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Original Article

Robot-assisted natural orifice transluminal endoscopic surgery for hysterectomy

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ABSTRACT

Objective: To describe the surgical procedures of robot-assisted natural orifice transluminal endoscopic surgery (NOTES) for hysterectomy and to evaluate its feasibility.
Materials and methods: From December 2014 to February 2015, four patients with benign diseases who were eligible for robot-assisted NOTES at Chang Gung Memorial Hospital were recruited to this study. Intraoperative and postoperative surgical outcomes were evaluated.
Results: Robot-assisted NOTES hysterectomy was successfully performed in all these patients. None of the patients had vaginal delivery, with two being nulliparous. The mean ± standard error of the mean uterine weight was 365.5 ± 69.2 g, the mean operative time was 198.8 ± 39.0 minutes, the mean docking time was 38.3 ± 2.4 minutes, the mean blood loss was 180.0 ± 56.1 mL, and the mean postoperative hospital stay was 2.5 ± 0.3 days. The final pathologic diagnoses were adenomyosis and/or leiomyomas.
Conclusion: The novel robot-assisted NOTES technology created scarless skin wounds. More importantly, the device allows the surgeon to reach deeper places to achieve hemostasis, and perform surgery on larger tumors using the curved cannulae-wristed instrument. However, its implementation is limited by the lack of appropriate instrumentation, which requires further development and break through. At this stage, robot-assisted NOTES is only useful for limited applications in highly selected patients.

Introduction

Natural orifice transluminal endoscopic surgery (NOTES) is a novel revolutionary surgical technique developed in the field of minimally invasive surgery [1,2]. NOTES uses the natural orifices of the body as the surgical channels for endoscopy, such as the urethra, the mouth, the anus, and the vagina to prevent visible scars on the abdominal wall [3,4]. NOTES also prevents complications of trocar wound, and achieves better cosmetic outcomes [2]. NOTES has been applied in general surgery and its safety and feasibility have already been proven [3,5]. Although various approaches had been developed for its utilization, transvaginal access is the most frequently used approach [6,7]. NOTES offers several benefits including scarless intervention, faster recovery, a shorter hospital stay, lower anesthesia requirements, and less pain compared with conventional open and laparoscopic procedures [1].

In recent times, the clinical application of transvaginal NOTES has broadened significantly; in the initial days, NOTES was used only for diagnostic purposes or to perform simple surgeries, but now it is also being used to accomplish complex procedures [3]. Lee et al [8] performed transvaginal NOTES by applying the method of laparoendoscopic single-site surgery using the wound-retractor-and-glove system via the vaginal route. Using this method, the authors of that study demonstrated that not only myomectomy and adnexal procedures but also hysterectomies and oncologic surgery could be performed safely and effectively in selected patients [9,10]. Besides, it was also reported that performing transvaginal NOTES to treat benign gynecologic disease is a feasible and attractive option [2,4,7].

In addition to NOTES surgery, application of a robotic platform is also a new revolution in performing minimally invasive surgery.

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The Food and Drug Administration approved the use of robotic platforms in gynecologic surgery in 2005 [11]. Robotic technology possesses several potential benefits over the existing methods, such as offering three-dimensional visualization, instruments' greater range of motion, precision, scaling, enhanced stability of the operative image and instrumentation, and better ergonomics [12,13]. Several publications have described the safety and feasibility of this new approach [11,14–19]. In addition, it overcomes the existing limitations and difficulties, which are commonly associated with traditional gynecologic surgeries.

Robot-assisted laparoscopic surgery has allowed more surgeries to be performed by adopting the minimally invasive route because it is easier to learn than traditional laparoscopic surgery owing to its advantages [11,18]. According to some reports, robotic surgery offers several advantages including decreased estimated blood loss, faster recovery, and reductions in major complications [20].

Furthermore, robot-assisted surgical approaches have been used progressively in the setting of risk-reducing uterine and adnexal surgery, and for the treatment of adnexal masses, cervical cancer, endometrial cancer, and ovarian cancer [16].

The current advancements in NOTES instrumentation has motivated the development of flexible robotic endoscopic devices, which possess a number of benefits over existing rigid endoscopes that are used in NOTES hysterectomy. Therefore, in this study, we decided to fully utilize the potential of robotic endoscopic devices and NOTES to perform hysterectomy. This combined technique will eliminate the need for surgical incision (NOTES) and improve depth perception (long robotic instrument). We herein present our experience in performing robot-assisted NOTES hysterectomy, and to the best of our knowledge, this is the first report published in the literature in this regard.

Materials and methods

Robot-assisted NOTES is a type of vaginal single-port surgery, which is routinely performed at our hospital. Institutional Review Board approval was not needed for this study. All patients undergoing surgery gave their written informed consent.

Patients

Patients scheduled for laparoscopic hysterectomy and willing to undergo robot-assisted surgery between December 2014 and February 2015 at Chang Gung Memorial Hospital were selected to receive robot-assisted NOTES. The procedure was not considered contraindicated in patients with obesity [body mass index (BMI) > 30 kg/m^2], those who never had vaginal deliveries, those in whom concomitant adnexal surgery was necessary, and those with a history of cesarean delivery or abdominal surgery. However, patients with virginity, suspected severe pelvic adhesions from previous abdominal surgery, tubo-ovarian abscesses, or endometriosis were excluded.

Surgical procedures

In brief, the surgical procedures are as follows: under general anesthesia with endotracheal intubation, patients were placed in the Trendelenburg position with their legs bandaged and supported in the stirrups. A 12-F Foley catheter was inserted. The operation began as in conventional vaginal surgery, with resection of the vaginal wall around the cervix. Anterior and posterior colpotomy was performed and the uterosacral ligaments were dissected. The uterine vessels were sealed and cut up to the level of the isthmus, with either suture–ligation or the LigaSure system (Valleylab Inc., Boulder, CO, USA).

The vaginal working channel was established by inserting a single-site multi-instrument silicon port (Intuitive Surgical, Sunnyvale, CA, USA). The patient-side cart of the da Vinci Surgical System was then driven between the patient's legs, and each responsible port was docked onto the assigned robotic arms (Figure 1). A zero-degree endoscope was used for the entire procedure. We used an EndoWrist plasma-kinetic bipolar grasper in the left robotic hand and EndoWrist monopolar curved scissors in the right hand (Intuitive Surgical Inc.).

Robot-assisted NOTES hysterectomy was performed after achieving adequate pneumoperitoneum. The remaining structures upward from the isthmic level including the broad ligaments, round ligaments, ovarian ligaments, and fallopian tubes or infundibulopelvic ligaments (for salpingo-oophorectomy) were then sealed and cut (Figures 2 and 3). After hemostasis was achieved, the patient-side cart was removed. The uterus was morcellated through the vagina. The surgery ended after closure of the vaginal cuff and routine check-up of cystoscopy.

Data analysis

Patient demographics, intraoperative findings, postoperative outcomes, and pathologic reports were all prospectively recorded as patients enrolled in the study. Surgical procedures and outcomes, including operative time, docking time, estimated blood loss, length of hospital stay, and intraoperative and postoperative complications were also recorded. “Operative time” is calculated as the time from docking to the end of surgery. “Docking time” is the time taken to set up the robotic instrument with curved cannulae before surgery.

Treatment protocol

Prophylactic antibiotic therapy was administered preoperatively using a single dose of parenteral cefazolin, and postoperatively using cefazolin and gentamicin for 24 hours. The Foley catheter was left in place overnight. According to the regulations of our national insurance scheme, patients could not be discharged until they were afebrile for at least 24 hours, had good wound healing, had full recovery of urinary and gastrointestinal functions, and there was no evidence of surgical complications. Vaginal intercourse was prohibited for 2 months after the operation. Patients were followed up in our outpatient clinic at 1 week and 6 weeks after the surgery. Three months later, patients were evaluated for general well-being and sexual function, including dyspareunia or postcoital bleeding.

Results

From December 2014 to February 2015, four patients who had preoperative benign disease requiring hysterectomy were recruited to this study. Patient demographic data are presented in Table 1. None of these patients had vaginal delivery, including two being nulliparous. Mean [standard error of the mean (SEM)] age of the study population was 45.5 ± 2.5 years, median parity was 1.0 ± 0.60, and mean BMI was 25.5 ± 1.2 kg/m^2. Robot-assisted NOTES hysterectomy was successfully completed in all patients. Among the four patients, concomitant pelvic surgical procedures including one salpingectomy, one salpingo-oophorectomy, and three extensive adhesiolysis were also performed. Mean (SEM) uterine weight was 365.5 ± 69.2 g (range 218–513 g). Mean operative time was 198.8 ± 39.0 minutes. Mean docking time was 38.3 ± 2.4 minutes. Mean blood loss was 180.0 ± 56.1 mL, mean decrease in hemoglobin concentration from before the operation to postoperative Day 1 was 1.6 ± 0.2 g/dL. Mean postoperative hospital stay was 2.5 ± 0.3 days. The final pathologic diagnoses were adenomyosis and/or leiomyomas.

Figure 1. Setting up the robot system in NOTES.

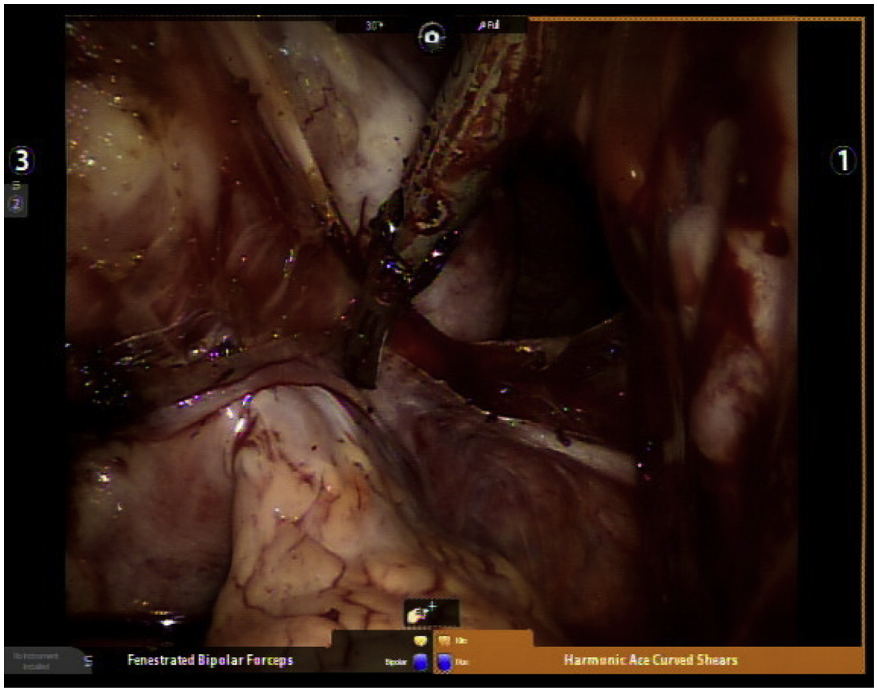

Figure 2. The left ovarian ligament is exposed when the round ligament is partially ligated.

Discussion

Conventional vaginal surgery has been used in gynecologic practice for a long time, and it can be used to avoid wounds on the abdominal wall. In a recent study, transvaginal NOTES was performed by applying the method of laparoendoscopic single-site surgery via the vaginal route. This technique reduced wound complications after the surgery, such as infection, hematoma formation, or herniation. Since 2010, we have adopted the transvaginal NOTES approach for hysterectomy, adnexal surgery, myomectomy, and staging surgery for endometrial cancer [9,10,21]. Our initial experience suggests transvaginal NOTES to be a safe and feasible procedure in highly selected patients.

Vaginal approach is still the first choice [22] for hysterectomy patients with benign conditions who require surgery. Compared with traditional vaginal surgery, transvaginal NOTES provides better surgical view for delicate dissection and hemostasis; additionally, the laparoscopic instrument allows to reach deeper areas,

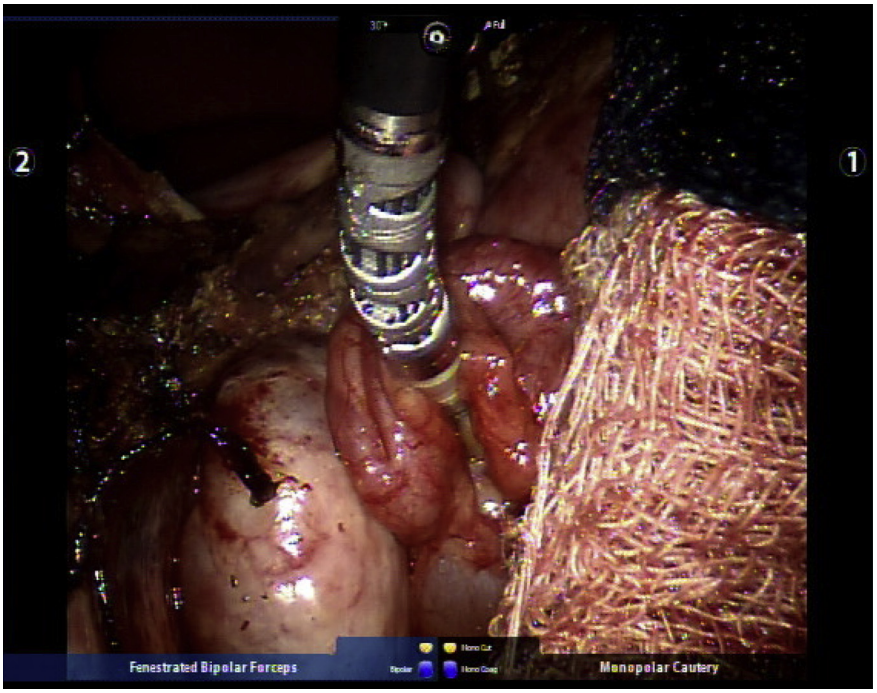

Figure 3. The right ovary and Fallopian tube are exposed.

Table 1
Patient characteristics and surgical outcomes.

Case no.	Age	Parity	BMI, kg/m^2	C/S	Diagnosis	Operation	Postoperative stay (d)	Uterine weight (g)	Operative time (min)	Blood loss (mL)	Hg decline (g/dL)	Docking time (min)
1	49	0	25	0	Leiomyoma	RNH + Adhesiolysis	3	513	248	300	1.5	34
2	50	2	24.5	2	Leiomyoma	RNH + BSO + Adhesiolysis	3	449	195	100	−1.4	36
3	39	2	23.6	2	Adenomyosis	RNH	2	218	90	70	1.3	45
4	44	0	29	0	Leiomyoma	RNH + RS + LS + Adhesiolysis	2	282	262	250	2.2	38

BMI = body mass index; BSO = bilateral salpingo-oophorectomy; C/S = cesarean delivery; LS = left salpingectomy; RNH = robotic NOTES Hysterectomy; RS = right salpingectomy; RSO = right salpingo-oophorectomy.

which helps to deal with a large pelvic tumor. Therefore, transvaginal NOTES broadens the application of vaginal surgery. However, because transvaginal NOTES is itself a modified single-port laparoscopic surgery, the problems generally encountered in single-port surgery still exist, such as in-line vision, instrument crash, and loss of triangulation.

Computer-enhanced telesurgery, called “robot-assisted surgery,” is the latest innovation in the area of minimally invasive surgery. It provides three-dimensional visualization, which allows for preserving vessels or nerves and their functions. Besides, robotic arms offer a wide range of motion and stability, thereby enabling precise dissection and coagulation. The novel method proposed here (i.e., combing the robotic platform with NOTES) helps to eliminate the disadvantages of NOTES. Besides, we wanted to combine the advantages of both NOTES and the robotic platform to eliminate the limitation of NOTES and to broaden its clinical application.

Undoubtedly, there are many advantages of using robot-assisted surgery in NOTES hysterectomy; for example, the curved cannula-wristed instruments of the robotic device offer a longer stretch, compared with the currently used instrument (52 cm vs. 42 cm). This enables the surgeon to remove larger uteri, and improves depth perception to achieve hemostasis while performing surgery to remove larger tumors. In addition, it offers clear visualization of the surgical field while performing the surgery. However, there are a few disadvantages. For example, the anterior and posterior fornices should first be cut and only then can surgery be performed. Moreover, the robotic device should be positioned between the narrow space of the patient's leg, which greatly reduces the space for assistants to sit. Besides, because the current technology is relatively new, docking set up is time consuming; however, with experience the docking time can significantly be reduced. Although the wrist instrument is flexible, it is heavier and can cause mechanical problems during surgery, leading to malfunction. Therefore, a thorough understanding of how to adjust the position of the curved cannula-wristed instrument in NOTES surgery still is important. Moreover, the current robot-assisted electrothermal bipolar-vessel-sealing device is not completely developed, and therefore the surgery is still performed using the conventional straight electrothermal vessel sealing instrumentation to achieve hemostasis when necessary. In addition, if bleeding occurs, there is no multifunctional irrigation and suction conduit to clear operative field. There are still many difficulties to overcome and significant improvements are required before the robotic device can be effectively utilized in NOTES.

Minimal invasiveness begins from multi-port laparoscopy, then progresses to robot-assisted, single-port laparoscopy and NOTES. Now we apply robot system in NOTES to perform robot-assisted

NOTES. The novel robot-assisted NOTES technology created scarless skin wounds. More importantly, the device allows the surgeon to reach deeper places to achieve hemostasis, and perform surgery on larger tumors using the curved cannulae-wristed instrument. However, its implementation is limited by the lack of appropriate instrumentation, which requires further development and break through. At this stage, robot-assisted NOTES is only useful for limited applications in highly selected patients.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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Authors' contributions

Dr C.-L. Lee is the principle investigator; Dr Chyi-Long Lee conceived and designed the study; Dr Kai-Yun Wu acquired the data; Drs Hsuan Su, Chien-Min Han, and Chih-Feng Yen analyzed and interpreted the data; Drs Chyi-Long Lee and Kai-Yun drafted the manuscript; Chyi-Long Lee and Dr Chih-Feng Yen reviewed the data and critically revised the manuscript for scientific and intellectual content. All authors approved the final version for submission.

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