

Robot-assisted segmental resection of tubal pregnancy followed by end-to-end reanastomosis for preserving tubal patency and fertility

An initial report

Joo Hyun Park, MD^{a,c}, SiHyun Cho, MD^{a,c}, Young Sik Choi, MD^{b,c}, Seok Kyo Seo, MD^{b,c},
Byung Seok Lee, MD, PhD^{b,c,*}

Abstract

The objective of this study was to evaluate whether robotic tubal reanastomosis after segmental resection of tubal pregnancy is a feasible means of preserving tubal integrity and natural fertility in those with compromised contralateral tubal condition.

The study was performed at a university medical center in a retrospective manner where da Vinci robotic system-guided segmental resection of tubal ectopic mass followed by reanastomosis was performed to salvage tubal patency and fertility in those with a single viable fallopian tube. Of the 17 patients with tubal pregnancies that were selected, 14 patients with successful tubal segmental resection and reanastomosis were followed up. The reproducibility of anastomosis success and cumulative pregnancy rates of up to 24 months were analyzed.

Patient mean age was 28.88 ± 4.74 years, mean amenorrheic period was 7.01 ± 1.57 weeks and mean human chorionic gonadotropin (hCG) level was 9289.00 ± 7510.00 mIU/mL. The overall intraoperative cancellation rate due to unfavorable positioning or size of the tubal mass was 17.65% (3/17), which was converted to either salpingectomy or milking of ectopic mass. Of the 14 attempted, anastomosis for all 14 cases was successful, with 1 anastomotic leakage. One patient wishing to postpone pregnancy and 2 patients where patency of the contralateral tube was confirmed during the operation, were excluded from the pregnancy outcome analysis. Cumulative pregnancy rate was 63.64% (7/11), with 3 (27.27%) ongoing pregnancies, 3 (27.27%) livebirths, and 1 missed abortion at 24 months. During the follow-up, hysterosalpingography (HSG) was performed at 6 months for those who consented, and all 10 fallopian tubes tested were patent. No subsequent tubal pregnancies occurred in the reanastomosed tube for up to a period 24 months.

For patients with absent or defective contralateral tubal function, da Vinci-guided reanastomosis after segmental resection of tubal pregnancy is feasible for salvaging tubal patency and fertility.

Abbreviations: ART = assisted reproductive technique, hCG = human chorionic gonadotropin, HSG = hysterosalpingography, IVF = in vitro fertilization, MTX = methotrexate.

Keywords: ectopic pregnancy, fertility-preserving surgery, robotic surgery, tubal factor infertility, tubal pregnancy, tubal reanastomosis, tubal segmental resection

1. Introduction

Ectopic pregnancy, the most common site being the fallopian tube, is known to affect approximately 20 of 1000 pregnant

women and accounts for 4% to 10% of pregnancy-related deaths.^[1-3] Unless spontaneous regression occurs, most tubal pregnancies without intervention, will rupture into the abdominal cavity creating various degrees of hemoperitoneum. The occurrence of tubal pregnancy in one tube predisposes to a 6–7-fold risk of developing another contralateral tubal pregnancy since both fallopian tubes share similar risk factors including inflammation and adhesion.^[3,4] For women who have unequivocal contralateral tubal function or received a previous salpingectomy, an additional salpingectomy predisposes to complete tubal factor infertility. Nevertheless, the most frequent form of surgery for tubal pregnancy is salpingectomy, where the procedure itself leads to permanent loss of fallopian tube structure and function.

Complete removal of the ectopically implanted embryo is usually achieved with the resection of the whole fallopian tube even when the remaining tubal segments are viable. Conventional options including methotrexate (MTX) therapy, salpingotomy, and milking of the ectopic implant can be considered for preserving the integrity of the affected fallopian tube. However, only a proportion of ectopic pregnancies are diagnosed early and are candidates for such conservative management.^[5] Tubal

Editor: Jian Liu.

The authors report no conflicts of interest.

^a Department of Obstetrics and Gynecology, Gangnam Severance Hospital,

^b Department of Obstetrics and Gynecology, Severance Hospital, ^c Institute of Women's Life Medical Science, Yonsei University College of Medicine, Seoul, South Korea.

* Correspondence: Byung Seok Lee, Department of Obstetrics and Gynecology, Yonsei University College of Medicine, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea (e-mail: ydob@yuhs.ac).

Copyright © 2016 the Author(s). Published by Wolters Kluwer Health, Inc. All rights reserved.

This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially.

Medicine (2016) 95:41(e4714)

Received: 6 May 2016 / Received in final form: 13 July 2016 / Accepted: 3 August 2016

<http://dx.doi.org/10.1097/MD.0000000000004714>

pregnancies are more commonly discovered when symptoms become prominent due to rupture or hemoperitoneum, narrowing the window of opportunity for a successful MTX therapy.^[6,7] Frequently, tubal pregnancies are accompanied by irreversible damage to the affected tubal segment due to trophoblastic invasion. As most implants are highly vascularized, sole evacuation of the conceptus becomes risky due to bleeding and a subsequent salpingectomy will frequently be chosen. Also, the concern over the added risk of suffering another tubal pregnancy in the salpingotomized fallopian tube has limited its popularity.^[8,9] When tubal factor infertility occurs as a result of losing both fallopian tube integrity, in vitro fertilization (IVF) is also an option for conceiving. However, preserving the possibility of natural pregnancy is nevertheless important depending on the patient's individual circumstances and regarding cost-effectiveness.

Tubal reanastomosis using the da Vinci system has been reported for patients who wish to recover fertility after tubal ligation^[10–15] and also with conventional laparoscopy.^[16–19] Robotically guided segmental resection of tubal pregnancy and end-to-end reanastomosis have not been previously elaborated. The da Vinci robotic system provides optimal microsurgical tubal reanastomosis conditions for this purpose, where the improved ergonomics provide a higher degree of freedom for suture placement and tissue handling.

Taking full advantage of the da Vinci robotic system, we propose performing segmental resection tubal pregnancy and subsequent end-to-end reanastomosis of the remaining segments as a means of salvaging natural fertility in women with a single viable fallopian tube. Cases where tubal pregnancy has occurred in those with absent or occluded contralateral fallopian tube were primarily recruited. The success rates, reproducibility of techniques, and pregnancy rates with a follow-up of up to 24 months were analyzed.

2. Methods

2.1. Patient selection

In this retrospective study, a total of 17 segmental resections of tubal pregnancy followed by end-to-end reanastomosis were attempted using the da Vinci robotic system (Intuitive Surgical, Mountain View, CA) for tubal pregnancy from Aug 2012 to April 2014 at the Department of Obstetrics and Gynecology, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, Korea. The study was approved by the institutional review board (Gangnam Severance Hospital). All surgeries were performed by a team with the same supervising faculty experienced with gynecologic laparoscopy as well as robotic surgery with the da Vinci system. The supervising surgeon also had expertise in mini-laparotomy-microscopy-guided and laparoscopy-guided tubal reanastomosis following tubal ligation. Collected data were retrospectively analyzed for up to a period of 24 months. A total of 14 patients were actually eligible for the reanastomosis since intraoperative findings rendered 3 patients inappropriate for the procedure and were converted to salpingectomies. Informed consent was obtained from all patients after providing a detailed description of the operative process and possible associated complications. The possibility of suffering another tubal pregnancy after the anastomosis was also informed. Primary indication for recruitment was those with a previous contralateral salpingectomy as a result of previous tubal pregnancy or isolated hydrosalpinx in which an additional

salpingectomy would result in complete tubal factor infertility. Patients with complete obstruction of the contralateral tube as a result of previous MTX therapy for contralateral tubal pregnancy were also recruited for the reanastomosis procedure. As patients who have received contralateral salpingectomy as a part of surgery for endometriosis or other benign ovarian tumors would have confounding factors for subsequent pregnancy rates, these patients were not enrolled for the analysis. Patients with both fallopian tubes with risk factors for tubal dysfunction wishing to preserve the affected tube were also recruited but were excluded from the pregnancy outcome analysis. Other options for future trial of pregnancy were also explained, including salpingectomy followed by assisted reproductive techniques. The diagnosis of tubal pregnancy was established through symptoms, menstrual history, pelvic ultrasonography findings, and adjunctive serum human chorionic gonadotropin (hCG) levels. Patient enrollment was decided based on the following criteria: those diagnosed with tubal pregnancy actively seeking to conceive afterwards with stable vital signs, ages under 40 years, those with spontaneous or post-MTX rupture, presence of fetal heartbeat, and serum hCG levels initially over 5000 mIU/mL or elevated hCG levels despite MTX therapy. Exclusion criteria were unstable vital signs including increased pulse rate and hypotension, intractable pain, hemoperitoneum greater than 500 mL, ectopic implants greater than 5 cm, preoperative serum hCG levels of less than 1500 mIU/mL without rupture where MTX therapy would be the primary choice, as well as those with hCG level decrease of more than 50% after 48 hours. Pregnancies within close proximity to or within the cornual area were also excluded as well as those occupying the fimbria. Information including detailed obstetrical and gynecological history with reference to medical records was obtained.

2.2. Positioning of the robotic system

The patients were placed in dorsal lithotomy and Trendelenburg position under general anesthesia. A Kronner uterine manipulator was inserted. A 12-mm trocar was placed at the umbilicus for a 30° camera insertion. An 8-mm trocar was placed for the 1st robotic arm, 8 cm left lateral and 2 cm caudal, and another 8-mm trocar for the 2nd robotic arm 8 cm right lateral and 2 cm caudal to the umbilical camera port. A transparent 5-mm accessory port was placed in the left lower quadrant at the level of left anterior superior iliac spine, making sure there is minimal collision with the robotic arms when accessory tools are used (Fig. 1). The robot was docked in a conventional manner between the patient legs. Irrigation, suction, introduction, and removal of suture materials as well as indwelling of silastic drainage at completion were carried out through the accessory port. The first assistant stood at the patient's left and the second assistant on the patient's right side.

2.3. The operative procedure

After appropriately placing the robotic tools into the abdominal cavity, complete suction, irrigation, and removal of any blood clots were performed. Using the Precise or fenestrated bipolar forceps, the fallopian tube was manipulated by grasping the serosa to delineate the portion which needs to be resected. Any adhesions were lysed and the broad ligament was mobilized to prevent distortion of the remaining tubal segments. Adequate bleeding control of the ectopic mass was established in prior, but a clean cut was eventually placed just

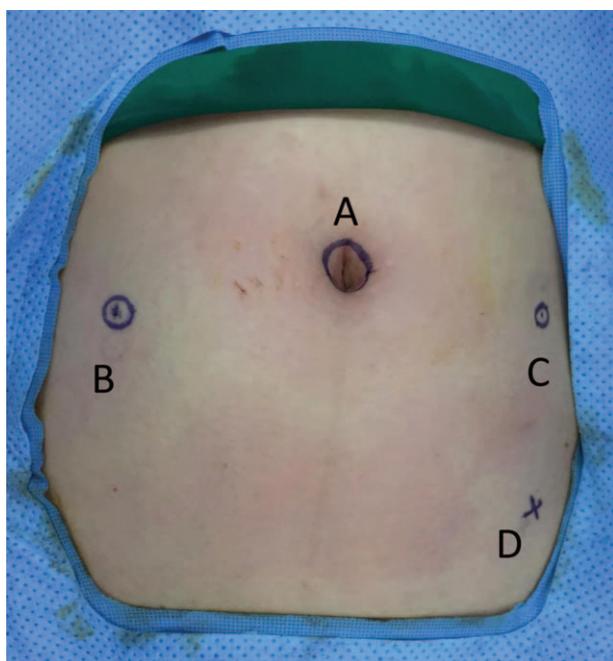


Figure 1. Port placement for the tubal reanastomosis procedure. A 12-mm camera is inserted at the umbilicus (A); 8-mm port for robotic arm 1, utilizing either monopolar scissors or a wristed needle driver (B); 8-mm port for robotic arm 2, typically using bipolar forceps (C), when the surgeon has right dexterity; a 5-mm transparent accessory port is placed in the left lower quadrant (D) for the 1st assistant to manipulate.

proximal and distal to the ectopic implant to minimize electrical injury to the tubal flaps. Bleeding from the mesosalpinx was controlled with limited, focal use of bipolar energy. Chromopertubation was performed before the anastomosis using diluted indigo carmine solution (5 mL in 100 mL of 0.9% NaCl solution) to check for patency of the proximal tubal segment (Fig. 2). To prevent thrombosis, diluted heparin solution (5000U in 1000 mL of 0.9% NaCl solution) was dripped on the resected tubal surface during anastomosis. Using the bipolar forceps as a grasper via the first robotic arm and the MegaSuture Cut (Intuitive Surgical, Mountain View, CA) forceps via the 2nd robotic arm, interrupted sutures were placed. The mesosalpinx was approximated using #6-0 Vicryls with interrupted sutures. With the direction of the mesosalpinx designated as 6 o'clock, the tubal epithelium was approximated with #7-0 Vicryls at the 12, 3, 6, and 9 o'clock sites with interrupted sutures. The sutures were left untied until sutures in all 4 directions were properly placed and were sequentially tied. The muscularis layer was then approximated with 4 interrupted sutures using #7-0 Vicryls. Then the serosa around the anastomosed area was approximated with interrupted sutures using #6-0 Vicryls (Fig. 3). To check for patency as well as any leakage at the anastomosis site, chromopertubation with indigo carmine solution was performed via the uterine cannula (Fig. 3). The abdominal cavity was thoroughly irrigated and an antiadhesive film was deposited on the anastomosed fallopian tube to prevent adhesion as well as shearing. A closed silastic drain was placed through the accessory port puncture site to check for postoperative bleeding. Parameters for successful immediate operative outcomes were measured and recorded.

2.4. Postoperative follow-up

Prognostic parameters including intrauterine pregnancy rates, ongoing pregnancies, live births, miscarriages, and subsequent ectopic pregnancies were recorded. Routine postoperative follow-ups were performed at 1 week, 6 months, 12 months, and 24 months, with exception for those who have already conceived. Routine blood workup and stitch out was performed at 1 week. During the follow-up period, hysterosalpingography (HSG) was performed at 6 months for those who have consented and pregnancy outcomes were monitored and analyzed at 12 months and 24 months postoperatively. GraphPad Prism software (La Jolla, CA) was used to test for normality and to evaluate mean, standard deviation, and confidence intervals or range.

3. Results

Of the 14 patients, 12 patients had previous history of tubal surgery or suspected tubal occlusion, 10 with contralateral salpingectomy and 2 with complete obstruction of the contralateral tube as a result of previous MTX therapy, confirmed during the surgery. The mean age of patients was 28.88 ± 4.75 (range 19–37) years and mean body mass index was 21.01 ± 1.28 (range 19.41–24.22) kg/m^2 . Mean gravidity and parity were 1.94 ± 0.99 and 0.06 ± 0.25 , respectively. The mean period of amenorrhea at the time of surgery was 7.01 ± 1.57 (range 3.71–10.29) weeks and mean preoperative serum hCG level was 9289.00 ± 7510.00 (range 1007.00–26353.00) mIU/mL. Time elapsed from diagnosis to the commencement of surgery on average was 28.31 ± 19.11 (range 4.65–70.20) hours. Two of the 14 (14.29%) patients had ruptured fallopian tubes after MTX therapy and surgical management was decided due to severe pain (Table 1).

3.1. Intraoperative and immediate postoperative findings

Mean total surgery time was 194.60 ± 31.28 (range 102.00–235.00) minutes, with mean 7.38 ± 1.63 (range 5.00–10.00) minutes docking time and 147.2 ± 32.54 (range 48.00–186.00) minutes console time. Mean tubal mass size was 3.47 ± 1.33 (range 1.60–5.50) cm. The mean volume of hemoperitoneum estimated at the beginning of surgery was 281.30 ± 228.70 mL. The most common site of implantation was the ampulla (78.57%, 11/14), followed by the isthmic portion (21.43%, 3/14). Mean preoperative hemoglobin level was 12.43 ± 1.41 g/dL and postoperative hemoglobin level was 10.08 ± 1.76 g/dL. After the reanastomosis, successful passage of indigo carmine dye via the fimbrial end was observed in all 14 cases. However, in one ampullary pregnancy where there was considerable discrepancy between the proximal and distal tubal segments, focal leakage of dye was observed at the anastomosis site. Mean residual tubal length after reanastomosis was 6.05 ± 0.75 (range 5.00–7.50) cm. From the 17 cases, initially attempted 14 (82.35%) cases were actually appropriate for reanastomosis and thus 3 were excluded from the final analysis. Two isthmic pregnancies too close to the cornual area and 1 pregnancy overlying the fimbrial end were considered inappropriate for the procedure. Either salpingectomy or milking was inevitably performed, showing an intraoperative cancellation rate of 17.65%. Postoperative transfusion was required in 2 of the 14 (14.29%) patients who received the anastomosis. Mean hospitalization time was 3.50 ± 0.82 days (Table 2).

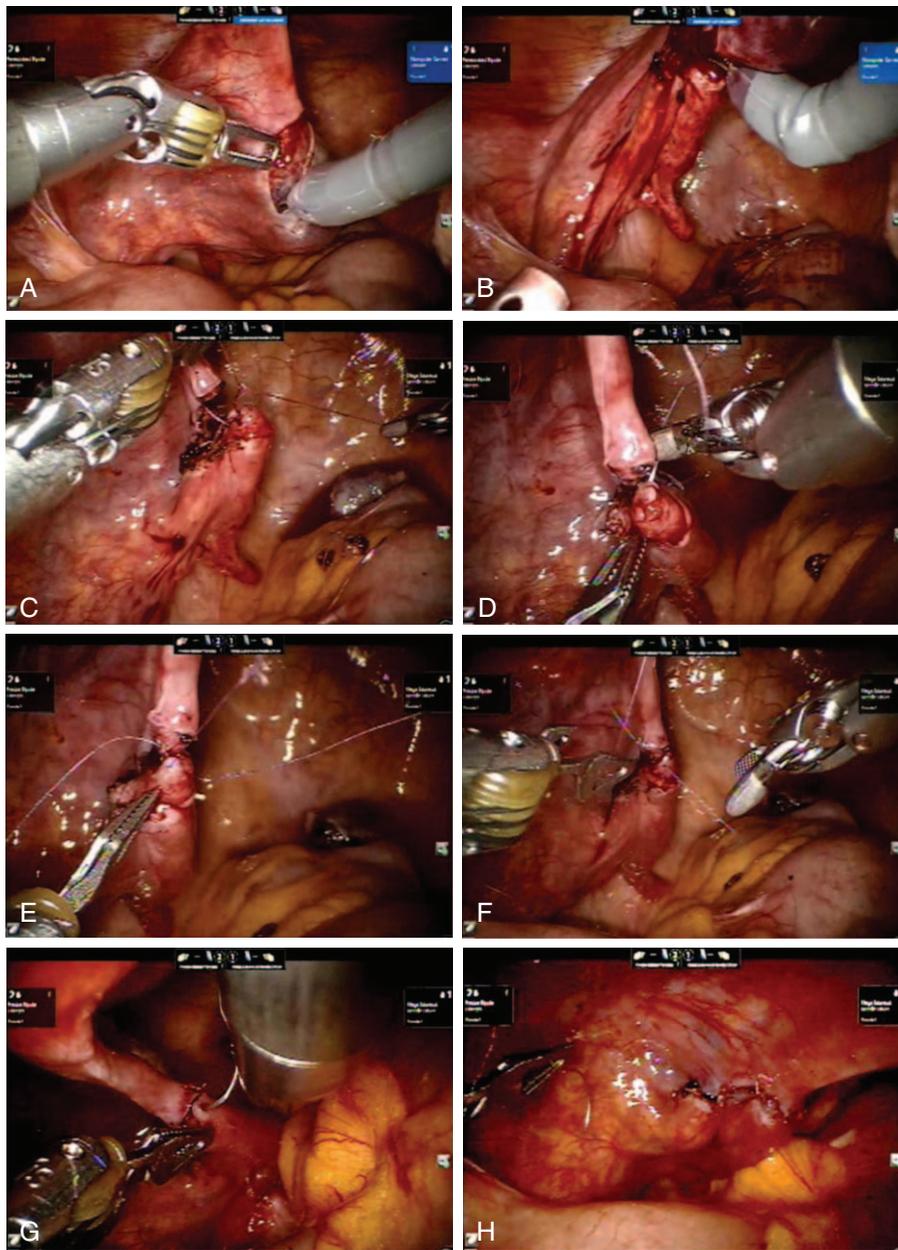


Figure 2. Procedure for a bulky tubal ectopic mass. A 31-year-old nulliparous woman with a previous history of MTX therapy due to right tubal pregnancy and intraoperatively obstruction of the previously affected fallopian tube was confirmed. The condition was diagnosed at 7.43 weeks of amenorrhea and the ectopic mass at the left ampulla was 4.3 cm in size, partially ruptured with initial hemoperitoneum of 200 mL. (A) The tubal implant is inspected to decide to what extent the fallopian tube including the ectopic mass causing permanent damage needs to be resected. Any surrounding adhesions are lysed. (B) Since extra trimming could be performed for the damaged tube later on, initially, the ectopic mass is resected conserving as much tubal segment as possible. (C) Resection of the antimesenteric portion with minimal usage of energy device. (D) Once the tubal implant is completely resected, chromopertubation is performed to check for proximal patency. (E) Healthy tubal epithelium is identified and approximated at 12, 3, 6, 9 o'clock with #7-0 Vicryls, placing sutures first and tying them sequentially at the end. (F) The muscularis is approximated also with #7-0 Vicryl. (G) The serosal layer is approximated with #6-0 Vicryls. (H) After the anastomosis is complete, chromopertubation is performed to check for patency as well as leakage at the anastomosis site. (I) Hysterosalpingography after 6 months.

3.2. Postoperative follow-up and pregnancy outcomes

During the 24-month follow-up, pregnancy outcome was monitored for 11 patients in whom pregnancy would occur only through the reanastomosed fallopian tube. Three of 14 patients with successful reanastomosis were not included in the pregnancy outcome analysis for several reasons. Two patients who chose reanastomosis were confirmed to have patent contralateral tubes during surgery, thus would yield inconclusive results as to which fallopian tube had contributed to the

pregnancy. One patient who inserted a levonorgestrel intrauterine device due to changes in family planning was also excluded. Of the 11 patients, there were 7 (63.64%) intrauterine pregnancies and 1 case of missed abortion. There were 3 (27.27%) ongoing pregnancies and 3 (27.27%) live births up to a 24-month follow-up. No tubal pregnancy occurred at the reanastomosed fallopian tube, but 1 (9.09%) patient that was not included in the pregnancy rate analysis had tubal pregnancy in the contralateral tube, which seemed patent at the

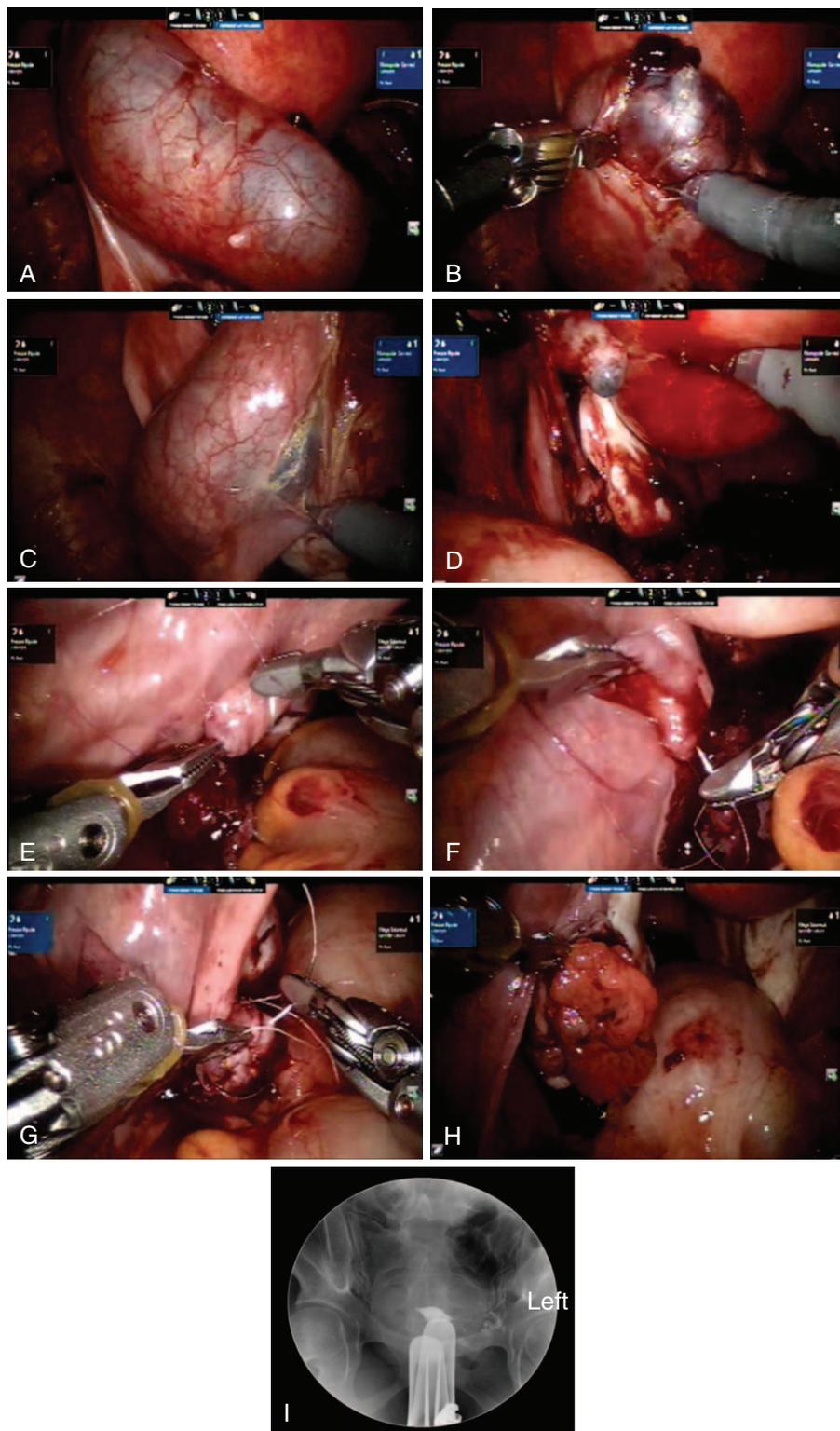


Figure 3. Stepwise description of standard operative procedure for resection of tubal ectopic mass followed by reanastomosis. A 35-year-old nulliparous woman with unruptured left tubal pregnancy, preoperative serum human chorionic gonadotropin (hCG) of 26,353 mIU/mL with presence of fetal heartbeat within the gestational sac and a history of right salpingectomy 10 years ago. (A) The proximal end is resected with monopolar scissors, using minimal energy source. The tissue is mainly handled by grasping the serosa covering the fallopian tube segment that is to be resected. (B) The distal end is also resected in the same manner. (C) The mesosalpinx is anchored using #6-0 Vicryls. (C) Interrupted sutures with #7-0 Vicryls are placed to approximate the fallopian tube epithelium. (D) The sutures for tubal epithelium are placed at 12, 3, 6, 9 o'clock directions and sequentially tied intracorporeally after all 4 sutures are completely placed. (E) The muscularis layer is approximated with #7-0 Vicryls. (F, G) The serosa is approximated with #6-0 Vicryls and any defects in the mesosalpinx are repaired.

Table 1**Patient characteristics.**

Parameters	Value
Age, y (mean ± SD)	28.88 ± 4.75
BMI, kg/m ² (mean ± SD)	21.01 ± 1.28
Gravidity (mean ± SD)	1.94 ± 0.99
Parity (mean ± SD)	0.06 ± 0.25
Amenorrhea, wk (mean ± SD)	7.01 ± 1.57
Preoperative hCG level, mIU/mL (mean ± SD)	9289.00 ± 7510.00
Preoperative hemoglobin level, g/dL (mean ± SD)	12.43 ± 1.41
Ultrasonographic presence of fetal heartbeat, % (n/N)	21.43 (3/14)
Tubal risk factor	
Presence of confirmed/suspected tubal risk factor, % (n/N)	85.71 (12/14)
Previous contralateral salpingectomy, % (n/N)	71.43 (10/14)
History of conservative treatment for pregnancy of contralateral tube, % (n/N)	14.29 (2/14)
Current MTX therapy before surgery, % (n/N)	14.29 (2/14)
Time lag from decision to surgery, h (mean ± SD)	28.31 ± 19.11

Kolmogorov–Smirnov test performed as normality test before obtaining mean values.

BMI = body mass index, hCG = human chorionic gonadotropin, MTX = methotrexate, SD = standard deviation.

time of surgery. At 6-month follow-up, HSG was performed for those with successful reanastomosis and not yet pregnant, and of the 10 anastomosed salpinges checked, all were patent (Table 3).

4. Discussion

Applying novel technique and technology is an important asset of gynecologic surgery with no exception for tubal reanastomosis. Conventionally, microsurgical tubal reanastomosis has been performed with a mini-laparotomy using an intraoperative microscope unit or laparoscopy for those who have received sterilization by means of bilateral tubal ligation, and have been described in detail by different groups.^[16–22] Despite the numerous merits of minimally invasive surgery, laparoscopy-guided microsurgery has not gained as much popularity as other

Table 2**Intraoperative parameters for tubal reanastomosis after segmental resection of tubal pregnancy.**

Parameters	Value
Tubal implant site	
Ampulla, % (n/N)	78.57 (11/14)
Isthmus, % (n/N)	21.43 (3/14)
Ectopic mass size, cm (mean ± SD)	3.47 ± 1.33
Ruptured ectopic mass, % (n/N)	85.71 (12/14)
Anastomosis success	
Completion of anastomosis on attempt, % (n/N)	100.00 (14/14)
Leakage at anastomosis site, % (n/N)	7.14 (1/14)
Residual tubal length, cm (mean ± SD)	6.05 ± 0.75
Operation time	
Total operating time, min (mean ± SD)	194.60 ± 31.28
Docking time, min (mean ± SD)	7.38 ± 1.63
Console time, min (mean ± SD)	147.20 ± 32.54
Immediate postoperative hemoglobin concentration, g/dL (mean ± SD)	10.08 ± 1.76
Transfusion rate, % (n/N)	14.29 (2/14)
Admission days, d (mean ± SD)	3.50 ± 0.82

Kolmogorov–Smirnov test performed as normality test performed before obtaining mean values. SD = standard deviation.

Table 3**Postoperative success parameters including cumulative pregnancy outcome.**

Parameters	Rate
Tubal patency by hysterosalpingography (6 months), % (n/N)	100.00 (10/10)*
Pregnancy outcome (24 months)	
Intrauterine pregnancy, % (n/N)	63.64 (7/11)†
Ongoing pregnancy, % (n/N)	27.27 (3/11)
Spontaneous abortion, % (n/N)	9.09 (1/11)
Live birth, % (n/N)	27.27 (3/11)
Ectopic pregnancy, % (n/N)	0 (0/11)

* Total number = not yet pregnant at 6 months that consented.

† Total number = from 14 patients who have completed the reanastomosis those wishing to postpone pregnancy/contralateral tubal patency were excluded.

gynecologic procedures due to limitations with conventional instrumentation, magnification, and its nonergonomic nature.

After the introduction of robotic surgery, tubal reanastomosis has been described by several authors as a novel means of restoring tubal patency for those who have received tubal ligation.^[10–15] The da Vinci robotic surgical unit is well suited for this purpose for several reasons. First of all, a combined optical–digital magnification of up to 15-fold is available with a more abstract binocular vision. A better view of the tubal lumen is available without any additional microscopic devices and the usage of finer suture materials and surgical techniques is possible using the robotic system. The articulated nature of the robotic arms allows a greater degree of freedom when multiple sutures are placed in various directions. Physiologic hand tremor, which is a major hindrance in microsurgery, is attenuated by the robotic system, facilitating the suturing process with consistency. Also, the surgeon sits at the console for the robotic procedure and fatigue is minimized. However, robotic surgery in most systems is 2 to 5-fold higher in cost. The set-up process including patient positioning and docking is more complex and tool exchange has to be performed by the assistant, with the surgeon out of the operative field.^[14–15]

When tubal pregnancy is diagnosed, the most common practice is a salpingectomy. Debate continues over whether conservative therapy for the affected tube improves pregnancy outcome when the contralateral tube is healthy.^[9,23–25] When the only existing tube is affected, however, preserving tubal integrity should be seriously considered. The history of the patient, ipsilateral adhesions, and contralateral tubal function are known factors that affect subsequent fertility and should be individualized as to which management is appropriate.^[8] When both salpinges are sacrificed as a result of bilateral salpingectomies, tubal factor infertility could be overcome by assisted reproductive technique (ART) including IVF.^[26,27] Yet, having ART as the only option is a burden for many couples wishing to conceive with regards to cost and may cause dilemma for those not yet with a life partner. When MTX therapy is ineffective, other conservative surgeries including salpingotomy and milking have been described. However, these conservative methods were reported to increase the odds of having another tubal pregnancy and cannot be performed when tubal damage is significant.^[9,28] With respect to future tubal function, complete removal of the affected tubal portion has the benefit of not leaving any residual conceptual tissue that may jeopardize patency afterwards. As a part of report on different conservative surgeries for tubal pregnancy, 3 cases of segmental resection of tubal pregnancy and reanastomosis have been reported with 2 successful pregnancies via laparotomy in the

past.^[28] Also, segmental resection with anastomosis of the remaining fallopian tube for tubal pregnancy has been reported with laparoscopy as a case report.^[29] Salpingotomy and delayed microsurgical reanastomosis as a secondary surgery for those with confirmed postoperative tubal obstruction have also been described in several cases.^[30] As such, reanastomosis following segmental resection of the affected tubal portions have been attempted, but the limitations in the ergonomics for laparoscopy and the invasiveness of open microsurgical procedure have limited its widespread application. As an alternative, salpingotomies have been performed more frequently, but the risk of leaving the bleeding focus and residual trophoblastic tissue has also limited its popularity. The pregnancy rates following salpingotomy were between 60.7% and 67.0%, and significant residual trophoblastic tissue of 20% has been reported. Conversion to salpingectomy was observed in up to 20% of the cases and usually salpingotomy was successful only for small, unruptured tubal pregnancies. Subsequent clean-up surgeries were required in about 4% to 5% of the cases, due to incomplete removal of conceptual tissue or rebleeding. Also recurrent tubal pregnancy in the affected tube was observed in 3% to 12% of the cases.^[8–9] In this study, the ergonomics of the robotic surgery has allowed reanastomosis of ruptured tubal pregnancies with a median conceptus diameter of 3.47 ± 1.33 cm. Robotic guided reanastomosis was possible for those with tubal rupture after MTX administration, where conventionally salpingectomy would have to be performed. Also, no subsequent residual trophoblastic tissues leading to additional interventions nor repeated tubal pregnancies have been observed up to a follow-up period of 24 months.

Pregnancy rates at 12 to 48-month follow-up after reanastomosis for tubal ligation lie in the range of 55% to 85% according to previous reports with laparoscopy and 68% to 83% with robotic surgery.^[15–19,31] After tubal reanastomosis following tubal pregnancy, the pregnancy rate was 63.6% at 24 months in this series, compatible with previous reports in the literature following tubal ligation. Lessons learned from previous reports on tubal reanastomosis following sterilization were taken into account for the surgical procedure. Thermal injury should be minimized when resecting the ectopic mass, because the mode of sterilization affects successful pregnancy outcome and residual tubal length is positively correlated with success.^[32,33] The range of residual tubal length was 5.50 to 7.00 cm in this study. Shortening of the effective tubal length could be minimized by resecting solely the portion of trophoblastic invasion while preserving the remaining portion of the tube only affected by bulging of the gestational sac or blood clot. These secondary dilatations of the fallopian tubes were reversible, confirmed by postoperative HSG.

Unlike reanastomosis after tubal ligation, many of these patients have underlying tubal dysfunction and preserving patency would not ensure functional integrity. However, our study indicates that a good proportion (63.64% at 24-month follow-up) of those who have received reanastomosis conceived naturally, where ART would have been required if salpingectomy had been performed. Patients receiving tubal reanastomosis due to ectopic pregnancy were generally young with a mean age of 28.88 ± 4.75 years and generally had less motivation for achieving immediate pregnancy, which may account for the slightly lower pregnancy rate at 24 months. Additional intrauterine pregnancies were observed at follow-ups beyond 24 months and with a longer follow-up period encompassing a larger number of patients, cumulative pregnancy rates will

become more evident. Repeated tubal pregnancy was an anticipated adversity, yet none had occurred during the 24 months follow-up period.

In comparison with reanastomosis after tubal ligation, certain distinctive features need to be considered for the tubal reanastomosis procedure following tubal pregnancy. The tubal implant is highly vascularized and the morphology and anatomical site of the lesion are less predictable. Thus, predicting the success of reanastomosis for tubal pregnancy becomes more difficult compared with reanastomosis following tubal ligation, showing a cancellation rate of 17.65% (3/17) in this analysis. Also the length of tubal segment that needs to be resected is usually longer and more distended, and thus greater degrees of discrepancies between the proximal and distal flaps are observed for reanastomosis following ectopic pregnancy. Since ectopic pregnancy is an implication of underlying tubal dysfunction, patients receiving reanastomosis following tubal pregnancy may have a lower pregnancy success rate despite successful intraoperative outcomes, and should be warned as such. Moreover, the mean awaiting time from decision to surgery in this series was 28.31 ± 19.11 hours; however, having on demand access to robotic surgery may not be available depending on the referral system.

Some technical challenges may be encountered in the initial cases, where being accommodated to the absence of tactile sensations and relying only on visual guidance to estimate tensile strength requires trial and error. This is a tedious task when dealing with delicate tissue and suture materials. Having the operator out of the operating field with the robotic system is also a disadvantage when handling fine suture materials in and out of the accessory port. For surgeons in training or those who have not yet reached the learning curve for either robotic surgery or tubal reanastomosis, intensive preclinical training with animal models should be followed by supervised clinical training.

The long-term outcomes and pregnancy rates of tubal reanastomosis following segmental resection of tubal pregnancy should be accumulated in future trials with larger number of patients, and should be reproduced by different teams in the field of reproductive surgery. This study demonstrates that tubal reanastomosis after segmental resection of tubal pregnancy using the da Vinci system is a feasible means of salvaging fallopian tube integrity and fertility in those with a single viable fallopian tube, demonstrating natural pregnancy rates compatible with that of conventional reanastomosis for tubal ligation.

References

- [1] Goldner TE, Lawson HW, Xia Z, et al. Surveillance for ectopic pregnancy—United States, 1970–1989. *MMWR CDC Surveill Summ* 1993;42:73–85.
- [2] Centers for Disease Control and Prevention (CDC) Ectopic pregnancy: United States, 1990–1992. *MMWR Morb Mortal Wkly Rep* 1995;44:46–8.
- [3] Farquhar CM. Ectopic pregnancy. *Lancet* 2005;366:583–91.
- [4] Shaw JL, Oliver E, Lee KF, et al. Cotinine exposure increases Fallopian tube PROKR1 expression via nicotinic AChR α 7: a potential mechanism explaining the link between smoking and tubal ectopic pregnancy. *Am J Pathol* 2010;177:2509–15.
- [5] Barnhart KT. Clinical practice. Ectopic pregnancy. *N Engl J Med* 2009;361:379–87.
- [6] Menon S, Collins J, Barnhart KT. Establishing a human chorionic gonadotropin cutoff to guide methotrexate treatment of ectopic pregnancy: a systematic review. *Fertil Steril* 2007;87:481–4.
- [7] Barnhart K, Hummel AC, Sammel MD, et al. Use of “2-dose” regimen of methotrexate to treat ectopic pregnancy. *Fertil Steril* 2007;87:250–6.

- [8] Pouly JL, Chapron C, Manhes H, et al. Multifactorial analysis of fertility after conservative laparoscopic treatment of ectopic pregnancy in a series of 223 patients. *Fertil Steril* 1991;56:453–60.
- [9] Mol F, van Mello NM, Strandell A, et al. Salpingotomy versus salpingectomy in women with tubal pregnancy (ESEP study): an open-label, multicentre, randomised controlled trial. *Lancet* 2014;383:1483–9.
- [10] Falcone T, Goldberg JM, Margossian H, et al. Robotic-assisted laparoscopic microsurgical tubal anastomosis: a human pilot study. *Fertil Steril* 2000;73:1040–2.
- [11] Degueldre M, Vandromme J, Huong PT, et al. Robotically assisted laparoscopic microsurgical tubal reanastomosis: a feasibility study. *Fertil Steril* 2000;74:1020–3.
- [12] Goldberg JM, Falcone T. Laparoscopic microsurgical tubal anastomosis with and without robotic assistance. *Hum Reprod* 2003;18:145–7.
- [13] Rodgers AK, Goldberg JM, Hammel JP, et al. Tubal anastomosis by robotic compared with outpatient minilaparotomy. *Obstet Gynecol* 2007;109:1375–80.
- [14] Dharia Patel SP, Steinkampf MP, Whitten SJ, et al. Robotic tubal anastomosis: surgical technique and cost effectiveness. *Fertil Steril* 2008;90:1175–9.
- [15] Cailliet M, Vandromme J, Rozenberg S, et al. Robotically assisted laparoscopic microsurgical tubal reanastomosis: a retrospective study. *Fertil Steril* 2010;94:1844–7.
- [16] Dubuisson JB, Swolin K. Laparoscopic tubal anastomosis (the one stitch technique): preliminary results. *Hum Reprod* 1995;10:2044–6.
- [17] Yoon TK, Sung HR, Cha SH, et al. Fertility outcome after laparoscopic microsurgical tubal anastomosis. *Fertil Steril* 1997;67:18–22.
- [18] Bissonnette F, Lapensee L, Bouzayen R. Outpatient laparoscopic tubal anastomosis and subsequent fertility. *Fertil Steril* 1999;72:549–52.
- [19] Cha SH, Lee MH, Kim JH, et al. Fertility outcome after tubal anastomosis by laparoscopy and laparotomy. *J Am Assoc Gynecol Laparosc* 2001;8:348–52.
- [20] Kim SH, Shin CJ, Kim JG, et al. Microsurgical reversal of tubal sterilization: a report on 1,118 cases. *Fertil Steril* 1997;68:865–70.
- [21] Kim JD, Kim KS, Doo JK, et al. A report on 387 cases of microsurgical tubal reversals. *Fertil Steril* 1997;68:875–80.
- [22] Silva PD, Schaper AM, Rooney B. Reproductive outcome after 143 laparoscopic procedures for ectopic pregnancy. *Obstet Gynecol* 1993;81:710–5.
- [23] Job-Spira N, Bouyer J, Pouly JL, et al. Fertility after ectopic pregnancy: first results of a population-based cohort study in France. *Hum Reprod* 1996;11:99–104.
- [24] Bangsgaard N, Lund CO, Ottesen B, et al. Improved fertility following conservative surgical treatment of ectopic pregnancy. *BJOG* 2003;110:765–70.
- [25] Rulin MC. Is salpingostomy the surgical treatment of choice for unruptured tubal pregnancy? *Obstet Gynecol* 1995;86:1010–3.
- [26] Karande VC, Korn A, Morris R, et al. Prospective randomized trial comparing the outcome and cost of in vitro fertilization with that of a traditional treatment algorithm as first-line therapy for couples with infertility. *Fertil Steril* 1999;71:468–75.
- [27] Posaci C, Camus M, Osmanagaoglu K, et al. Tubal surgery in the era of assisted reproductive technology: clinical options. *Hum Reprod* 1999;14 (Suppl 1):120–36.
- [28] Oelsner G. Ectopic pregnancy in the sole remaining tube and the management of the patient with multiple ectopic pregnancies. *Clin Obstet Gynecol* 1987;30:225–9.
- [29] Templeman C, Davis C, Janik G, et al. Laparoscopic microsurgical anastomosis of the blocked, solitary post-ectopic Fallopian tube: case report. *Hum Reprod* 2002;17:1630–2.
- [30] DeCherney AH, Boyers SP. Isthmic ectopic pregnancy: segmental resection as the treatment of choice. *Fertil Steril* 1985;44:307–12.
- [31] Hanafi MM. Factors affecting the pregnancy rate after microsurgical reversal of tubal ligation. *Fertil Steril* 2003;80:434–40.
- [32] Rock JA, Guzick DS, Katz E, et al. Tubal anastomosis: pregnancy success following reversal of Falope ring or monopolar cautery sterilization. *Fertil Steril* 1987;48:13–7.
- [33] Paul PG, Bhosale SA, Khan S, et al. Fertility outcome in laparoscopic single tube reanastomosis. *J Reprod Med* 2015;60:30–6.