



Contents lists available at ScienceDirect

Gynecology and Minimally Invasive Therapy

journal homepage: www.e-gmit.com

Review article

Review of transvaginal natural orifice transluminal endoscopic surgery in gynecology



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ARTICLE INFO

Article history:

Received 31 August 2016

Received in revised form

2 November 2016

Accepted 24 November 2016

Available online 20 January 2017

Keywords:

laparoendoscopic single-site surgery
minimally invasive surgery
natural orifice transluminal endoscopic surgery
single-incision laparoscopic surgery

ABSTRACT

Recent technologic advances in endoscopic instrumentation and optics have allowed the development of a less invasive alternative to conventional laparoscopic surgery. During the past decade, natural orifice transluminal endoscopic surgery (NOTES) flourished in the field of general surgery, and it has emerged as a new concept of minimally invasive surgery. NOTES yields access to the abdominal cavity without any incisions on the abdominal wall (scarless surgery), and the natural orifices of the body surface, such as the mouth and the vagina, serve as the gateway to the peritoneal cavity. In gynecology, the vagina of a woman can be considered as an additional route for surgery. Recently, clinical application of transvaginal NOTES has broadened significantly in gynecology. Using transvaginal NOTES by applying the method of single-incision laparoscopic surgery via the vaginal route, not only adnexal surgery and hysterectomy, but also myomectomy and oncologic surgery could be performed safely and effectively in selected patients. In future, further studies should be conducted to evaluate the true clinical feasibility and safety of transvaginal NOTES.

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Introduction

Recent technologic advances in endoscopic instrumentation and optics have allowed the development of a less invasive alternative to conventional laparoscopic surgery. By aiming to reduce surgical morbidity, the evolution from laparotomy to laparoscopy has now broadened to include even less invasive techniques, such as single-incision laparoscopic surgery (SILS), also known as laparoendoscopic single-site surgery, and natural orifice transluminal endoscopic surgery (NOTES). Minimally invasive surgery not only improves cosmetic outcome, but also reduces surgical injury. SILS achieves access through an abdominal approach using a transumbilical single incision. Many studies have described its feasibility, safety, and surgical outcome. By contrast, NOTES uses the natural orifices of the body surface, such as the mouth and the

vagina, as surgical channels of endoscopy to avoid incision scars on the abdominal wall.

During the past decade, NOTES flourished in the field of general surgery, and it has emerged as a new concept of minimally invasive surgery. The first published experience was transvaginal endoscopic cholecystectomy performed by Zorron et al¹ at University Hospital of Teresopolis, Brazil. Afterward, Bessler et al² at Columbia University Medical Center, New York, USA, and Marescaux et al³ at University Louis Pasteur, Paris, France, reported similar procedures. Together with robotic surgery, NOTES is considered to be the next-generation minimally invasive surgical procedure; thus, numerous efforts in this area are being made in many countries. Recently, transvaginal NOTES has been performed in cholecystectomy, appendectomy,^{4,5} nephrectomy,⁶ and gynecologic diseases. NOTES can be performed via a variety of approaches, including that through the stomach,^{7–9} but the majority of NOTES procedures have been performed transvaginally. The vagina can be easily decontaminated, and it provides direct access. Culdotomy has been used widely for several surgical procedures (not only by gynecologists, but also by general surgeons for extraction of large specimens), and it has been approved as safe and easy to close. With regard to closure of the perforation site within the natural orifices

Conflicts of interest: The author declares no conflicts of interest relevant to this article.

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<http://dx.doi.org/10.1016/j.gmit.2016.11.007>

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except the vagina, an acceptable closure method is not yet present. Currently, to select the transvaginal port is the most reliable for human application of NOTES.

In gynecology, the vagina of a woman can be considered as an additional route for surgery. The concept of transvaginal endoscopy was originally called “culdoscopy.” In recent times, clinical application of transvaginal NOTES has broadened significantly; in the initial days, NOTES was used only for diagnostic purposes¹⁰ or performed with transabdominal assistance,^{11,12} but now it is being used to accomplish complex procedures. Different gynecologic procedures have been effectively performed by means of pure transvaginal NOTES. These procedures seem to be feasible and safe. Reduced pain and improved cosmesis are supposed to be the potential advantages of transvaginal NOTES. The objective of this article is to review the published literature on transvaginal NOTES in gynecology.

Transvaginal NOTES in gynecology

As NOTES is relatively new, the current literature on the use of this technique in gynecology is somewhat limited. As a result of a MEDLINE/PubMed literature search of all publications in English language using the search term “natural orifice transluminal endoscopic surgery,” as well as a review of all references to summarize the existing clinical experience on NOTES in gynecology, a total of 17 articles were found to include gynecologic procedures (Table 1).^{13–29}

Review of published literature of transvaginal NOTES in benign gynecology

Although NOTES is a relatively new field, a variety of NOTES procedures with use of modern laparoscopic instrumentation and optics evolved into transvaginal NOTES have been reported in gynecology.

Adnexal surgery

Lee et al¹³ reported the first case series of pure transvaginal NOTES for adnexal diseases in 2012. Ten consecutive patients underwent transvaginal NOTES, including tubal sterilization in three, salpingectomy because of ectopic pregnancy in three, and ovarian tumor enucleation in four. The NOTES procedure failed in one patient because a misdiagnosed peritoneal mucinous tumor was located in front of the uterus and was inaccessible using the transvaginal approach, leading to subsequent conversion to conventional laparoscopy. They found that transvaginal NOTES, compared with transumbilical SILS, offered a larger space and a decreased incidence of instrument clashing during handling because of the large colpotomy wound. They also found several technical drawbacks to transvaginal NOTES. In comparison with transumbilical SILS, transvaginal NOTES was performed in an anatomically reverse direction, which might initially cause disorientation for surgeons; however, operators were quickly able to adapt to the new orientation because gynecologists were familiar with vaginal surgical procedures. They concluded that their method of combining the concepts of culdoscopy using the vaginal approach and SILS with the wound retractor represented a new way to perform transvaginal NOTES. Ahn et al¹⁴ and Kim¹⁵ described their initial experience in 10 women with benign adnexal diseases that were treated successfully with transvaginal NOTES using a single port. Procedures consisted of oophorectomy in three patients, salpingostomy and salpingectomy in two each, and ovarian cystectomy, paratubal cystectomy, and ovarian wedge resection in one each. They concluded that the selection of

appropriate patients could be important for successful surgical outcomes because of the requirement of secure colpotomy. Yang et al¹⁶ also described the initial clinical experience of transvaginal NOTES using a wound retractor and a surgical glove performed in seven women with adnexal masses. Main procedures consisted of unilateral salpingo-oophorectomy in three patients, unilateral oophorectomy in three patients, and paraovarian cystectomy in one patient. Transvaginal NOTES was successfully and safely completed in all cases. They concluded that transvaginal NOTES was a feasible and effective surgical technique in properly selected female patients with adnexal masses.

Xu et al¹⁷ were the first to report a prospective randomized study of transvaginal NOTES for tubal ectopic pregnancy. They prospectively enrolled 40 patients, each of whom had been scheduled for salpingectomy, and randomized them into the two groups: transvaginal endoscopic surgery ($n = 18$) and laparoscopic surgery ($n = 20$). Transvaginal endoscopic salpingectomy was performed using a double-channel endoscope through a vaginal puncture, and pure NOTES was performed in 17 cases except the first case in which hybrid NOTES was performed. The duration of time for transvaginal endoscopic surgery was slightly longer than that for laparoscopic surgery, however, there was no statistically significant difference between the two groups. Transvaginal NOTES was associated with lower pain scores at 4 hours after surgery. The group that underwent transvaginal endoscopic surgery was more satisfied with the absence of external scars than the group that underwent laparoscopic surgery, which left scars. They concluded that the safety and efficacy of transvaginal endoscopic salpingectomy for tubal ectopic pregnancy were equivalent to those of laparoscopic salpingectomy, and that lesser postoperative pain and more satisfactory cosmetic outcome would make it the preferred approach and superior to laparoscopic surgery in simple cases.

Wang et al¹⁸ recently published a study comparing surgical outcomes between NOTES-assisted ovarian cystectomy (NAOC) and laparoscopic ovarian cystectomy (LOC). A total of 277 patients were recruited in the study (34 in the NAOC group and 243 in the LOC group). The mean operative time and postoperative hospital stay were significantly less for the NAOC group than for the LOC group. Although the mean amount of blood loss was significantly less for the LOC group than for the NAOC group, it was <50 mL in the two groups. They compared a propensity score matched sample of 68 LOC patients with 34 NAOC patients using a “nearest-neighbor” approach. In this approach, each NAOC patient was matched to two LOC patients with the closest propensity scores. They found that there was a linear correlation between operative time and mass size, and between estimated blood loss and mass size in the LOC group, but that similar results were not seen in the NAOC group. They concluded that performing ovarian cystectomy by combining NOTES technique with conventional vaginal surgery for benign and large ovarian tumors was possible in well-selected patients, and that NAOC offered superior operative efficiency compared with conventional LOC.

Hysterectomy

Su et al¹⁹ reported the first case series of transvaginal NOTES for performing hysterectomy in 2012. Sixteen patients with benign uterine diseases underwent hysterectomy using transvaginal NOTES, which was performed by applying the techniques of SILS via the vaginal route. Transvaginal NOTES was completed in each patient without conversion to conventional laparoscopy or even laparotomy. They concluded that hysterectomy could be feasibly performed using transvaginal NOTES, which not only overcame limitations, but also broadened the indications for vaginal hysterectomy. Lee et al²⁰ evaluated the feasibility and safety of hysterectomy using transvaginal NOTES in benign uterine

Table 1
Transvaginal natural orifice transluminal endoscopic surgery procedures in gynecology.

Source, year	Study type	No. of patients	Main surgery type	Access ports	Optics	Operative time (min)	Blood transfusion	Complications, including conversion to conventional laparoscopy or laparotomy
Lee et al, ²⁵ 2015	Case series	4	Robot-assisted hysterectomy	Single-site multi-instrument silicon port	0° endoscope	198.8 ^a	0	None
Wang et al, ¹⁸ 2016	Retrospective matched case–control	34	NOTES-assisted ovarian cystectomy	Wound retractor & surgical glove	10-mm 0° laparoscope	38.1 ^a	0	None
Baekelandt, ²³ 2015, Baekelandt, ²⁴ 2016	Case series	10	Hysterectomy	Wound retractor or laryngeal mask airway & surgical glove	10-mm rigid 0° laparoscope	97 ^a	0	2 (1 cystitis, 1 vault hematoma)
Baekelandt, ²⁹ 2015	Video report	1	Adnexectomy	Wound retractor & surgical glove	10-mm rigid 0° laparoscope	NA	0	None
Lee et al, ²⁶ 2014	Case series	3	Myomectomy	Lagiport kit multiple-instrument access port	10-mm 0° endoscope	138.7 ^a	1 (preoperatively)	None
Lee et al, ²⁷ 2014	Case series	3	NOTES-assisted hysterectomy + salpingo-oophorectomy + pelvic lymphadenectomy	Lagiport kit multiple-instrument access port	10-mm 0° endoscope	249.3 ^a	0	None
Wang et al, ²² 2015	Retrospective matched case–control	147	NOTES-assisted hysterectomy	Wound retractor & surgical glove	10-mm 0° laparoscope	76.7 ^a	9	4 (2 low-grade fever, 1 relaparoscopy, 1 bladder injury)
Lee et al, ²⁰ 2014	Case series	137	NOTES-assisted hysterectomy	Wound retractor & surgical glove	5-mm 30° or 10-mm conventional endoscope	88.2 ^a	10	5 (3 lower abdominal pain with fever, 1 urinary tract infection, 1 urinary retention), 7 conversion to laparoscopy (5 failure of colpotomy, 1 massive vaginal bleeding, 1 bladder perforation)
Xu et al, ¹⁷ 2014	Prospective randomized	18	Salpingectomy (pure NOTES = 17, hybrid NOTES = 1)	One 10-mm trocar	Double-channel endoscope	53.3 ^a	0	None
Yang et al, ²¹ 2014	Retrospective matched case–control	16	NOTES-assisted hysterectomy	Wound retractor & surgical glove	10-mm rigid 30° laparoscope	70.6 ^a	0	None
Yang et al, ¹⁶ 2013	Case series	7	Salpingo-oophorectomy (n = 3), oophorectomy (n = 3), paraovarian cystectomy (n = 1)	Wound retractor & surgical glove	10-mm rigid 30° laparoscope	45 ^b	0	None
Lee et al, ²⁸ 2012	Case series	15	Tubal sterilization (n = 2), salpingectomy (n = 2), ovarian tumor enucleation (n = 1), NOTES-assisted hysterectomy (n = 10)	Wound retractor & surgical glove	5-mm 30° endoscope	64.3 ^a	1	None
Su et al, ¹⁹ 2012	Case series	16	NOTES-assisted hysterectomy	Wound retractor & surgical glove	5-mm 30° endoscope	146.1 ^a	4	None
Ahn et al, ¹⁴ 2012, Kim, ¹⁵ 2013	Case series	10	Oophorectomy (n = 3), salpingostomy (n = 2), salpingectomy (n = 2), ovarian cystectomy (n = 1), paratubal cystectomy (n = 1), ovarian wedge resection (n = 1)	SILS port	5-mm flexible 0° or rigid 30° endoscope	70.6 ^a	1 (preoperatively)	None
Lee et al, ¹³ 2012	Case series	10	Tubal sterilization (n = 3), salpingectomy (n = 3), ovarian tumor enucleation (n = 4)	Wound retractor & surgical glove	5-mm 30° endoscope	75.3 ^a	1	1 conversion to laparoscopy

NA = not available; NOTES = natural orifice transluminal endoscopic surgery; SILS = single-incision laparoscopic surgery.

^a Mean.

^b Median.

diseases. In their study, hysterectomy using transvaginal NOTES was successfully completed in 130 of 137 patients (94.9%), whereas in seven patients (5.1%) the procedure was converted to conventional laparoscopy. In two patients there was intraoperative hemorrhage or unintended cystotomy, and in another five transvaginal colpotomy failed because of narrow vagina, cul-de-sac obliteration by dense adhesions, or mass obstruction. Complications in these seven patients (5.1%) were successfully managed with conventional laparoscopy. Five patients (3.6%) experienced postoperative urinary retention or febrile morbidity, and recovered uneventfully with conservative treatment. Transvaginal NOTES could be feasibly performed concurrent with salpingectomy, salpingo-oophorectomy, extensive adhesiolysis, and ovarian tumor enucleation with suture repair without additional difficulty in performing hysterectomy. They found that the only impeding factor of transvaginal NOTES was obstruction of the cul-de-sac. However, once transvaginal posterior colpotomy was successfully performed, specimen size was no longer an impeding factor of the procedure. They concluded that performing hysterectomy using transvaginal NOTES was generally beneficial, with short operative time and high patient satisfaction with no abdominal wound as in vaginal surgery.

Yang et al²¹ described the initial clinical experience of NOTES-assisted vaginal hysterectomy (NAVH), and investigated its feasibility and surgical outcomes compared with single-port laparoscopic-assisted vaginal hysterectomy (SP-LAVH). Sixteen patients with benign uterine diseases who underwent NAVH were matched in a 1:2 fashion to patients treated with SP-LAVH. There was no statistical difference in all matching criteria between the two groups. There was also no significant difference in perioperative outcomes except for operative time and length of postoperative hospital stay between both groups. The mean operative time and median postoperative hospital stay for NAVH were significantly shorter than those for SP-LAVH. They found that a large opening into the pelvic cavity for NAVH helped overcome instrument crowding and enhanced instrument manipulation during transvaginal NAVH, unlike transumbilical SP-LAVH. They concluded that NAVH was a feasible and safe surgical technique for performing hysterectomy and offered similar surgical outcomes and superior cosmesis compared with SP-LAVH. Wang et al²² compared surgical outcomes between transvaginal NOTES hysterectomy (tVNOTEH) and laparoscopically assisted vaginal hysterectomy (LAVH). A total of 512 patients were recruited in the study (147 in the tVNOTEH group and 365 in the LAVH group). These patients were stratified into six subgroups according to uterine weight and type of hysterectomy. The mean operative time, amount of blood loss, and postoperative hospital stay were significantly less for the tVNOTEH group than for the LAVH group, regardless of uterine weight. There was no difference in the overall incidence of operative complications between the two groups, but there were more complications in the LAVH group for uterine weight more than 500 g. They compared a propensity score matched sample of 147 tVNOTEH patients with the same number of LAVH patients using a “nearest-neighbor” approach. In this approach, each tVNOTEH patient was matched to one LAVH patient with the closest propensity scores. They found that there was a significant linear correlation between operative time and uterine weight in both groups, and that a similar result was seen on estimated blood loss. They concluded that tVNOTEH could be safely performed for large and nonprolapsed uterus, and that the operative efficiency of tVNOTEH increased compared with LAVH as uterine weight increased.

Baekelandt^{23,24} reported his technique of total vaginal NOTES hysterectomy (TVNH), in which the entire procedure was performed using transvaginal NOTES under the pneumovagina. TVNH performed in 10 patients with benign uterine diseases was

successfully completed within reasonable operative time, and without major complications and conversion to conventional laparoscopy or laparotomy. The major difference between TVNH and vaginally assisted NOTES hysterectomy (VANH) lay in the opening of the anterior and posterior peritoneum and the transection of the uterosacral ligaments. This procedure was performed entirely endoscopically in the TVNH, whereas it was performed by conventional vaginal surgery in the VANH (Table 2). Therefore, he found that due to the pneumovagina, TVNH was not more difficult in nulliparous than in parous women. He concluded that by incorporating the advantages of endoscopic surgery, TVNH broadened the indications for vaginal hysterectomy and helped overcome its limitations.

Lee et al²⁵ recently presented the first surgical procedure of robot-assisted NOTES hysterectomy using the vaginal working channel established by inserting a single-site multi-instrument silicon port (Intuitive Surgical, Sunnyvale, CA, USA). Robot-assisted NOTES hysterectomy was successfully completed in all four patients with benign uterine diseases. They found that the novel robot-assisted NOTES technology allowed the surgeon to reach deeper places, but that its implementation was limited by the lack of appropriate instrumentation, which required further development and breakthrough. They concluded that at this stage robot-assisted NOTES was useful only for limited applications in highly selected patients.

Myomectomy

Currently, only one study on transvaginal NOTES myomectomy, reported by Lee et al²⁶ in 2014, has been published. Three patients with posterior wall fibroids, eligible for laparoscopic myomectomy, were recruited to undergo transvaginal NOTES. Transvaginal NOTES myomectomy was successfully completed in all the patients. They found that its procedure was more complex and potentially involved a greater risk than that of conventional laparoscopic myomectomy because of a relatively restricted vision. Therefore, they concluded that conversion to conventional laparoscopy was essential in a discrepant condition between preoperative image studies and operative findings.

Review of published literature of transvaginal NOTES in gynecologic oncology

Transvaginal NOTES can be used to carry out technically challenging gynecologic procedures, including oncologic surgery. Lee et al²⁷ described a comprehensive technique to carry out laparoscopic staging surgery using transvaginal NOTES for early-stage endometrial cancer: hysterectomy, bilateral salpingo-oophorectomy, and bilateral pelvic lymphadenectomy. Three patients with early-stage endometrial cancer underwent surgical staging using transvaginal NOTES. In their preliminary study, they concluded that staging surgery using transvaginal NOTES was a new, safe, and feasible minimally invasive surgery for early-stage endometrial cancer. However, they also concluded that a large case series or even prospectively randomized controlled trials should be conducted to evaluate the true clinical feasibility, safety, and, most importantly, long-term survival outcomes of this approach.

Future perspectives of transvaginal surgery

With ongoing efforts to decrease the size and/or number of incisions, improve patient outcomes, and increase patient satisfaction, SILS and NOTES represent the next leap in laparoscopic surgery. The goal of NOTES is to improve patient outcomes by rapid

Table 2
Types of NOTES hysterectomy.

Abbreviation	Name	Description
VANH	Vaginally assisted NOTES hysterectomy	Total hysterectomy where, first, the caudal part of the uterus is dissected vaginally under direct vision, and afterward the rest of hysterectomy is performed by means of transvaginal NOTES using an endoscope and laparoscopic instruments
TVNH	Total vaginal NOTES hysterectomy	Total hysterectomy where the entire uterus is dissected by means of transvaginal NOTES using an endoscope and laparoscopic instruments

NOTES = natural orifice transluminal endoscopic surgery.

convalescence and superior cosmesis. Conventional transvaginal surgery has the advantage of the absence of abdominal scarring. In comparison with conventional transvaginal surgery, the surgical field of transvaginal NOTES can be demonstrated clearly with endoscopic guidance, and any pathology beyond the reach of operator's fingers can be managed easily with the assistance of laparoscopic instruments. Transvaginal NOTES is especially beneficial in patients with nulliparity, obesity, or narrow vagina, which are all considered as relative contraindications in conventional transvaginal surgery because of restricted downward traction of pelvic organs for surgical manipulation and hemostasis. Transvaginal NOTES appears to be another form of SILS, but provides invisible scar and a lesser degree of loss of triangulation and instrument crowding due to vaginal elasticity. A surgeon who wants to perform transvaginal NOTES should be confident in SILS. Being experienced in SILS certainly helps keep the learning curve short and shorten operative time.

Conclusion

NOTES is a novel revolutionary surgical technique developed in the field of minimally invasive surgery. NOTES has been applied in general surgery, and its feasibility and safety have been already proved. Recently, clinical application of transvaginal NOTES has broadened significantly in gynecology. Using transvaginal NOTES by applying the method of SILS via the vaginal route, not only adnexal surgery and hysterectomy, but also myomectomy and oncologic surgery could be performed safely and effectively in selected patients. In future, further comparative studies or even prospectively randomized controlled trials should be performed to confirm the advantages and significance of transvaginal NOTES in clinical practice.

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