Robotic surgery in reproductive endocrinology

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Abstract

In the last years, the practice of surgery is evolved thanks to the introduction of videolaparoscopic and robotic techniques. Laparoscopic surgery has revolutionized the concept of minimally invasive surgery in the last decades but it presents limitations due to the normal mechanism of the human hand. The robotic-assisted surgery is designed to overcome these limitations. In comparison with laparoscopic surgery, the robotic technique presents many advantages such as 3-dimensional vision, a decrease of surgeon’s fatigue and tremors, and an increase of wrist motion improved dexterity and greater surgical precision. Many procedures have already been performed with this technique in urology, cardiac surgery and general surgery. Nowadays the use of the robotic technique is becoming more frequent also in gynaecological surgery and it is preferred to conventional laparoscopy for the treatment of gynaecological malignancies and most of the benign disease of certain complexity, such as hysterectomy or myomectomy.

Key words: robotic technology, gynaecologic surgery, myomectomy, endometriosis

Introduction

Reproductive surgery is a procedure to correct anatomical disorder of the reproductive tract. In obstetrics and gynaecology, surgery is traditionally performed by means of a laparotomy or a vaginal approach. Laparotomy is a procedure that is preferred by the surgeon compared to other techniques because it offers to him depth perception and tactile feedback from the resistance of tissue. Despite this, it presents disadvantages for the patient, including a large abdominal incision, prolonged hospitalization, increased postoperative analgesic requirements and increased morbidity [1]. Minimally invasive surgery is becoming increasingly common in gynaecological surgery. Both patients and surgeons experiment the benefits of laparoscopic surgery compared with laparotomy. First of all, they experience aesthetic results associated with small incision, shorter hospitalization and quicker return to work [2]. Compared with open surgery, laparoscopy has inherent sensory and mechanical requirements which make this procedure a challenging issue. Sensory limitations include loss of stereoscopic vision and partial loss of tactile sensation. Mechanical limitations are caused by operating through a fulcrum (the anterior abdominal wall) with levers (the shafts of the laparoscopic instruments). The robotic-assisted surgery is designed to overcome these limitations by enabling minimally invasive surgery with three-dimensional vision, ergonomically optimal positioning, tremor filtration and laparoscopic instruments with intra-abdominal articulation [3]. Robotic technology is a step in the continued evolution of laparoscopic technology. It was designed to facilitate laparoscopic surgery by improving precision, efficiency and comfort. Nowadays there is only one robot being used in gynaecologic surgery and approved for this specific use by the U.S. Food and Drug Administration (FDA): the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA). It consists of three components: the console, the Insite vision system and the surgical cart or patient-side cart. The first one is located remotely from the patient bedside and is connected by a cable to the video cart and robotic tower. The console houses a stereo viewer, which has an infrared beam to deactivate the robotic arms whenever the surgeon moves his head out of the console. The surgeon’s hands are inserted into manipulators, which convert the movements of the surgeon’s wrist and fingertips into electrical signals. The Insite video system consists of two video camera control boxes and two light sources. The robotic three-dimensional (3D) endoscope enters the abdominal cavity through an 8.5 or 12 mm cannula placed at or above the umbilicus. The surgical cart supports robotic arms and Endowrist instruments. Currently the system is available with either three or four robotic arms. One of the arms holds the endoscope,
while the other two to three arms hold the various Endo-
strong instruments. Robotic instruments enter through
dedicated 5 or 8 mm steel cannulas. Although 5 mm ro-
botic instruments do exist, their use in gynecologic
surgery is limited at this time, mostly due to the lack of
electrosurgical instrumentation [4]. Surgeon, seating at
the console, far from the operating table, telemanipulate
laparoscope and robotic arms using hands and feet. The
surgeon can perform intuitive movements at the console,
just as if he or she was operating in a conventional open
case. Moreover, the accuracy of movement of the robotic
arms and instruments can be scaled down to the surgeon’s
preference. Hand movements at the console occur in a
fluid and unrestricted environment. Foot switches are
used to activate monopolar and bipolar electrical currents
to the robotic instruments, to activate an harmonic
instrument, to operate the laparoscope in order to focus
the image, and to disengage the robotic arms from the
surgeon’s hands [5]. Three-dimensional vision tremor
filtration and motion scaling are some of the advantages of
robotic surgery [6]. Movement downscaling results in
improved surgeon accuracy and precision, while filtering
of hands tremor appears to have a lesser role for accuracy
[7]. The tip of the robotic instruments allows seven
degrees of freedom, surpassing the movements of the
human wrist. Many studies have shown the advantages of
robotic performance with respect to laparoscopy. Im-
proved suturing precision and faster intracorporeal knot
tying with robotic systems have been shown in studies
using training models as compared to laparoscopy [8].
Another important advantage of the robotic instrumentation is its usefulness in morbidly obese patients; in fact, the operating surgeon feels no resistance to the mo-
tement of the robotic instruments through the thick
abdominal wall [9]. A limitation of the da Vinci surgical
system is its size. Miniaturization of surgical robots is one
of the first achievements to be expected. Lack of tactile
haptics or tactile feedback (but it can be compensated by
three dimensional image), bulky robotic arms with large
excursion arcs that can lead to frequent collisions, limited
instrumentation, and the inability to move the surgical
table once the robot arms are attached to the ports, are
other disadvantages. One another potential disadvantage is the economics of the da Vinci. The current cost for the
da Vinci surgical system is around 1.5 milion dollars. Each
instruments costs $2000 for ten uses [5]. Concerning its
clinical applications, the da Vinci surgical system has
achieved increasing popularity in reproductive especially
in robotic assisted myomectomy, tubal re-anastomosis and
fertility preservation.

**Robotic applications in gynaecological surgery**

**Myomectomy**

Fibromatosis is the most common benign pelvic tu-
mor in women in reproductive age. Data show that 10%
to 15% ageing between 20 and 60 years require a sur-
gical procedure fro myomas [15]. Myomectomy is the
gold standard for the conservative surgical management
of leiomyomata in women desiring to preserve their fer-
tility [16]. The minimally invasive management of leio-
myomata, particularly laparoscopic, is often assumed to
be associated with greater morbidity and complicapa-
tions than traditional open abdominal myomectomy.
Laparoscopic myomectomy has always possessed inhe-
rent technical problems such as hemostasis, uterine
closure, and tissue extraction, all of which have been
associated with limitations of conventional laparoscopy
[17]. Because of this, many surgeons prefer to perform
conservative myomectomy through a laparotomic ap-
proach. Endoscopic management of leiomyomas is one
of the more challenging procedures in minimally invasive
surgery and requires a skilled surgeon [17]. Robotic-
assisted myomectomy has been introduced and encour-
aged to overcome laparoscopic limitations encountered
with the key steps of hysterotomy, enucleation, repair,
and extraction [18]. In 2004, Advincula and his team
published the first feasibility study with data from 35 pa-
ients [19]. The mean myoma weight was 223.2 ± 244.1 g
and the mean diameter was 7.9 ± 3.5 cm. The median
myoma number was 1.6 (range: 1 to 5). The mean blood
loss was 169 ± 198.7 ml; the mean operating time was
230.8 ± 83 minutes. Patients went home within a day.

Two major reproductive considerations have to be
made comparing open myomectomy techniques to mini-
mally invasive approaches: preservation of the endome-
trial cavity and adequate closure of the myometrium in
order to avoid uterine rupture [20].

For the success of a robot-assisted laparoscopic ap-
proach to myomectomy is important determining the size
and location of leiomyomata pre-operatively and the
selection of appropriate candidates for robotic myomect-
tomy. Women who may not be appropriate for robotic
myomectomy include patients with a uterus larger than
16-week size, multiple leiomyomas (more than 5 total),
which would necessitate significant reconstruction, a
single fibroid larger than 15 cm, or myomas close to the
cervix, broad ligament, uterine cornua, or uterine arte-
ries. These criteria are derived from the exclusion cri-
ria used in the 2009 Cochrane review of laparoscopic
myomectomy [20, 21]. Although a robotic approach may
be attempted in these patients, the risk of conversion to
laparotomy is expected to be higher. Considering that tactile sensation is lost with current robotic platforms, detailed preoperative imaging studies become a fundamental prerequisite for robot-assisted laparoscopic myomectomy. Preoperative mapping has several goals: assess the number, size, and location of all myomata in reference to the endometrial cavity, rule out adenomyosis and provide additional reassurance as to the benign nature of large uterine masses. Magnetic resonance imaging (MRI) has a high sensitivity and a low specificity for diagnosing leiomyomas and a high specificity and a low sensitivity for diagnosing adenomyosis [22].

The largest comparative study to compare robotic myomectomy with the standard laparoscopic approach was conducted also by Advincula et al. [23]. Fifty-eight patients with symptomatic leiomyomas were studied in a retrospective case-matched analysis with 29 patients in each arm. As expected, there were no differences in the case-matched variables of age, body mass index, and fibroid weight. Noteworthy were the findings of decreased estimated blood loss (mean, 195.69 [228.55] ml; 90% central range (CR), 50.00-700.00 vs 364.66 [473.28] ml; 90% CR, 75.00-550.00) and length of stay (mean 1.48 [0.95] days; 90% CR, 1.00-3.00) vs 3.62 [1.50] days; 90% CR, 3.00-8.00) compared with the laparotomy group. Both of these differences were statistically significant at \( p < 0.05 \). Complication rates were also lower in the robotic group. Operative time was longer in the robotic group (mean, 231.38 [85.10] minutes; 95% CI, 199.01-263.75) vs 154.41 [43.14] minutes; 95% CI, 138.00-170.82) \( (p < 0.05) \).

Nehzat, in 2009, compared the technical procedure, timing, and end results of robotic-assisted laparoscopic myomectomy (RALM) to a matched control standard laparoscopic myomectomy. They reviewed 15 cases of robotic surgery with 35 cases of laparoscopy. They found that surgical time for the robotic technique was 234 minutes (range 140-445) compared with 203 minutes (95-330) for the standard LM. The average time for assembly of the robot was 14 minutes (range 10-25 min) and the disassembly time was 3 minutes. There were no significant differences in mean blood loss or mean postoperative hospitalization time between the two groups. The RALM was more expensive than the standard LM.

Behara and his team [25] reported a cost minimization analysis of 3 myomectomy approaches: laparotomic (AM), laparoscopic (LM) and robotic assisted (RA) surgery. In the baseline analysis for the Existing Robot Model, abdominal myomectomy was the least expensive approach, compared with LM and RA. In the sensitivity analysis, the abdominal route remained the least expensive except for length of hospital stay, which for AM was greater than 4.3 days. In this case LM became the least expensive. When the 2 minimally-invasive options, LM and RA, were compared, the cost of the robotic approach was consistently higher.

Upfront hospital charges and professional reimbursement rates in the robotic group may be a deterrent to the application of this type of technology to a gynaecologic surgery practice. However, as technologic costs such as those attributable to depreciation are lowered, a robot-assisted approach to myomectomy may become the preferred option for hospitals because of significantly lower complication rates, length of stay, and nursing costs.

**Endometriosis**

Endometriosis is a chronic gynaecologic disorder that affects more than 70 million women and adolescents worldwide. Endometriosis can determine decrease in quality of life, sexual impairment and infertility. The monthly fecundity rate in women with endometriosis (2-10%) is significant lower than in those without endometriosis (15-20%) [26]. Surgery is considered the correct management when conservative therapy fails. In the past decades, laparoscopy, has replaced laparotomy for the treatment of endometriosis. Since the introduction of robotic surgery, the attention has focused on its advantages as compared to laparoscopic surgery. Liu et al, in 2008, experimented the feasibility of robotics for infiltrating bladder endometriosis. The bladder lesions were resected and the defects were then closed in two layers. Additional resection of infiltrating endometriosis was then performed. The authors reported an estimated blood loss of 100 ml with a total operative time of 297 min. There were no complications to the procedure, and the patient was discharged home on postoperative day number two [27].

Nezhat and his team published a retrospective study comparing 40 robotically-assisted laparoscopies and 38 traditional laparoscopies for the treatment of endometriosis. Patients were matched for age, body mass index and stage of endometriosis. This study failed to find any significant difference in blood loss, hospitalization, intra-operative, or post-operative complications. The robotic surgical arm had a significantly longer mean operative time compared to traditional laparoscopy (191 min and 159 min, respectively). Of note, the majority of the cases in this study had minimal or mild disease with 77.5% or the robotic cases and 78.9%, of the traditional cases being stage I or II disease [28]. They concluded that the use of the robotic system is not recommended for surgical removal of endometriosis, in
particular if stage I or II disease, but the number of patients enrolled was definitely too low to consider those results as reliable, especially with regard to stage III and IV disease. Robotic surgery for endometriosis was successful for stage IV endometriosis without conversion to laparotomy.

Concerning the treatment of endometriosis, perhaps the use of computer-enhanced technology may be reserved as an enabling device for more severe cases, such as segmental bladder, bowel and ureteral resection.

Recently Ercoli et al. evaluated the robotic treatment of colorectal endometriosis. They performed 22 robotic-assisted laparoscopic excisions of deep infiltrating endometriosis with colorectal involvement. They reported no laparotomic conversions, no necessity of any blood transfusion, no intra-operative complications. None of the patients had ileostomy or colostomy. No major post-operative complications were observed, except one small bowel occlusion 14 days post-surgery that was resolved in 3 days with medical treatment. Post-operatively, a statistically significant improvement of patient symptoms was shown for all the investigated parameters [29]. Very important is the preoperative assessment of deep infiltrating endometriosis. The goal diagnostic exam is the three-dimensional (3D) MRI reconstructions, in addition of ultrasound examination. In particular, improves diagnostic accuracy and staging of deep infiltrating endometriosis providing the exact volume of the lesions and enabling a precise mapping of these before surgery in the rectosigmoid and bladder wall involvement [30].

Tubal re-anastomosis

Tubal disease is responsible for the 25% to 35% of female infertility [10]. Tubal sterilization is a popular contraceptive option for women even if the regret from this kind of procedure is reported to be about 20.3% especially in young patients. After permanent sterilization, restoring fertility is possible only through in vitro fertilization program or tubal re-anastomosis. Tubal re-anastomosis is a procedure traditionally performed as an open surgery. When minimally invasive surgery started to become integrated into gynaecological surgery, laparoscopic tubal re-anastomosis emerged [11]. Laparoscopic procedure is highly challenging because tubal anastomosis requires adequate visualization of the fallopian tube lumen, precise suturing, and careful manipulation of delicate tubes, so the use of robotic technology comes easily into consideration.

In 2000, the first study for tubal re-anastomosis on the da Vinci surgical system was published by Degueildre et al. [12]. They considered 8 patients who had previously undergone laparoscopic tubal sterilization and who requested tubal re-anastomosis. Sixteen tubes were successfully repaired. The mean time of duration of the robotic-assisted procedure was 140 minutes, while the mean surgical time was 52 minutes per tube. Five of the 8 patients underwent hysterosalpingography, which demonstrated at least unilateral patency, and 2 pregnancies were reported within 4 months after surgery. Moreover, the operating time was shorter with the one of open surgery. Rodgers et al. compared 26 robot-assisted tubal re-anastomosis cases with 41 re-anastomosis performed through minilaparotomy. No difference was found for blood loss or duration of hospitalization. Surgical times were significantly longer for the robotic procedure compared with open surgery. Considering the costs, robotic re-anastomosis results more expensive than the laparotomic one: they reported a median cost differential of $1446 (cost analysis did not include the base cost of the surgical system and the annual maintenance fee [13]. Hospitalization times, pregnancy (61% robotic versus 79% minilaparotomy), and ectopic pregnancy rates were not significantly different. Complications occurred less frequently in the robotic group, and the return to normal activity was shorter in this group (0.8 weeks vs 2.8 weeks). The prospective cohort study by Dharia Patel et al. compared robot-assisted tubal re-anastomosis versus open microsurgical tubal re-anastomosis cases with hospital admission [14]. Surgical times were significantly longer for the robot compared with open surgery. Time to recovery was significantly less for the robot-assisted re-anastomosis group compared with the open surgery group (11.1 days: range: 2 to 28 days, and 28.1 days: range: 21 to 42 days, respectively). Pregnancy (62.5% robotic versus 50% open) and ectopic pregnancy rates were not significantly different.

Data seem to indicate that robot-assisted tubal re-anastomosis is safe and its results are comparable with those obtained by classic tubal microsurgery performed by trained REI subspecialists. 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.

Fertility preservation

Also in fertility preservation field may benefit from the use of robotics. Early stages of cervical cancer can be treated with radical trachelectomy and lymph node dissection, leaving the uterus for future childbearing. The
technique, using the robotic system, was performed by Burnett in five women and he reported two significant complications including one port-site bowel herniation requiring surgery and one haemorrhage from the inferior epigastric vessel requiring transfusion [31]. Ramirez et al. also published a series of four patients with the only complication reported being a transient post-operative neuropathy [32].

Ovarian cryopreservation and transplantation is an option offered to women affected by a oncological disease and that have to deal with gonadotoxic chemotherapy. The reimplantation of the ovarian tissue can restore women’s fertility and give to this patients the possibility to achieve pregnancy. The reimplantation procedure is highly challenging because it requires very fine suture and the necessity to not damage the ovarian tissue. Recently, the da Vinci system was used in ovarian tissue transplantation [33]. Clearly, additional studies are needed to further explore the use of robotic surgery for ovarian transplantation.

Conclusion

Robotic began as a form of entertainment and has evolved into a technology used in the fields of computers, automotives, entertainment, ocean/space exploration, and health care. In medicine and more specifically in surgery, robotic technology has become a viable surgical alternative to provide minimally invasive surgery with the advantages of traditional open surgical techniques. Robotic-assisted laparoscopy is new to the field of surgery. Since its introduction, surgeons have been intrigued by it, and each discipline is trying to find its appropriate role. It appears to assist the less-skilled laparoscopist in performing surgery that one might have not attempted. It might be the answer to the shortcomings of laparoscopy being adopted by more surgeons. Robotic-assisted laparoscopy simply acts as a bridge between laparotomy and advanced operative laparoscopy. It provides 3D vision and easier suture capability without tremor. Robotic is nothing more than an enhancement along the continuum of laparoscopic technological advances and represents only the beginning of numerous more forthcoming advances. The high cost of this technology is holding back a more widespread use, but expected market competition may induce an acceleration in the diffusion and advancement of robotic surgery.

References

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