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Robotically assisted laparoscopic microsurgical tubal reanastomosis: a feasibility study

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Objective: To assess the feasibility and reproducibility of laparoscopic microsurgical tubal anastomosis using a remote-controlled robot.

Design: Descriptive case study.

Setting: Academic medical center.

Patient(s): Eight patients with previous laparoscopic tubal sterilization who requested tubal reanastomosis.

Intervention(s): Systematization of the operative steps for laparoscopic tubal reanastomosis using a remote-controlled robot.

Main Outcome Measure(s): Primary outcome measures were feasibility and reproducibility; secondary measures were tubal patency, operative time, complications, and ergonomic qualities.

Result(s): The 16 tubes were successfully reanastomosed and patency was confirmed. The mean time that the robotic system was in use was 140 minutes, and mean surgical time was 52 minutes per tube.

Conclusion(s): Laparoscopic microsurgical tubal reanastomosis after tubal sterilization can be performed using a remote-controlled robotic system. The robot, which has three-dimensional vision, allows the surgeon to perform ultraprecise manipulations with intraabdominal articulated instruments while providing the necessary degrees of freedom. Systematization of the operative steps allowed performance of the operation at a speed that compares favorably with the time needed for open microsurgical techniques. Larger series are needed to assess postoperative pregnancy rates. (Fertil Steril® 2000;74:1020–2. ©2000 by American Society for Reproductive Medicine.)

Key Words: Robot, laparoscopy, microsurgery, tubal anastomosis

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Use of robotic master/slave tools in surgery aims to improve both motor (efferent) and perceptive (afferent) performance of the surgeon, thereby benefiting the patient. Laparoscopic microsurgical tubal anastomosis is an interesting example. Gomel (1) standardized use of this technique in open surgery more than 20 years ago. The U.S. National Survey of Family Growth estimates that among the approximately 1 million sterilization procedures performed each year, 1% of patients request reversal of tubal ligation. Fertility outcome in large series after open microsurgery have been extensively evaluated (2), with subsequent pregnancy rates of up to 70% and rates of ectopic pregnancy from 5% to 7%.

Although the development of assisted procreation techniques and laparoscopy have gradually modified the approach to male and female infertility, microsurgical tubal reanastomosis is the first choice for patients > 37 years of age. In younger patients, the burden of tubal reanastomosis, a single surgical procedure, must be weighed against possible multiple IVF attempts.

Laparoscopic microsurgery has not yet gained wide acceptance. It is time-consuming and nonergonomic, and it tends to be oversimplified to overcome the technical limitations inherent in classic endoscopic surgery (3). Robotically assisted laparoscopic tubal reanastomosis may prove to combine the advantages of open microsurgery and laparoscopy without the disadvantages associated with abdominal incision, exposure of the pelvic viscera, and compromised precision in laparoscopy.

TABLE 1

Operating time, robotic use time, and total operating time.

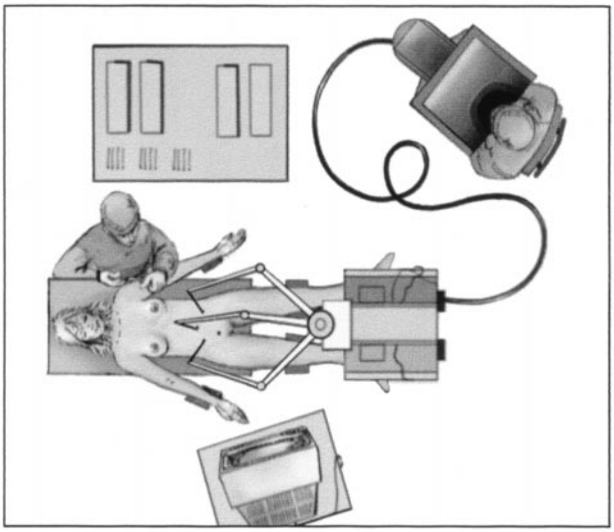
Patient	Left tube (min)[a]	Right tube (min)[a]	Robotic use time (min)[b]	Total time (min)[b]
1	74	68	244	272
2	52	41	125	195
3	45	40	125	200
4	82[d]	45	150	175
5	42	50	120	150
6	47	41	109	134
7	46	48	127	166
8	45	61[e]	124	160

[a] Time needed for dissection, removal of clips or fibrosis, and suture of all layers.
[b] Total laparoscopic time from the moment the robot is positioned until the robot is removed.
[c] Total time = complete procedure (skin to skin)
[d] Adhesiolysis and resection of an important fibrotic reaction on the tube.
[e] Mechanical problem (mispositioning of the right robotic arm).

Degueldre. Robotic laparoscopic tubal reanastomosis. Fertil Steril 2000.

FIGURE 1

Patient–robot position and remote-controlled surgical unit.



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We describe a new laparoscopic procedure using remotely controlled robotic technology for the microsurgical reanastomosis of human fallopian tubes.

MATERIALS AND METHODS

Subjects

Eight women 30–44 years of age (mean, 39.8 years), parity 1–4, body mass index 20–29 kg/m^2 (mean, 23 kg/m^2) who requested restoration of their fertility after tubal sterilization were included in the study. Seven patients had undergone laparoscopic sterilization with Hulka clips; one (case 6, Table 1) had undergone postpartum ligation using the technique of Pommeroy. The male partner of each patient had normal results on semen analysis. The eight patients were asked to undergo hysterosalpingography 3 months after surgery if they were not pregnant.

The ethical committee of University Hospital Saint-Pierre approved the study. Patients underwent the surgery after providing written informed consent.

Robot

The da Vinci Surgical System (Intuitive Surgical, Mountain View, CA) is a computer-driven surgical tool with two major components: a mobile console and a surgical arm unit. The mobile console, which is operated by the surgeon with two handles and three foot pedals, controls the three mobile arms of the robot, intraabdominal manipulations, camera movements, and unipolar coagulation. The console can be positioned anywhere in or outside the operating theatre. In a sitting position, the surgeon looks through a binocular three-dimensional (3-D) viewing monitor. The movements of the operator are digitalized, scaled at 1/1, 1/3, or 1/5, and transmitted by computer without noticeable delay to the intraabdominal instruments.

The extraabdominal movements of the instruments controlled by the robotic arms have four degrees of freedom. The intraabdominal articulations of the microinstruments at 2 cm from the tip are comparable to those of the human hand and wrist, with the same degrees of freedom.

For all procedures performed in this study (which represents an evaluation phase), an engineer was present.

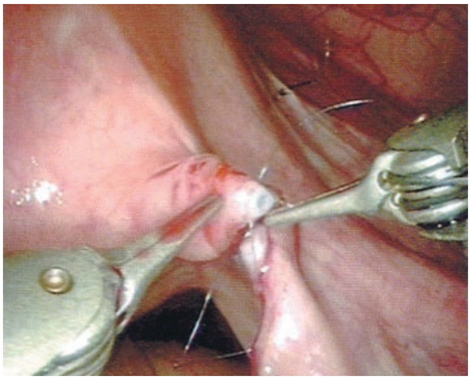
Perioperative Settings

The patient is placed in a modified dorsal lithotomy and Trendelenburg position, with thighs slightly flexed, to allow proper positioning of the robot and mobilization of the uterus. A Foley catheter and a uterine manipulator allowing chromotubation are inserted. After creation of a pneumoperitoneum, a 12-mm trocar and 10-mm laparoscope are inserted to assess pelvic status and feasibility. Two 8-mm trocars are introduced lateral to the epigastric arteries, 2 cm below the umbilical level. A fourth trocar, 5 mm, is inserted in the suprapubic region at 2 cm from the midline. Periadnexal and pelvic adhesions are treated.

While this classic laparoscopy is being performed, the surgical robotic unit is draped. The robot is then positioned with its three mobile arms at the leg-end of the operating table (Fig. 1). The central arm of the robot is connected to a 12-mm stereolaparoscope. The two lateral arms are connected to the robotic instruments. This preparation takes about 15 minutes.

FIGURE 2

A forceps grasps the proximal portion of the right tube, and 8-0 Prolene thread is passed through the muscularis by using a microneedle holder. Both instruments are articulated intra-abdominally.



Degueldre. Robotic laparoscopic tubal reanastomosis. Fertil Steril 2000.

Microsurgical Technique

The uterus is positioned to allow optimal access to the adnexa. The operation, performed under robotic control, is divided into two sequences for each tube—dissection and suture—to minimize external manipulation of instruments.

Dissection

The larger grasper is used to grasp the tubal clip. While gentle traction is applied, the proximal and distal parts of the tube are dissected using microscissors. A second surgeon irrigates the operating field with a saline solution at 37°C to optimize visualization. Hemostasis, when needed, is done under manual control by the second surgeon using microbipolar forceps. The excised clip is immediately removed through the 5-mm trocar.

Suture

To reduce tension, the defect of the mesosalpinx is stitched intracorporeally with 6-0 Prolene thread on a curved needle by using two microdissector forceps. For this and the following steps, the suture material is brought into the abdominal cavity by the second surgeon through the 5-mm trocar by using a traumatic grasper.

End-to-end tubal anastomosis is performed in two layers by using microforceps. The muscularis is sutured at 6-, 10-, and 2 o'clock with 8-0 Prolene thread (Fig. 2). The serosal layer is sutured with three to four knots by using 7-0 Prolene thread. All knots are tied by using the intracorporeal technique. After every suture, the needle is either fixed in the prevesical peritoneum or removed immediately through the 5-mm trocar by the second surgeon. Patency of the anastomosis is assessed by injection of methylene blue dye through the uterine chromopertubator.

As all the requirements of microsurgical manipulations are met, the technique is the exact replication of dissection and suture in open procedures and does not vary for the consecutive cases.

RESULTS

Bilateral tubal anastomosis was performed in eight patients, and patency of each tube was assessed. Operating times are shown in Table 1.

We created 128 intracorporeal sutures. Of the 48 knots with 8-0 Prolene thread, 4 sutures broke when tying (2 owing to excessive traction on the knot and 2 owing to lack of parallelism of the jaws of the needle holder).

No patient experienced perioperative or postoperative complications. Patients left the hospital after a mean stay of 1.5 days in good general condition.

Five of the eight patients underwent hysterosalpingography. Four patients had bilateral patent tubes, and one had unilateral patency. Two pregnancies occurred within 4 months after surgery.

DISCUSSION

Both motor and perceptive performance are poor in laparoscopy. The length of the instruments, the fixed entry place on the abdominal wall with a subsequent lever effect, and the absence of intraabdominal articulated tools limit motor performance. Perceptive performance is reduced by two-dimensional vision and partial loss of tactile sensations. Robotic technology may help to overcome some of these problems. The first task is to find an adequate robotic instrument.

In the preclinical phase, we tested several positions of a robotic surgical unit in a cadaver model. Because of the design of the unit's three mobile arms and the fact that reanastomosis is a symmetrical bilateral procedure, the best position is between the legs. This position interferes with access to the uterine manipulator, but the procedure requires few uterine displacements. The symmetrical position of the two lateral trocars gives all the extracorporeal degrees of freedom required for movements of the surgical arms without twisting of the instruments. The central arm conducting the laparoscope performs few movements and is far away from the other arms, because the operating field is confined to a restricted area. This central position limits access to the patient. For this reason, the suprapubic port is inserted 2 cm lateral to the midline.

Because none of the instruments (except for a large hook) is suitable for unipolar or bipolar coagulation, it became clear after the first operation that the procedure required only three robotic instruments: a large grasper, microscissors, and micrograsping forceps. Because the change of instruments, although easy, takes about 1 minute, we defined the sequences of instrument entry for a two-step procedure.

The second operator has access to the surgical field through a 5-mm suprapubic port. In the first sequence, this port is used for irrigation and microbipolar coagulation. During the second sequence, the port is used to insert and cut suture material and to remove needles. The time wasted in changing the instruments manipulated by the robotic arms is limited but important. The operator remains focused on the operative field while the second operator performs the ancillary manipulations. At this stage of development, the da Vinci robot improves the motor (efferent) aspect of reanastomosis.

The robotic arms and the unique design of the instruments with intraabdominal articulations give the surgeon all necessary degrees of freedom, allowing performance of complex movements in a limited space. Herein lies the fundamental difference between the robotically controlled procedure and other laparoscopic techniques: The mobile arm gives the necessary stability, but the lever effect inherent in the length of laparoscopic instruments is eliminated by the intraabdominal articulations.

The microinstruments are well suited to the task and the size of the suture material. Knots can be tied easily. The computer eliminates unintentional small hand movements and tremors—an important improvement in surgical precision compared with open microsurgery. The surgeon's movements can be minimized according to the task being performed.

The improvement in perception afforded by the robotic system is binocular 3-D vision. This provides the surgeon with operation facilities comparable to those offered by using an operating microscope.

One important element is missing: a haptic interface with tactile perception. This limitation can only be overcome by cognitive integration of the desired forces applied on tissue and suture material. This lack of tactile perception accounts for 11% of ruptured suture material.

Despite these limitations, the remote-controlled system has advantages. The robot is easy to manipulate, and the procedure can be learned quickly. In this series, from the second patient on, the operating time compared favorably with the time required to perform open microsurgery.

Open abdominal procedures tend to be replaced by endoscopic surgery. Although a report by Koh and Yoon (3) has shown the feasibility of a laparoscopic microsurgical approach with excellent results (pregnancy rates of 71% and 77.5%), the procedure requires time and dexterity and is far from ergonomic. Falcone et al. (4) provided the first published report of microsurgical anastomosis with a master/slave robot on animal uterine horns and in humans. The robot that was used improved the surgeon's ergonomic performance by suppressing tremors and allowing scaling of the maneuvers. However, the fundamental limitation inherent in laparoscopy—partial loss of degrees of freedom of intraabdominal mobility—was not solved because of the absence of intraabdominal articulations.

Laparoscopic microsurgery might show success rates similar to those of open surgical procedures using the same technique. Only a study in large, controlled series with similar outcome measures (feasibility, patient satisfaction, and intrauterine pregnancy rate) will define the utility of robotically assisted laparoscopic microsurgery.

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References

1. Gomel V. Tubal reanastomosis by microsurgery. Fertil Steril 1977; 28:59–65.
2. DeCherney A, Mezer H. Current approach to tubal anastomosis. Obstet Gynecol Annu 1985;14:277–87.
3. Koh CH, Janik GM. Laparoscopic microsurgical tubal anastomosis. Obstet Gynecol Clin North Am 1999;26:189–200.
4. Falcone T, Goldberg J, Garcia-Ruiz A, Margossian H, Stevens L. Full robotic assistance for laparoscopic tubal anastomosis: a case report. J Laparoendosc Adv Surg Tech A 1999; 9:107–13.