguments for the paper: RAY, EJOG, JHA. Made critical revisions and approved final version: RAY, EJOG. All authors reviewed and approved of the final manuscript.

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References

1. Currie A. *The History of Robotics*. 1999.
2. Rosheim ME. *Leonardo's Lost Robots*. Berlin, Germany: Springer; 2006:69.
3. Zunt D. Who did actually invent the word "robot" and what does it mean? Karel Capek website. http://capek.misto.cz/english/robot.html. Accessed June 30, 2013.
4. WeBSurg.com. The history of robotics. 2006;6. http://www.websurg.com/ref/doi-ed01en0021.htm.
5. Satava RM. Robotics, telepresence and virtual reality: a critical analysis of the future of surgery. *Minimally Invasive Therapy.* 1992;1:357–363.
6. Litynski GS. Profiles in laparoscopy: Mouret, Dubois, and Perrisat: the laparoscopic breaktrhough in Europe (1987–1988). *JSLS*. 1999:3:163–167.
7. Cuschieri A. Visual displays and visual perception in minimal access surgery. *Semin Laparosc Surg.* 1995;2(3):209–214.
8. Green PS, Hill JH, Satava RM. Telepresence: Dextrous procedures in a virtual operating field *Surg Endosc*. 1991;57:192(abstr).
9. Satava RM. Virtual reality and telepresence for military medicine. *Comput Biol Med.* 1995;25(2):229–236.
10. Buchloz RD, Greco DJ. Image-guided surgical techniques for infections and trauma of the central nervous system. *Neurosurg Clin N Am*. 1996;7(2):187–200.

11. Hockstein NG, Gourin CG, Faust RA, Terris DJ. A history of robots: from science fiction to surgical robotics. *J Robotic Surg*. 2007;1:113–118.
12. Visco AG, Advincula AP. Robotic gynecologic surgery. *Obstet Gynecol*. 2008;112:1369–1684.
13. Ayala-Yáñez R, Olaya-Guzmán EJ, Haghenbeck Altamirano FJ. Robotics in gynecology. Background, feasibility and applicability [in Spanish]. *Ginecol Obstet Mex*. 2012;80:409–416.
14. Advincula AP, Wang K. Evolving role and current state of robotics in minimally invasive gynecologic surgery. *J Minim Invasive Gynecol.* 2009;16:291–301.
15. Diaz Arrastia C, Jurnalov C, Gomez G, Townsend C Jr. Laparoscopic hysterectomy using a computer-enhanced surgical robot. *Surg Endosc*. 2002;16(9):1271–1273.
16. Nezhat C, Saberi N, Shahmohamady B, Nezhat F. Robotic-assisted laparoscopy in gynecological surgery. *JSLS.* 2006;10:317–320.
17. Soto E, Lo Y, Friedman K, et al. Total laparoscopic hysterectomy versus da Vinci hysterectomy: is using the robot beneficial? *J Gynecol Oncol*. 2011;22:253–259.
18. Shashoua RA, Gill D, Locher SR. Robotic-assisted total laparoscopic hysterectomy versus conventional total laparoscopic hysterectomy. *JSLS*. 2009;13:364–369.
19. Sarlos D, Kots L, Stevanovic N, Schaer G. Robotic hysterectomy versus conventional laparoscopic hysterectomy: outcome and cost analysis of a matched case control study. *Eur J Obstet Gynecol Reprod Biol*. 2010; 150:92–96.
20. Sarlos D, Kots LV, Stevanovic N, von Felten S, Schär G. Robotic compared with conventional laparoscopic hysterectomy: a randomized controlled trial. *Obstet Gynecol*. 2012;120:604–611.
21. Nezhat C, Lavie O, Lemyre M, Gemer O, Bhagan L. Laparoscopic hysterectomy with and without a robot: Stanford experience. *JSLS.* 2009;13:125–128.
22. Reynolds RK, Advincula AP. Robot-assisted laparoscopic hysterectomy: technique and initial experience. *Am J Surg*. 2006;191:555–560.
23. Kho RM, Higer WS, Hentz JG, Magtibay PM, Magrina JF. Robotic hysterectomy: tehcnique and initial outcomes. *Am J Obstet Gynecol*. 2007;197:113.e1–e4.
24. Uccella S, Chezzi F, Mariani A, et al. Vaginal cuff closure after minimally invasive hysterectomy: our experience and systematic review of the literature. *Am J Obstet Gynecol*. 2011;205(2):119.e1–e12.
25. Uccella S, Ceccaroni M, Cromi A, et al. Vaginal cuff dehiscence in a series of 12,398 hysterectomies: effect of different types of colpotomy and vaginal closure. *Obstet Gynecol*. 2012;120:516–523.
26. Bernot K, Goyert GL. Impact of robotic surgery on obstetric-gynecologic resident training. *J Reprod Med*. 2009;544:675–677.
27. Gallo T, Kashani S, Patel DA, Elsahwi K, Silasi DA, Azodi M. Robotic-assisted laparoscopic hysterectomy: outcomes in obese and morbidly obese patients. *JSLS.* 2012;16:421–427.
28. Al-Mahrizi S, Tulandi T. Treatment of uterine fibroids for abnormal uterine bleeding: myomectomy and uterine artery embolization. *Best Pract Res Clin Obstet Gyneacol.* 2007;21:995–1005.
29. Bedient CE, Magrina JF, Noble BN, Kho RM. Comparison of robotic and laparoscopic myomectomy. *Am J Obstet Gynecol*. 2009;201:566.e1–e5.
30. Nezhat C, Lavie O, Hsu S, Watson J, Barnett O, Lemyre M. Robotic-assisted laparoscopic myomectomy: a retrospective matched control study. *Fertil Steril*. 2009;91:556–559.
31. Advincula AP, Xu X, Goudeau S, Ransom SB. Robot-assisted laparoscopic myomectomy versus abdominal myomectomy: a comparison of short-term surgical outcomes and immediate costs. *J Minim Invasive Gynecol*. 2007;14:698–705.
32. Ascher-Walsh CJ, Capes TL. Robot-assisted laparoscopic myomectomy is an improvement over laparotomy in women with a limited number of myomas. *J Minim Invasive Gynecol*. 2010;17:306–310.
33. Pitter MC, Gargiulo AR, Bonaventura LM, Lehman JS, Srouji SS. Pregnancy outcomes following robot-assited myomectomy. *Hum Reprod*. 2013;28(1):99–108.
34. http://www.hgm.salud.gob.mx/descargas/pdf/area_medica/gineco/guías_gineco/19-prolaps-organos-pélvicos.pdf
35. Weber AM, Richter HE. Pelvic organ prolapse. *Obstet Gynecol*. 2005; 106:615–634.
36. Nygaard IE, McCreery R, Brubaker L, et al. Pelvic Floor disorders network. Abdominal sacrocolpopexy: a comprehensive review. *Obstet Gynecol.* 2004; 104:805–823.
37. AAGL Advancing Minimally Invasive Gynecology Worldwide. AAGL position statement: Robotic-assisted laparoscopic surgery in benign gynecology. *J Minim Invasive Gynecol.* 2013;20(1):2–9.
38. Akl MN, Long JB, Giles DL, et al. Robotic-assisted sacrocolpopexy: technique and learing curve. *Surg Endosc.* 2009;23(10):2390–2394.
39. Abelha MC, Costa RR, Lopes VM, Reis RC, Silva CM. Tubal reanastomosis: analysis of the results of 30 years of treatment [in Portuguese]. *Rev Bras Ginecol Obstet*. 2008;30:294–299.
40. Sert B, Abeler V. Robotic radical hysterectomy in early-stage cervical carcinoma patients, comparing results with total laparoscopic radical hysterectomy cases: the future is now? *Int J Med Robot*. 2007;3:224–228.
41. Persson J, Kannisto P, Bossmar T. Robot-assisted abdominal laparoscopic radical trachelectomy. *Gynecol Oncol*. 2008;111:564–567.
42. Gehrig PA, Cantrell LA, Shafer A, Abaid LN, Mendivil A, Boggess JF. What is the optimal minimally invasive surgical procedure for endometrial cancer staging in the obese and morbidly obese woman? *Gynecol Oncol*. 2008; 111:41–45.
43. Peiretti M, Zanagnolo V, Bocciolone L, et al. Robotic surgery: Changing the surgical approach for endometrial cancer in a referral cancer center. *J Minim Inv Gynecol*. 2009:16:427–431.
44. Chandra V, Nehra D, Parent R, et al. A comparison of laparoscopic and robotic assisted suturing performace by experts and novicies. *Surgery*. 2010; 147:830–839.
45. Beste TM, Nelson KH, Daucher JA. Total laparoscopic hysterectomy utilizing a robotic surgical system. *JSLS*. 2005;9:13–15.
46. Barbash GI, Glied SA. New technology and health care costs: the case of robot-assisted surgery. *N Engl J Med*. 2010;363:701–704.