



Natural orifice transluminal endoscopic surgery in gynecology: What do we know till now?

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ABSTRACT

Surgical advancements are focusing currently on minimally invasive techniques, the latest of which is natural orifice transluminal endoscopic surgery. Though this approach is feasible through different natural orifices, the vaginal approach is the one which gained attention the most, given the vaginal flexibility and the ability to access pelvic and abdominal organs. Compared to gynecologists, general surgeons were precedents for using the vaginal orifice as a port of surgical entry. However, this vaginal approach is being more frequently implemented during gynecological surgeries nowadays. Advantages of natural orifice transluminal endoscopic surgery include scarless surgery, better exposure, reduced pain scores, less peri-operative complications, shorter hospital stay and improved patient satisfaction. This article provides an idea on the application of vaginal natural orifice transluminal endoscopic surgery in gynecology along with future potentials.

1. Introduction

Current surgical developments focus on accessing internal organs through single-port entries. Natural orifice transluminal endoscopic surgery (NOTES) is an example of this technique that uses straight or circuitous routes into the viscera.¹ NOTES was mainly developed in mid 2000's,² with the first preclinical trials on animal models being described in 2004.³

NOTES spares the abdominal wall from any incisions, limiting surgical site infections, hernias, scars and post-operative pain.¹ Though complications associated with the entry of the first trocar are rare, they can be very serious, including visceral and vascular injuries.⁴ NOTES eliminates the risk of such complications.⁵

NOTES is mainly described as two variants: either pure NOTES with access through the natural orifice, or hybrid NOTES with a combination of transabdominal and natural orifice access.⁶ Though NOTES can be performed by accessing different natural orifices, vaginal NOTES

(vNOTES) has gained a special interest mainly because colpotomy was proven to be a safe port of entry.⁷ While avoiding abdominal incisions, vNOTES allows for a wide access and excellent visualization of the abdominal cavity.⁸ It makes use of an endoscope which provides good visibility and reduces the associated risk of nearby organ damage. Hence, vNOTES is gaining remarkable interest in the field of gynecology for its safe utility in hysterectomy, adnexectomy, salpingectomy, vaginal vault suspension, myomectomy and others.⁹

However, this technique requires mastering special skills.⁸ Previous data suggested that the learning curve of NOTES can be described as fast,^{9,10} such that 20 cases comprised the initial learning curve, 100 cases are needed to acquire a competent phase, and 180 cases for the proficiency and to acquire enough confidence to tackle more complicated cases.¹¹

Another limitation is the restriction caused by conflict between instruments introduced through a single port. The latter can be overcome by proper selection of flexible instrumentation.⁸ For instance, in 2017,

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the Food and Drug Administration (FDA) in the United States approved a flexible robotic device to be used for colorectal surgery. Later in 2018, it was used for the first time to perform 4 separate surgeries, one of which was salpingo-oophorectomy.¹

Several contraindications of vNOTES were described, including virginity,¹² morbid obesity especially when gasless laparoscopy is employed, ovarian mass suspicious of malignancy with no frozen section for confirmation, history of severe endometriosis, history of pelvic inflammatory disease, history of 3 or more prior open abdominal/pelvic surgeries, pelvic adhesions, and definitely serious medical conditions that do not allow any surgical intervention.¹³ Those contraindications should be assessed pre-operatively through a bimanual rectovaginal examination to exclude masses, scar tissue or nodularity in both the anterior and posterior cul-de-sac. Also, full history focusing on previous pelvic surgeries, symptoms of endometriosis and pelvic inflammatory disease is warranted.⁵

In this article, we presented a review of vNOTES in gynecology to further clarify the implementation of such procedures with their feasibility, safety, and complications and to present an insight into the future of vNOTES.

1.1. Hysterectomy

vNOTES hysterectomy has emerged as a new technique in the field of gynecology. Recently, several studies were conducted to study the feasibility, safety and application of this procedure.¹⁴ In a review of 33 studies including 384 hysterectomies, vNOTES hysterectomy was proven to be a safe procedure.¹⁵ Given the fact that vNOTES is less invasive, the introduction of vNOTES decreased the number laparoscopic trans-abdominal hysterectomies, though it did not decrease the number of classical vaginal hysterectomies.¹⁶

The first hysterectomy to be performed by vNOTES was actually a successful hybrid vNOTES without conversion to laparoscopy or laparotomy.¹⁷ Hybrid vNOTES was found to be more efficient compared to laparoscopically-assisted vaginal hysterectomy as the size of the uterus increases.¹⁸ Later, Baekelandt was the first to report the feasibility of pure vNOTES hysterectomy. He demonstrated that the procedure can be performed successfully, while reporting no intra-operative complications. Mean operative time was 97 min, but the main advantage was the reduced post-operative pain scores.¹⁶

In a prospective case series of 33 patients, vNOTES hysterectomy was shown to combine both the advantages of vaginal surgery and laparoscopy. Compared to conventional laparoscopic hysterectomy, it allowed for a better access into internal organs, overcame the limits presented by minimal uterine descent, limited gas insufflation, and favored a moderate Trendelenburg positioning over the overt one applied in conventional laparoscopy.⁹ Additional advantages include better operative outcomes, shorter operative time, lower estimated blood loss, and shorter post-operative hospital stay.¹⁸ While avoiding abdominal wall incisions, inexpensive conventional laparoscopy instruments can be safely used for vNOTES hysterectomy. Thus, reasonable costs can be combined with operative superiority and higher post-operative patient satisfaction, namely when it comes to pain reduction and cosmetics.⁵ vNOTES allows the surgeon to clearly survey and access the pelvis after completion of vaginal hysterectomy without any additional abdominal incisions. Thus, vNOTES should always be considered as a rescue surgery after vaginal hysterectomy for pelvic procedures.¹⁹ Also, vNOTES subtotal hysterectomy can be a safe option in case the cervix is to be preserved.²⁰

In one study, vNOTES had a shorter operative time with a mean difference of 22.04 min, and a shorter length of hospital stay despite higher cost in hospital charges.²¹ Similarly, Housmans et al. reported a mean difference in operative time between vNOTES and the conventional laparoscopy approaches of 16.73 min, in favor of vNOTES being faster.²²

On the other hand, in their review of 40 vNOTES hysterectomies and 120 laparoscopic assisted vaginal hysterectomies, Kim et al. found that LAVH had a mean operative time of 58.3min compared with 75.4min for vNOTES.²³

Several studies have been performed to compare vNOTES hysterectomy to conventional laparoscopic techniques in terms of complications. Baekelandt et al., 2017 reported no differences in post-operative complication rate between vNOTES and laparoscopic assisted vaginal hysterectomy.²¹ vNOTES has also led to less blood loss and a shorter hospital stay compared with.²² However, vNOTES procedure was superior in terms of bleeding loss.²³ In a large study where 750 patients underwent vNOTES hysterectomies, the total complication rate was in total 5.2%, with 30-day post-operative complications being more frequent than intra-operative ones (3.8% versus 1.4%). Though the total incidence of complications in vNOTES hysterectomy was higher than that reported in all gynecologic vNOTES performed in the 1000 patients of the same study (5.2% versus 3.9%),²⁴ the 30-day complication rate of vNOTES hysterectomy is still lower than the 30-day post-operative complication rate of laparoscopic hysterectomy (8%) and abdominal hysterectomy (15%).²⁵

Interestingly, vNOTES hysterectomy was performed in female-to-male transgender men. Similar results were encountered between the vNOTES group and the conventional laparoscopy group in terms of operative time, estimated blood loss, and operative complications; however, post-operative pain was significantly reduced in the vNOTES group.²⁶

One specific limitation in vNOTES hysterectomy is the disproportion between uterine tumor size and vaginal dimensions.²⁷ Though one study showed that vNOTES hysterectomy for uteri larger than 1000g can be still feasible and safe,²⁸ larger uterine masses may increase operative time and estimated blood loss.^{29,30}

The first robotic vNOTES hysterectomy was performed in 2015 by replacing the conventional endoscope used previously in such procedures. Operative time was much higher than the previously described values, at 198.8 ± 39.0 min. This can be explained by the fact that proper instrumentation was not yet available for robotic vNOTES. However, using the curved cannula-wristed instrument, robotic vNOTES allows for accessing deeper locations and resecting larger tumors. Thus, the use of this technique should be limited to certain circumstances and patient population.³¹ Three years later, flexible robotic vNOTES hysterectomy was introduced into gynecologic surgeries using the Flex® Robotic System with Colorectal Drive. The surgery was successfully performed with operative time of 78min, although laparoscopic assistance was needed for uterine manipulation.¹ Later, Yang et al. in 2019 reported that scarless and gasless robotic vNOTES hysterectomy is a feasible and safe procedure as a scarless and gasless surgical technique in their study conducted on 13 patients. Only one patient required laparoscopic assistance with zero conversion rate, and no post-operative complications were encountered.³² Then in 2020, Lowenstein et al. used the Hominis surgical system for robotic vNOTES hysterectomy. The system had light weight and small footprint, which ensured easy mobility and short setup time. All surgeries were performed completely using the system with no intra-operative complications. However, post-operative urinary tract infection occurred in 10% of the cases.³³

1.2. Salpingo-oophorectomy

Salpingo-oophorectomy via vNOTES after vaginal hysterectomy was well described in the literature.⁸ It is mainly performed following vaginal hysterectomy to avoid abdominal incisions,⁸ given the limitations that are overcome once the uterus is removed and a better view of the pelvis is achieved.³⁴ Though the adnexa are barely accessible through vaginal port without hysterectomy, vNOTES using colpotomy for adnexal

procedures can be a solution when hysterectomy is to be avoided, like in ectopic pregnancy.³⁵

It is important to note that the limitations of adnexectomy using vNOTES are spillage, especially in the context of unexpected malignant tumors, and the presence of adhesions extending from the adnexa to the uterus or to the pelvic fascia.¹⁵

Though vNOTES has been used in general surgery for years, the first paper to describe adnexal procedures using NOTES was issued in 2012 and included 3 cases of tubal sterilization, 3 cases of salpingectomy for ectopic pregnancy, and 4 cases of enucleation of ovarian tumor. All were completed using vNOTES except for one case of ovarian tumor which was misdiagnosed and found to be an inaccessible mucinous tumor anterior to the uterus, thus conversion into transabdominal laparoscopy was warranted to avoid spillage.³⁶ In the same year, ovarian cystectomy, salpingectomy, salpingostomy, oophorectomy, para-tubal cystectomy and ovarian wedge resection were successfully performed via vNOTES, all in a single study.³⁷ Then in 2013, adnexectomy through vNOTES was again described in 7 patients. They successfully underwent vNOTES for adnexal masses without any post-operative complications and reported high level of satisfaction concerning the cosmetic outcome of the surgery.³⁸

vNOTES can decrease estimated blood loss (EBL), operative time (OT) and length of hospital stay. In one study, 33 patients were operated on using vNOTES for adnexectomy, while 203 patients underwent conventional laparoscopic adnexectomy. EBL in the vNOTES group was lower (14.0 mL vs 27.6 mL), operating time was shorter (39.2 min vs 51.9 min), and hospital stay was reduced (1.4 days vs 2.1 days). However, hospital charges were much higher in the vNOTES group (p -value < 0.05).³⁹ In a newer study including 33 patients who successfully submitted to adnexectomy, OT and EBL both decreased as surgeons performed more procedures, thus a good learning curve was established.⁹

A review paper compared vaginal ovarian cystectomy to conventional laparoscopic cystectomy for benign indications. 525 patients from 10 different studies were included, 299 of whom underwent laparoscopic ovarian cystectomy. 5 main approaches were utilized for vaginal ovarian cystectomy. They varied mainly by the technique of entering the cul-de-sac and the technique of cystectomy.⁴⁰ One of these techniques in the included studies was vNOTES.^{41–43} In one study, 14 patients successfully underwent fertility-sparing vNOTES ovarian cystectomy for benign indications. In each patient, the cul-de-sac was accessed through a 2.5 cm colpotomy, and a vaginal NOTES port was introduced, through which the excised cyst was removed. No post-operative complications were reported.⁴² Wang et al. found no significant difference in costs between vNOTES for benign ovarian cystectomy and laparoscopic ovarian cystectomy. Though estimated blood loss (EBL) was significantly higher in vNOTES (31 mL versus 21 mL in laparoscopic approach, p -value of 0.028), the difference had no clinical impact. However, mean OT was reduced in the vNOTES group ($n = 34$) compared to laparoscopic ovarian cystectomy group ($n = 243$) (38 versus 54 min) (p -value < 0.001).⁴³ A much higher mean OT (74 min) was observed by Ding et al. in 6 patients who underwent ovarian cystectomy using vNOTES.⁴¹ These studies showed that vNOTES can be a feasible approach for ovarian cystectomy.

A huge recent study included 1000 patients undergoing vNOTES, out of 270 patients submitted to pelvic surgeries without hysterectomy. Pelvic organs were accessed through a single 2.5 cm posterior colpotomy. Intraoperative complications were not reported, and post-operative complications were documented just in 0.4% of these cases, but none was of Clavien-Dindo grades 3 or 4.²⁴ Thus, vNOTES can be safely used in pelvic surgeries even without hysterectomy.

One important advantage of vNOTES is decreased post-operative pain. Salpingo-oophorectomy for benign indications was performed via vNOTES by a single surgeon on 6 different patients. Mean post-operative pain scores using visual analog scale were 4.1 at 6 h, 2.5 at 12 h and 0.67

at 24 h. Those scores were reduced in vNOTES given the absence of abdominal incisions.⁵ Similarly, in another study, pain scores were significantly lower in patients who underwent vNOTES salpingectomy compared to those who underwent conventional laparoscopic salpingectomy (2.22 ± 0.65 versus 2.75 ± 0.72), and patient cosmetic satisfaction was significantly higher post vNOTES, with p -value < 0.05.⁴⁴ Also, salpingo-oophorectomy using vNOTES was performed in female-to-male transgender men, and significantly lower pain scores were recorded than conventional procedures of laparoscopy.²⁶

One technical problem in vNOTES is gas leakage, making the use of pneumoperitoneum impractical.¹⁴ However, gasless laparoscopy for salpingo-oophorectomy via vNOTES was described to be successfully performed in 10 patients, without the need of any abdominal incision or gas insufflation. The mean operative time was 22.2 min, with no intra-operative complications.¹³ Another advantage of gasless laparoscopy is avoiding the risks imposed by the use of intra-abdominal carbon dioxide, including subcutaneous emphysema, air embolism, hypercapnia, hemodynamic changes and cardiopulmonary dysfunction.⁴⁵

In 2018, the flexible robotic device approved by the FDA for colorectal surgery was used for the first time to perform 4 separate surgeries, one of which was salpingo-oophorectomy. The technique was called vaginal access minimally invasive surgery (VAMIS), where hysterectomy and right salpingo-oophorectomy were performed. Salpingo-oophorectomy was achieved in 13.5 min, totally using robotic VAMIS, but laparoscopic assistance was needed.¹ A newer study reported the successful use of robotic vNOTES for bilateral salpingo-oophorectomy on 8 women. Median operative time was 45 min, but it decreased as more surgeries were done indicating a reasonable learning curve for robotic vNOTES. Surgeon's usability assessment was made on a score from 1 to 5, with a median of 5 (good). This shows that robotic vNOTES can be taught and utilized in gynecologic surgeries.⁴⁶ Thus, flexible robotic system can be used in direct-target NOTES.

1.3. Ectopic pregnancy

Many studies have emphasized on the role of vNOTES (natural orifice transluminal endoscopic surgery), as an alternative to conservative treatment, for treating ectopic pregnancies in selected cases. Baekelandt et al. described the role of transvaginal hydrolaparoscopy (TVHL) in the diagnosis of pregnancy of unknown location (PUL) and the role of vNOTES in treating 12 patients with ectopic pregnancies (IMELDA technique). All women were successfully treated with a 2.5-cm colpotomy followed by vNOTES salpingectomy or salpingostomy. On the other hand, 3 women with PUL were explored with TVHL. All of those explorations were negative, leaving only a 4 mm perforation. On follow up, 2 of them had normal intrauterine pregnancies and one had persistent elevated hCG for which she has been treated with methotrexate.⁴⁷

Similarly, Chen et al. performed successful hybrid NOTES with trans-abdominal assistance on 4 patients, and pure NOTES on 8 cases with ectopic pregnancies. Conversion rate to traditional laparoscopy or laparotomy was zero, and peri-operative complications were not reported, with a median operative time of 47.5 min. None of them required laparotomy or laparoscopy. Post-operative pain scores were low, ranging between 1 and 3. To note that all of the included patients have had a previous vaginal delivery which could have enhanced elasticity.⁴⁸ More recently, a quick uncomplicated vNOTES procedure of 36-min duration was successfully performed on a 27-year-old gravida 3 para 0 woman, with a history of left salpingectomy, who presented for a left tubal stump pregnancy.⁴⁹

1.4. Myomectomy

We know of only 2 articles reporting the use of vNOTES for myomectomy. One study in 2017 included 8 patients treated for intramural,

subserosal and pedunculated myomas. In case of a posterior myoma, a 2.5 cm posterior colpotomy was made, the pouch of Douglas was opened and vNOTES port was inserted. In case of an anterior myoma, an anterior colpotomy was made, and vNOTES port was inserted. None had complications. The author advised to reduce the surgical time, in a first-world hospital, with the use of an autlocking suture and NOTES port. This article suggested that stage 3–7 myomas can be treated by a minimally invasive technique like vNOTES.⁵⁰

In the same year, Liu et al. demonstrated a successful stepwise approach of applying transvaginal vNOTES in a 42-year-old lady, gravida 2, para 2, to remove a 6-cm left anterior myoma with uterine preservation. It was combined with a traditional transvaginal anterior colpotomy. The surgery resulted in the resolution of her pain with minimal blood loss.⁵¹

vNOTES for myomectomy allows the instruments to reach deeper location in the pelvis and hence resect larger myomas. This is attributed to vaginal flexibility that improves the extension of the colpotomy incision.¹⁵

2. Vault suspension procedures

Vault suspension procedures such as sacrocolpopexy and uterosacral ligament suspension constitute an important part of urogynecology. Recently, a trend emerged to perform mesh sacrocolpopexy partially via the vaginal route.¹⁵

One study compared mesh-related complications between total vaginal hysterectomy with laparoscopic sacrocolpopexy (TVH-LSC) and laparoscopic supracervical hysterectomy with laparoscopic placement of sacrocolpopexy mesh (LSH-LSC). It showed no significant difference in terms of mesh-related complications, intra-operative complications, and re-operation for recurrent prolapse. However, operative time was decreased by more than 1 h in case of vaginal mesh attachment in TVH-LSC.⁵² In another retrospective case series, 26 patients with stage II to IV pelvic organ prolapse underwent vNOTES sacrocolpopexy. Only 3 cases were converted to single incision abdominal laparoscopy. No post-operative complications were encountered, and significant improvement was seen one month after surgery in terms of both, physical prolapse and quality of life.⁵³

This approach is a reasonable option for patients who desire a minimally invasive approach with excellent cosmetic results. In particular, the use of hydro-dissection and anterior mesh anchoring before reducing prolapse are surgical techniques that aid in effectively performing this procedure.⁵¹

According to Jallad et al., sacrocolpopexy via NOTES allowed for improved visualization, safe access to the sacrum, and possibility to more accurately tension the mesh.¹⁴ Similarly, Lowenstein et al. stated that this technique provided better exposure and decreased the risk of ureteral injury, while avoiding mesh associated complications and abdominal wound infection.⁵⁴ An important advantage of vNOTES is that it decreases the risk of ureter kinking due to good ureteral exposure, thus allowing safe placement of the stitch.¹⁰ vNOTES helps avoiding bladder injuries as well as bleeding by building an extraperitoneal access to the sacrum, thus allowing the mesh to go along the access to the presacral region, surpassing the intra peritoneal organs.⁵⁵

Though this is a new technique that requires special training, negative significant correlation has been described between a surgeon's experience and surgery duration. vNOTES USLS was proven feasible and safe with improvement in surgical performance in a short period of time. This was evidenced by a decrease in mean surgical time from 140 min to 103 min after half of the cases.¹⁰

2.1. Lymphadenectomy

Several reports have described the importance of vNOTES in benign

surgical indications. However, data are scarce concerning resection of tumors or lymph nodes. The role of transvaginal vNOTES for lymphadenectomy in patients with endometrial cancer is becoming an innovation. One study on 3 endometrial cancer cases demonstrated that vNOTES can be used not only to perform hysterectomy and salpingo-oophorectomy, but also to remove lymphatic tissue around the external iliac vessels, the hypogastric vessels and the obturator nerve. The three cases were stage 1 cancer with no metastasis or nodal involvement. Average operative time was 249.3 min with no peri-operative complications.⁵⁶

Similarly, Leblanc et al. highlighted the role of vNOTES, in addition to sentinel node policy, in treating an 85-year-old lady with IB grade 2 endometrial cancer. A vaginal hysterectomy was performed first using a 5 mm vessel sealer, uterine corpus was delivered vaginally, then a single port device was installed. A right sentinel node was identified and dissected under color-segmented fluorescence. Finally, a salpingo-oophorectomy was performed.⁵⁷

Most recently, in 2019, Baekelandt et al. showed that the entire retroperitoneal space including the caudal part of the obturator fossa, the iliac arteries, the sacral plexus and the lower para-aortic region can successfully be accessed via a para cervical incision in the lateral vaginal fornix (retroperitoneal vNOTES). This was in comparison to the *trans*-peritoneal approach that gives good access only to the cranial pelvic retroperitoneum.⁵⁸

Sentinel lymph node (SLN) mapping was described for the first time using vNOTES in 2019 by Lee et al. 4 patients with clinical stage 1 endometrial cancer were included, and mapping was performed using indocyanine green-based near-infrared fluorescence imaging technique. The overall and bilateral detection rates were both fully achieved in all 4 cases, and hence, was 100%. Conversion rate to traditional laparoscopy or laparotomy was zero. This study showed that SLN mapping using vNOTES helped avoid radical lymph node resection along with its morbidities.⁵⁹ In the same year, the first case of lymph node dissection using vNOTES for endometrial cancer was reported. A 57-year-old lady submitted for vNOTES hysterectomy and bilateral salpingo-oophorectomy for pre-operatively benign diagnosis. However, she was found to have Grade 1 endometrioid carcinoma. Indocyanine-green-positive lymph nodes were found in the internal iliac and obturator areas, bilaterally. Thus, the indocyanine-green-guided vNOTES resection of lymph nodes was shown accidentally to be feasible.⁶⁰

2.2. Future of notes

The future of NOTES mainly relies on the continuous development of novel instruments and techniques that could aid surgeons and facilitate the application of those procedures.¹⁵ Several achievements have been already reported. In 2019, Naval et al. described the use of a transcervical instrument for uterine manipulation which gave a better exposure and allowed the use of one hand for retraction of bowels and adnexa instead of retracting the uterus.⁶¹ Also, according to Atallah et al., the addition of flexible elbows to robotic or hand operated effector arms represent an important step forward in instrument design.¹ Similarly, with the new surge of robotic vNOTES hysterectomy which is characterized by a rapid learning curve and the flexibility obtained the robot's joints, it is mostly likely that surgeons will be able to perform more complex procedures with minimal strain.³³

vNOTES is a safe procedure if performed on selected patients by a skilled surgeon, but considerations of positioning, colpotomy and proper diagnosis of masses if present should be made prior to surgery.³⁹ Clear cutoffs, guidelines and techniques are hence warranted. In addition, it is well known that "practice makes perfect".

As the number of vNOTES procedures performed increases, the operative time and complication rate decrease. This can be explained by learning curves of surgeons who are gaining more experience. Therefore

it is safe to expect that vNOTES outcomes will significantly improve with time.^{9–11}

Women are still reluctant in choosing the vNOTES approach.¹⁵ Studies have shown that younger women are more likely to refuse vNOTES,⁶² maybe because of concerns regarding fertility and sexual activity.¹⁵ However, current data show that there is no association between vNOTES and dyspareunia.⁶³ To overcome this limitation, we should focus on the superiority of NOTES procedures compared to conventional ones upon application.¹⁴

In conclusion, vNOTES can be the next frontier in gynecologic surgeries. Thus the development of both surgical procedures and instrumentation must continue for vNOTES to mature into viable widespread techniques.¹⁵

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Declaration of competing interest

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References

- Atallah S, Hodges A, Larach SW. Direct target NOTES: prospective applications for next generation robotic platforms. *Tech Coloproctol*. 2018;22(5):363–371. <https://doi.org/10.1007/s10151-018-1788-z>.
- Rattner D. Introduction to NOTES white paper. *Surg Endosc*. 2006;20(2):185. <https://doi.org/10.1007/s00464-005-3007-z>.
- Kalloor AN, Singh VK, Jagannath SB, et al. Flexible transgastric peritoneoscopy: a novel approach to diagnostic and therapeutic interventions in the peritoneal cavity. *Gastrointest Endosc*. 2004;60(1):114–117. [https://doi.org/10.1016/s0016-5107\(04\)01309-4](https://doi.org/10.1016/s0016-5107(04)01309-4).
- Ahmad G, Baker J, Finnerty J, et al. Laparoscopic entry techniques. *Cochrane Database Syst Rev*. 2019;18(1). <https://doi.org/10.1002/14651858.CD006583.pub5>. CD006583.
- Kale A, Saribrabrahim B, Başol G. Hysterectomy and salpingo-oophorectomy by transvaginal natural orifice transluminal endoscopic surgery (NOTES): Turkish surgeons' initial experience. *Int J Surg*. 2017;47:62–68. <https://doi.org/10.1016/j.ijsu.2017.09.062>.
- Baekelandt JF, De Mulder PA, Le Roy I, et al. Transvaginal natural orifice transluminal endoscopic surgery (vNOTES) adnexectomy for benign pathology compared with laparoscopic excision (NOTABLE): a protocol for a randomised controlled trial. *BMJ Open*. 2018;8(1), e018059. <https://doi.org/10.1136/bmjopen-2017-018059>.
- Tolcher MC, Kalogera E, Hopkins MR, et al. Safety of culdotomy as a surgical approach: implications for natural orifice transluminal endoscopic surgery. *J Soc Laparoendosc Surg*. 2012;16(3):413–420. <https://doi.org/10.4293/108680812X13462882735854>.
- Jallad K, Siff L, Thomas T, et al. Salpingo-oophorectomy by transvaginal natural orifice transluminal endoscopic surgery. *Obstet Gynecol*. 2016;128(2):293–296. <https://doi.org/10.1097/AOG.0000000000001513>.
- Karkia R, Giacchino T, Taylor J, et al. Hysterectomy and Adenectomy via transvaginal natural orifice transluminal endoscopic surgery (vNOTES): a UK perspective with a case series of 33 patients. *Eur J Obstet Gynecol Reprod Biol*. 2019; 242:29–32. <https://doi.org/10.1016/j.ejogrb.2019.08.023>.
- Lowenstein L, Matanes E, Lauterbach R, et al. Feasibility and learning curve of transvaginal natural orifice transluminal endoscopic surgery for hysterectomy and uterosacral ligament suspension in apical compartment prolapse. *Female Pelvic Med Reconstr Surg*. 2021;27(1):e171–e176. <https://doi.org/10.1097/SPV.0000000000000875>.
- Wang CJ, Go J, Huang HY, et al. Learning curve analysis of transvaginal natural orifice transluminal endoscopic hysterectomy. *BMC Surg*. 2019;19(1):88. <https://doi.org/10.1186/s12893-019-0554-0>.
- Chene G, Nohuz E, Mansoor A, et al. Easy way to perform salpingectomy by transvaginal natural orifice transluminal endoscopic surgery (vNOTES) (with video). *J Gynecol Obstet Hum Reprod*. 2020;50(5), 102005. <https://doi.org/10.1016/j.jjogoh.2020.102005>.
- Liu T, Chen Y, Wang X. Transvaginal salpingo-oophorectomy with gasless laparoscopy - an optional pure natural orifice transluminal endoscopic surgery. *Ginekol Pol*. 2020;91(1):1–5. <https://doi.org/10.5603/GP.2020.0001>.
- Jallad K, Walters MD. Natural orifice transluminal endoscopic surgery (NOTES) in gynecology. *Clin Obstet Gynecol*. 2017;60(2):324–329. <https://doi.org/10.1097/GRF.0000000000000280>.
- Li CB, Hua KQ. Transvaginal natural orifice transluminal endoscopic surgery (vNOTES) in gynecologic surgeries: a systematic review. *Asian J Surg*. 2020;43(1): 44–51. <https://doi.org/10.1016/j.asjsur.2019.07.014>.
- Baekelandt J. Total vaginal NOTES hysterectomy: a new approach to hysterectomy. *J Minim Invasive Gynecol*. 2015;22(6):1088–1094. <https://doi.org/10.1016/j.jmig.2015.05.015>.
- Su H, Yen CF, Wu KY, et al. Hysterectomy via transvaginal natural orifice transluminal endoscopic surgery (NOTES): feasibility of an innovative approach. *Taiwan J Obstet Gynecol*. 2012;51(2):217–221. <https://doi.org/10.1016/j.tjog.2012.04.009>.
- Wang CJ, Huang HY, Huang CY, et al. Hysterectomy via transvaginal natural orifice transluminal endoscopic surgery for nonprolapsed uteri. *Surg Endosc*. 2015;29(1): 100–107. <https://doi.org/10.1007/s00464-014-3639-y>.
- Guan X, Bardawil E, Liu J, et al. Transvaginal natural orifice transluminal endoscopic surgery as a rescue for total vaginal hysterectomy. *J Minim Invasive Gynecol*. 2018; 25(7):1135–1136. <https://doi.org/10.1016/j.jmig.2018.01.028>.
- Su H, Huang L, Han CM, et al. Natural orifice transluminal endoscopic surgery (NOTES) subtotal hysterectomy: a feasibility study. *Taiwan J Obstet Gynecol*. 2018; 57(3):355–359. <https://doi.org/10.1016/j.tjog.2018.04.005>.
- Baekelandt J, De Mulder PA, Le Roy I, et al. Postoperative outcomes and quality of life following hysterectomy by natural orifice transluminal endoscopic surgery (NOTES) compared to laparoscopy in women with a non-prolapsed uterus and benign gynaecological disease: a systematic review and meta-analysis. *Eur J Obstet Gynecol Reprod Biol*. 2017;208:6–15. <https://doi.org/10.1016/j.ejogrb.2016.10.044>.
- Housmans S, Noori N, Kapurubandara S, et al. Systematic review and meta-analysis on hysterectomy by vaginal natural orifice transluminal endoscopic surgery (vNOTES) compared to laparoscopic hysterectomy for benign indications. *J Clin Med*. 2020;9(12):3959. <https://doi.org/10.3390/jcm9123959>.
- Kim SH, Jin CH, Hwang IT, et al. Postoperative outcomes of natural orifice transluminal endoscopic surgery-assisted vaginal hysterectomy and conventional laparoscopic-assisted vaginal hysterectomy: a comparative study. *Obstet Gynecol Sci*. 2018;61(2):261–266. <https://doi.org/10.5468/ogs.2018.61.2.261>.
- Baekelandt J, Kapurubandara S. Benign gynaecological procedures by vaginal natural orifice transluminal endoscopic surgery (vNOTES): complication data from a series of 1000 patients. *Eur J Obstet Gynecol Reprod Biol*. 2021;256:221–224. <https://doi.org/10.1016/j.ejogrb.2020.10.059>.
- Louie M, Strassle PD, Moulder JK, et al. Uterine weight and complications after abdominal, laparoscopic, and vaginal hysterectomy. *Am J Obstet Gynecol*. 2018; 219(5):480.e1–480.e8. <https://doi.org/10.1016/j.ajog.2018.06.015>.
- Lee YL, Hsu TF, Jiang LY, et al. Transvaginal natural orifice transluminal endoscopic surgery for female-to-male transgender men. *J Minim Invasive Gynecol*. 2019;26(1): 135–142. <https://doi.org/10.1016/j.jmig.2018.04.022>.
- Lee CL, Wu KY, Huang CY, et al. Subtotal hysterectomy by natural orifice transluminal endoscopic surgery. *Gynecol Minim Invasive Ther*. 2017;6(4):195–198. <https://doi.org/10.1016/j.gmit.2017.02.005>.
- Wang X, Li J, Hua K, et al. Transvaginal natural orifice transluminal endoscopic surgery (vNOTES) hysterectomy for uterus weighing ≥ 1 kg. *BMC Surg*. 2020;20(1): 234. <https://doi.org/10.1186/s12893-020-00897-3>.
- Temtanakitpaisan T, Wu KY, Huang CY, et al. The outcomes of transvaginal NOTES hysterectomy in various uterine sizes. *Taiwan J Obstet Gynecol*. 2018 Dec;57(6): 842–845. <https://doi.org/10.1016/j.tjog.2018.10.013>.
- Nulens K, Bosteels J, De Rop C, et al. vNOTES hysterectomy for large uteri: a retrospective cohort study of 114 patients. *J Minim Invasive Gynecol*. 2020; S1553–4650(20):31083–31089. <https://doi.org/10.1016/j.jmig.2020.10.003>.
- Lee CL, Wu KY, Su H, et al. Robot-assisted natural orifice transluminal endoscopic surgery for hysterectomy. *Taiwan J Obstet Gynecol*. 2015;54(6):761–765. <https://doi.org/10.1016/j.tjog.2015.08.023>.
- Yang YS. Robotic natural orifice transluminal endoscopic surgery (NOTES) hysterectomy as a scarless and gasless surgery. *Surg Endosc*. 2020;34(1):492–500. <https://doi.org/10.1007/s00464-019-07115-z>.
- Lowenstein L, Mor O, Matanes E, et al. Robotic vaginal natural orifice transluminal endoscopic hysterectomy for benign indications. *J Minim Invasive Gynecol*. 2020; S1553–4650(20):31110–31119. <https://doi.org/10.1016/j.jmig.2020.10.021>.
- Kho RM, Magrina JF. Round ligament technique and use of a vessel-sealing device to facilitate complete salpingectomy at the time of vaginal hysterectomy. *J Minim Invasive Gynecol*. 2015;22(6):1084–1087. <https://doi.org/10.1016/j.jmig.2015.05.010>.
- Chene G, Lambin G, Chabert P, et al. [How I do... salpingectomy or adnexectomy during vaginal hysterectomy in a safe manner?]. *Gynecol Obstet Fertil Senol*. 2018; 46(4):437–439. <https://doi.org/10.1016/j.gofs.2018.01.001>.
- Lee CL, Wu KY, Su H, et al. Transvaginal natural-orifice transluminal endoscopic surgery (NOTES) in adnexal procedures. *J Minim Invasive Gynecol*. 2012;19(4): 509–513. <https://doi.org/10.1016/j.jmig.2012.02.005>.
- Ahn KH, Song JY, Kim SH, et al. Transvaginal single-port natural orifice transluminal endoscopic surgery for benign uterine adnexal pathologies. *J Minim Invasive Gynecol*. 2012;19(5):631–635. <https://doi.org/10.1016/j.jmig.2012.04.001>.
- Yang YS, Hur MH, Oh KY, et al. Transvaginal natural orifice transluminal endoscopic surgery for adnexal masses. *J Obstet Gynaecol Res*. 2013;39(12):1604–1609. <https://doi.org/10.1111/jog.12108>.
- Li YC, Ku FC, Kuo HH, et al. Transvaginal endoscopic surgery-assisted versus conventional laparoscopic adnexectomy (TVEA vs. CLA): a propensity-matched study

- and literature review. *Taiwan J Obstet Gynecol.* 2017;56(3):336–341. <https://doi.org/10.1016/j.tjog.2017.04.013>.
40. Galazis N, Mappouridou S, Saso S, et al. Applying the vaginal approach for benign ovarian cystectomy: current evidence and future applications. *Future Sci OA.* 2020; 6(5):FSO470. <https://doi.org/10.2144/fsoa-2019-0138>.
 41. Ding DC, Chu TY, Hong MK. Hysterectomy and ovarian cystectomy using natural orifice transluminal endoscopic surgery: an initial experience at Tzu Chi General Hospital. *Ci Ji Yi Xue Za Zhi.* 2017;29(4):208–212. https://doi.org/10.4103/tcmj.tcmj_127_17.
 42. Baekelandt J. Transvaginal natural orifice transluminal endoscopic surgery: a new approach to ovarian cystectomy. *Fertil Steril.* 2018;109(2):366. <https://doi.org/10.1016/j.fertnstert.2017.10.037>.
 43. Wang CJ, Wu PY, Kuo HH, et al. Natural orifice transluminal endoscopic surgery-assisted versus laparoscopic ovarian cystectomy (NAOC vs. LOC): a case-matched study. *Surg Endosc.* 2016;30(3):1227–1234. <https://doi.org/10.1007/s00464-015-4315-6>.
 44. Xu B, Liu Y, Ying X, et al. Transvaginal endoscopic surgery for tubal ectopic pregnancy. *J Soc Laparosc Surg.* 2014;18(1):76–82. <https://doi.org/10.4293/108680813X13693422519875>.
 45. Li SH, Deng J, Huang FT, et al. Impact of gasless laparoscopy on circulation, respiration, stress response, and other complications in gynecological geriatrics. *Int J Clin Exp Med.* 2014;7(9):2877–2882.
 46. Lowenstein L, Matanes E, Weiner Z, et al. Robotic transvaginal natural orifice transluminal endoscopic surgery for bilateral salpingo oophorectomy. *Eur J Obstet Gynecol Reprod Biol X.* 2020;7:100113. <https://doi.org/10.1016/j.eurox.2020.100113>.
 47. Baekelandt J, Vercammen J. IMELDA transvaginal approach to ectopic pregnancy: diagnosis by transvaginal hydrolaparoscopy and treatment by transvaginal natural orifice transluminal endoscopic surgery. *Fertil Steril.* 2017;107(1):e1–2. <https://doi.org/10.1016/j.fertnstert.2016.09.024>.
 48. Chen X, Liu H, Sun D, et al. Transvaginal natural orifice transluminal endoscopic surgery for tubal pregnancy and a device innovation from our institution. *J Minim Invasive Gynecol.* 2019;26(1):169–174. <https://doi.org/10.1016/j.jmig.2018.05.013>.
 49. Ozceltik G, Yeniel AO, Atay AO, et al. Transvaginal natural orifice transluminal endoscopic surgery for tubal stump pregnancy. *J Minim Invasive Gynecol.* 2021;28(4): 750–751. <https://doi.org/10.1016/j.jmig.2020.06.026>.
 50. Baekelandt J. Transvaginal natural-orifice transluminal endoscopic surgery: a new approach to myomectomy. *Fertil Steril.* 2018;109(1):179. <https://doi.org/10.1016/j.fertnstert.2017.09.009>.
 51. Liu J, Lin Q, Blazek K, et al. Transvaginal natural orifice transluminal endoscopic surgery myomectomy: a novel route for uterine myoma removal. *J Minim Invasive Gynecol.* 2018;25(6):959–960. <https://doi.org/10.1016/j.jmig.2018.01.011>.
 52. Nosti PA, Carter CM, Sokol AI, et al. Transvaginal versus transabdominal placement of synthetic mesh at time of sacrocolpopexy. *Female Pelvic Med Reconstr Surg.* 2016; 22(3):151–155. <https://doi.org/10.1097/SPV.0000000000000222>.
 53. Liu J, Kohn J, Fu H, et al. Transvaginal natural orifice transluminal endoscopic surgery for sacrocolpopexy: a pilot study of 26 cases. *J Minim Invasive Gynecol.* 2019; 26(4):748–753. <https://doi.org/10.1016/j.jmig.2018.08.009>.
 54. Lowenstein L, Baekelandt J, Paz Y, et al. Transvaginal natural orifice transluminal endoscopic hysterectomy and apical suspension of the vaginal cuff to the uterosacral ligament. *J Minim Invasive Gynecol.* 2019;26(6):1015. <https://doi.org/10.1016/j.jmig.2019.04.007>.
 55. Liu J, Kohn J, Sun B, et al. Transvaginal natural orifice transluminal endoscopic surgery sacrocolpopexy: tips and tricks. *J Minim Invasive Gynecol.* 2019;26(1):38–39. <https://doi.org/10.1016/j.jmig.2018.03.021>.
 56. Lee CL, Wu KY, Su H, et al. Hysterectomy by transvaginal natural orifice transluminal endoscopic surgery (NOTES): a series of 137 patients. *J Minim Invasive Gynecol.* 2014; 21(5):818–824. <https://doi.org/10.1016/j.jmig.2014.03.011>.
 57. Leblanc E, Narducci F, Bresson L, et al. Fluorescence-assisted sentinel (SND) and pelvic node dissections by single-port transvaginal laparoscopic surgery, for the management of an endometrial carcinoma (EC) in an elderly obese patient. *Gynecol Oncol.* 2016;143(3):686–687. <https://doi.org/10.1016/j.ygyno.2016.10.010>.
 58. Baekelandt JF. New retroperitoneal transvaginal natural orifice transluminal endoscopic surgery approach to sentinel node for endometrial cancer: a demonstration video. *J Minim Invasive Gynecol.* 2019 Dec;26(7):1231–1232. <https://doi.org/10.1016/j.jmig.2019.05.002>.
 59. Tantitam T, Lee C-L. Application of sentinel lymph node technique to transvaginal natural orifices transluminal endoscopic surgery in endometrial cancer. *J Minim Invasive Gynecol.* 2019;26(5):949–953. <https://doi.org/10.1016/j.jmig.2018.10.001>.
 60. Htay WT, Huang CY, Lee CL. Sentinel pelvic lymph node dissection by natural orifices transvaginal endoscopic surgery approach after indocyanine green dye detection in early endometrial cancer of posthysterectomy patient. *Gynecol Minim Invasive Ther.* 2019;8(3):135–137. https://doi.org/10.4103/GMIT.GMIT_80_18.
 61. Naval S, Naval R, Naval S. Transvaginal natural orifice transluminal endoscopic surgery hysterectomy aided by transcervical instrumental uterine manipulation. *J Minim Invasive Gynecol.* 2019;26(7):1233. <https://doi.org/10.1016/j.jmig.2019.05.004>.
 62. Gerntke CI, Kersten JF, Schön G, et al. Women's perception of transvaginal natural orifice transluminal endoscopic surgery (NOTES): results of a survey of female medical staff and literature review. *Surg Innovat.* 2016;23(2):201–211. <https://doi.org/10.1177/1553350615598621>.
 63. Mofid H, Emmermann A, Alm M, et al. Is the transvaginal route appropriate for intra-abdominal NOTES procedures? Experience and follow-up of 222 cases. *Surg Endosc.* 2013;27(8):2807–2812. <https://doi.org/10.1007/s00464-013-2812-z>.