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Transvaginal natural orifice endoscopic surgery for hysterectomy: a prospective cohort study

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Abstract

Objective Vaginal natural orifice transluminal endoscopic surgery (vNOTES) is widely recognized for its advantages, including reduced postoperative pain and the absence of visible scarring. However, the anatomical specificity required for vNOTES may increase the risk of injury to nearby organs, such as the rectum and bladder. This study aims to evaluate the safety and potential benefits of vNOTES compared to transumbilical laparoendoscopic single-site surgery (LESS) for Hysterectomy.

Methods The Longitudinal Vaginal Natural Orifice Transluminal Endoscopic Surgery Study (LovNOTESS), conducted in Chengdu, China, included 192 patients who underwent hysterectomy between May and October 2023. This study prospectively collected and compared perioperative and follow-up data between the two groups.

Results The vNOTES group demonstrated shorter surgery times, postoperative flatus time, and hospital stays, but it also had a higher conversion rate. Specifically, the vNOTES approach reduced surgery duration by approximately 29.8 min (95% CI: -41.31, -18.34, $P < 0.001$) but increased intraoperative blood loss by about 41.82 mL (95% CI: 25.81, 57.82, $P < 0.001$).

Conclusion By combining laparoscopy with traditional vaginal surgery, vNOTES offers advantages such as shorter surgery times, faster postoperative recovery, reduced hospital stays, greater minimal invasiveness, and improved cosmetic outcomes. However, it is essential for surgeons to continually enhance and standardize preoperative assessments and surgical techniques to minimize conversion rates and reduce intraoperative blood loss.

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Keywords Hysterectomy, Natural orifice endoscopic surgery, Laparoscopes, Prospective study, Enhanced recovery after surgery

Introduction

Hysterectomy, the most common radical treatment for benign gynecological diseases and certain early-stage cancers, is a crucial procedure in gynecological surgery [1]. Research shows that there are more than 600,000 women undergoing hysterectomy each year in the United States [2]. Currently, there are several main approaches to hysterectomy for benign gynecological conditions: abdominal hysterectomy, vaginal hysterectomy, multi-port laparoscopic hysterectomy, transumbilical laparo-endoscopic single-site surgery (LESS), and transvaginal natural orifice endoscopic surgery (vNOTES) [3].

With the advancement of minimally invasive techniques and the concept of enhanced recovery after surgery (ERAS), surgeons are increasingly focused on achieving effective, safe treatments while promoting faster recovery, improved quality of life, reduced trauma, and better cosmetic outcomes [4, 5]. LESS and vNOTES have gained popularity among gynecologists and patients as the most aesthetically pleasing surgical options with minimal surgical trauma [6, 7].

Currently, LESS is widely applied in hysterectomy, with its safety and feasibility well-established [8]. vNOTES offers advantages such as reduced postoperative pain, lower risk of wound infection, and the absence of abdominal scarring [9–11]. Both LESS and vNOTES are laparoscopic surgeries performed through natural channels, but due to differences in surgical approaches, there are certain differences in surgical recovery between the two approaches. Due to the fact that the vNOTES incision is located in the posterior fornix of the vagina, it is not sensitive to incision pain and is considered to cause milder postoperative pain and without any surface scars [12]. By combining laparoscopy with traditional vaginal surgery, it provides an enhanced field of view and broader operating range for hysterectomy [13, 14]. However, due to the anatomical complexity of the vNOTES approach, there is an elevated risk of injury to nearby organs, such as the rectum and bladder [15, 16]. Therefore, it is necessary to investigate the safety and efficacy of vNOTES surgery in hysterectomy.

Therefore, we conducted a prospective cohort study to collect and analyze perioperative data from patients undergoing total hysterectomy with vNOTES and LESS. This study aims to evaluate the safety and efficacy of vNOTES for total hysterectomy and to support the broader adoption of vNOTES in gynecological surgery.

Materials and methods

Study design and participants

This study is based on a Longitudinal Vaginal Natural Orifice Transluminal Endoscopic Surgery Study (LovNOTESS) conducted in Chengdu (China Clinical Trials Registry ChiCTR2200059282, April 28, 2022) and approved by the Ethics Committee of Chengdu Women and Children's Central Hospital (No. 202130). This study was conducted strictly in accordance with the Declaration of Helsinki. Based on previous studies using LESS and vNOTES for hysterectomy, and increasing the sample size by 10% to control the dropout rate, the required sample size for each group is 74 cases [17]. This subgroup study prospectively collected perioperative data of patients underwent hysterectomy in 2023 between May and October. This study excluded patients with absolute contraindications to vNOTES, such as clear vaginal infections, severe pelvic adhesions, endometriosis, advanced malignancy. Meanwhile, Patients who underwent other operations during the operation, such as ovarian cysts, anterior vaginal wall repair, etc., patients who were lost to follow-up 1 month after surgery, and patients whose postoperative examination indicated malignant tumors were excluded. In fact, following comprehensive patient education regarding the features of both surgical approaches (vNOTES/LESS) and their assessment for suitability, patients were given autonomy to select their preferred surgical approach. The surgeons did not provide any preference regarding the selection of surgical approach. Depending on the surgical approach, patients were categorized into LESS and vNOTES groups. The LESS group was used as the control group, and the vNOTES group was used as the experimental group to analyze the safety and effectiveness of the vNOTES approach compared to the LESS approach.

Data collection

The patients' perioperative data were collected from the hospital's electronic medical record system, including data related to general patient information (age, body mass index, maximum diameter of uterine, principal diagnosis, and history of abdominal surgery), surgical-related information (surgical approach, operation duration, intraoperative blood loss, pelvic adhesions, and complications during surgery), perioperative recovery status (decrease in hemoglobin during the perioperative period, hospital stays, pain score 6 h after surgery, anal flatus time, complications after surgery) and follow-up information (readmission, short-term complication).

Standard operating procedures for vNOTES and TU-LESS

Preoperative Preparation

All surgeries were performed under general anesthesia, with the patient positioned in the lithotomy position. To prevent infection, cefmetazole (1 g) was administered intravenously 30 min before the procedure. The vaginal and perineal areas were thoroughly disinfected with iodophor, and Foley catheters were inserted for all patients.

Intraoperative procedure

In the TU-LESS group, a 2 cm incision was made at the umbilicus, through which multiple instrument access ports (Beijing Aerospace Cardi Technology Development Institute, HK-TH-60.4TY) were inserted. A large vessel closure device was used to coagulate and cut the left round ligament, left fallopian tube, and open the anterior leaf of the left broad ligament. The bladder peritoneal fold was opened, and the bladder was pushed down below the external cervical os. The same procedure was performed on the right side. The uterine parametrium was dissected to expose the left uterine vessels, and the large vessel closure device was used to coagulate and cut the left uterine artery and left cardinal ligament. The same procedure was applied to the right side. A monopolar electrosurgical hook was used to make a circular incision along the colpotomy cup, and the uterus was removed through the vagina. The vaginal cuff was closed with continuous 2–0 barbed sutures.

In the vNOTES group, a cervical clamp was used to pull the cervix outward. An arc-shaped incision was made 0.5 cm above the bladder groove on the anterior vaginal wall and extended circumferentially around the cervix. The left uterosacral ligament and left uterine artery were coagulated and cut using a Bakri clamp and electrocautery, with the stumps ligated using 7–0 silk sutures. The same procedure was applied to the right side. The peritoneal reflection of the bladder and the posterior vaginal fornix were incised, and a PORT was inserted. The left round ligament, left fallopian tube, and left ovarian ligament were coagulated and cut using an ultrasonic scalpel and bipolar forceps. The same procedure was applied to the right side. The excised uterus and bilateral fallopian tubes were then removed through the vagina.

For both groups, pneumoperitoneum was established by insufflating CO₂ to 14 mmHg. Visualization was achieved using a 10 mm, 30-degree rigid laparoscope (Karl Storz GmbH & Co. KG, Tuttlingen, Germany). For a detailed illustrated guide of this surgical procedure, please refer to our previous study [18].

Surgical indication for hysterectomy

Preoperative examination confirmed the benign nature of uterine lesions. These benign lesions included uterine

myoma, adenomyosis, high-grade squamous intraepithelial lesions, and endometrial complex hyperplasia with atypia. To rule out malignant uterine lesions, it was essential to perform a ThinPrep cytology test and diagnostic curettage prior to the hysterectomy.

Statistical analysis

SPSS software (version 27.0; IBM Corp., Armonk, NY, USA) were used to perform the all statistical analyses. Fisher's exact or Chi-square tests were used to analyze categorical data, reporting as counts (percentages). The mean $\pm$ standard deviation values of continuous variables were evaluated via Student's t-test and least significant difference Student's t-test. Multivariate linear regression analysis was used to detect the factors influencing duration of surgery, intraoperative bleeding, and postoperative flatus time. All statistical significance was set at $P < 0.05$ with two-tailed tests.

Results

Figure 1 shows the process of patient attrition in this study. A total of 236 patients underwent hysterectomy were recruited initially. After excluding 27 patients who underwent other operations during the operation, 11 patients who were lost to follow-up, and 7 patients who were indicated by postoperative examination as malignant tumors, 192 patients were finally included for analysis, including 100 cases of uterine fibroids, 32 cases of adenomyosis 35 cases of cervical intraepithelial neoplasia III (CIN III), and 24 cases of other diagnoses. Table 1 shows the demographic characteristics of the enrolled patients. The average age of the patients, duration of amenorrhea, and BMI at recruitment were 50.12 ± 6.78 years, 6.92 ± 2.26 cm, 24.3 ± 3.03 kg/m², respectively. In addition, 43.2% of the patients had had pelvic surgery and 34.4% had dysmenorrhea. Among the 192 patients, 122 (63.5%) underwent LESS and 70 (36.5%) underwent vNOTES (Table 1).

No statistically significant differences were observed in demographic characteristics between the two groups. The vNOTES group had a shorter surgical duration, a shorter hospital stay, a shorter flatus time but a higher surgical conversion rate and more hemoglobin reduction (Table 2).

The duration of surgery is a comprehensive index that reflects the difficulty of surgery, the skill level of doctors, the condition of patients, etc. The results of the analysis of the duration of surgery by using multiple linear regression are shown in Table 3 With each 1 cm increase in the diameter of uterine, the duration of surgery increased by approximately 5.5 min (95%CI:2.92,8.08, $P < 0.001$). v-NOTES decreased the duration of surgery by approximately 29.8 min (95%CI:-41.31,-18.34, $P < 0.001$). As the severity of pelvic adhesions increased by one

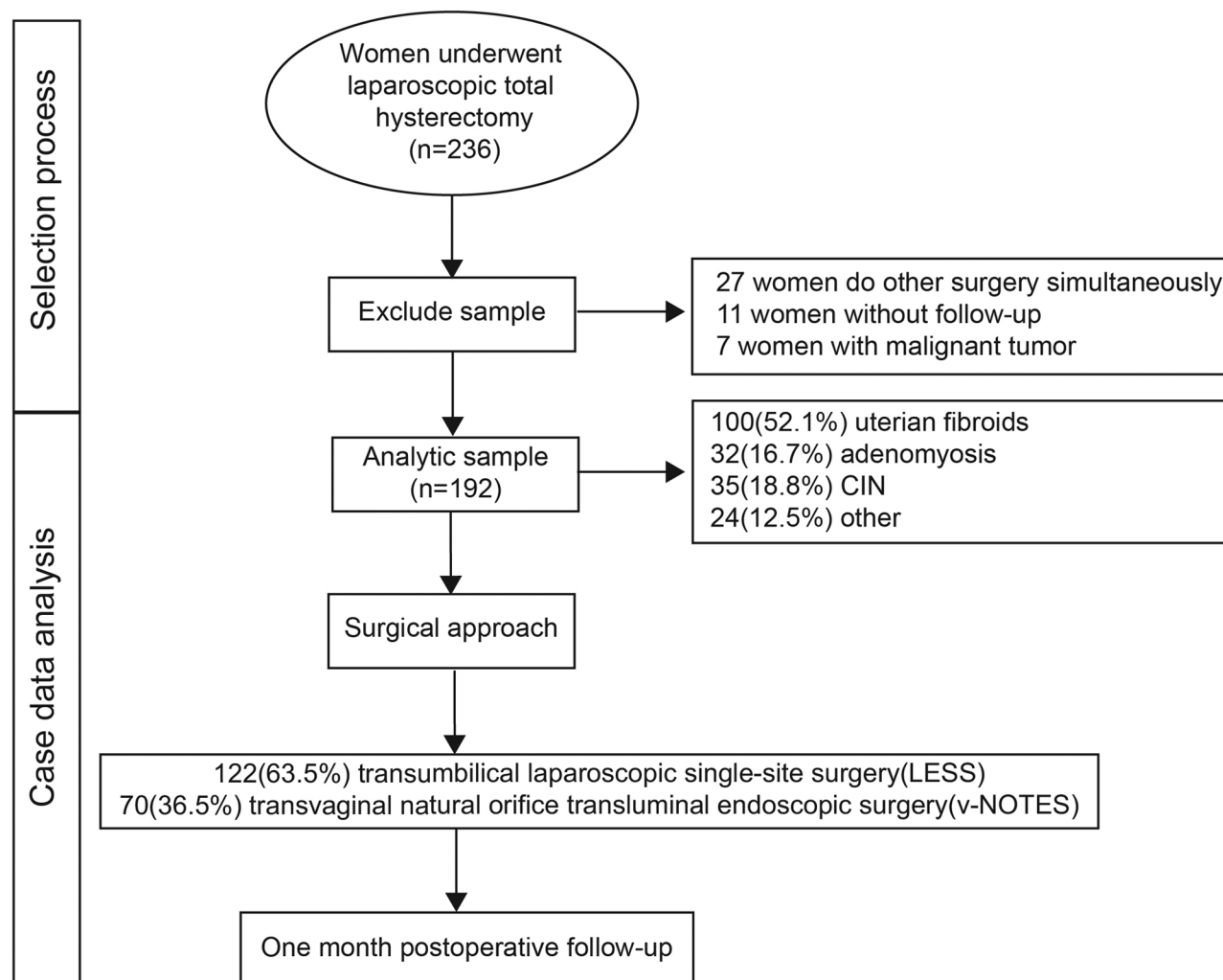


Fig. 1 The selection process for this study

Table 1 Description of the patients demographic characteristics and operation types

Variable	Total
Patient	192
Age	50.12 ± 6.78
BMI(kg/m ²)	24.3 ± 3.03
Maximum uterine diameter (cm)	6.92 ± 2.26
History of abdominal surgery	83(43.2%)
Dysmenorrhea	66(34.4%)
Principal Diagnosis	
Uterine leiomyomas	100(52.1%)
Adenomyosis	32(16.7%)
Cervical intraepithelial neoplasia III	36(18.8%)
Other	24(12.5%)
Hysterectomy Type	
LESS	122(63.5%)
v-NOTES	70(36.5%)

BMI: body mass index, LESS: transumbilical laparoendoscopic single-site surgery, v-NOTES: transvaginal natural orifice endoscopic surgery

level, surgery duration increased by approximately 30.9 min(95%CI 19.15,42.66, $P < 0.001$). Surgeons with more than 20 years of experience saved approximately 20.9 min of surgical duration compared to surgeons with more than 10 years of experiences(95%CI:-34.30,-7.54, $P = 0.002$).

Intraoperative blood loss can reflect the intraoperative injury. After excluding 11 cases of massive hemorrhage (≥ 400 ml), the factors affecting intraoperative blood loss were further analyzed by multiple linear regression analysis. As shown in Table 4, the longest diameter of uterus, operative approach, duration of operation and intraoperative blood loss had significant statistical significance. The intraoperative blood loss was increased by about 5.6 ml for every 1 cm increase in the longest diameter of uterus(95%CI 1.97,9.29, $P = 0.003$), and 41.82 ml for v-NOTES(95%CI 25.81,57.82, $P < 0.001$). The intraoperative blood loss increased by about 0.64 ml for each

Table 2 Description of the patient characteristics by cystectomy types

Variables	LESS	v-NOTES	P-value
Patients	N=122	N=70	
Age(year)	49.72 ± 6.48	50.81 ± 7.27	0.284 ^d
BMI(kg/m ²)	24.42 ± 3.08	24.09 ± 2.95	0.469 ^a
Maximum uterine diameter(cm)	7.14 ± 2.38	6.53 ± 2.00	0.071 ^a
History of abdominal surgery	54(44.26%)	29(41.43%)	0.703 ^b
Dysmenorrhea	44(36.97%)	22(31.43%)	0.515 ^b
Principal Diagnosis			0.720 ^b
Uterine leiomyomas	68(55.74%)	32(45.72%)	
Adenomyosis	24(19.67%)	8(11.43%)	
Cervical intraepithelial neoplasia	18(14.75%)	18(25.71%)	
Other	12(9.84%)	12(17.14%)	
Operative information			
Duration of surgery(min)	139.76 ± 49.98	105.17 ± 37.69	< 0.001 ^d
Bleeding volume(ml)	82.29 ± 109.13	111.5 ± 137.40	0.107 ^d
Surgical conversion	0(0%)	3(4.29%)	0.047 ^c
Post-Operative information			
Hemoglobin decline (g/L)	13.18 ± 10.60	17.90 ± 12.72	0.006 ^d
Hospital stay(day)	6.16 ± 1.75	5.44 ± 2.46	0.020 ^a
Postoperative time to first flatus (hour)	42.09 ± 12.46	36.68 ± 12.73	0.005 ^a
Pain scores (6 h after surgery)	2.75 ± 0.53	2.74 ± 0.47	0.884 ^a
Postoperative fever	12(9.84%)	2(3.33%)	0.088 ^c

^aAverage and standard deviation. Student's t-Test^bNumber (percentage). Chi-squared Test^cNumber (percentage). Fisher Exact Test^dAverage and standard deviation. Kruskal-Wallis Test**Table 3** Association between duration of surgery and perioperative characteristics

Variables	Beta	95% CI	P-value	VIF
R ² = 0.336				
Age (year)	-0.199	(-1.07,0.67)	0.654	1.204
BMI (kg/m ²)	0.392	(-1.45,2.23)	0.675	1.056
Maximum uterine diameter (cm)	5.501	(2.92,8.08)	< 0.001	1.170
History of abdominal surgery	6.393	(-5.58,18.37)	0.294	1.203
Surgical approach(v-NOTES)	-29.824	(-41.31,-18.34)	< 0.001	1.053
Surgical transfer	51.203	(5.87,96.54)	0.027	1.095
Pelvic adhesion	30.904	(19.15,42.66)	< 0.001	1.036
Surgeon	-20.919	(-34.30,-7.54)	0.002	1.038

BMI: body mass index, v-NOTES: vaginal natural orifice transluminal endoscopic surgery, VIF: variance inflation factor

1-minute increase in the duration of surgery (95%CI 0.45,0.83, $P < 0.001$).

Flatus time can be used as an important indicator to evaluate the recovery of intestinal function and the

Table 4 Association between intraoperative bleeding volume and perioperative characteristics

Variables	Beta	95% CI	P-value	VIF
R ² = 0.296				
Age(year)	0.757	(-0.38,1.88)	0.186	1.214
BMI(kg/m ²)	1.733	(-0.62,4.09)	0.148	1.055
Maximum uterine diameter(cm)	5.631	(1.97,9.29)	0.003	1.252
History of abdominal surgery	-4.953	(-20.56,110.65)	0.532	1.199
Surgical approach(v-NOTES)	41.816	(25.81,57.82)	< 0.001	1.198
Surgical transfer	-16.653	(-74.66,41.35)	0.572	1.121
Duration of surgery	0.639	(0.45,0.83)	< 0.001	1.427
Pelvic adhesion	5.120	(-11.26,721.50)	0.538	1.193

BMI: body mass index, v-NOTES: vaginal natural orifice transluminal endoscopic surgery, VIF: variance inflation factor

Table 5 Association between postoperative time to first flatus and perioperative characteristics

Variables	Beta	95% CI	P-value	VIF
R ² = 0.128				
Age(year)	-0.058	(-0.34,0.22)	0.680	1.223
BMI(kg/m ²)	-0.602	(-1.19,-0.02)	0.043	1.061
Maximum uterine diameter(mm)	-0.528	(-1.41,0.35)	0.239	1.367
History of abdominal surgery	-2.144	(-5.60,1.67)	0.268	1.212
Surgical approach(v-NOTES)	-2.528	(-6.61,1.56)	0.224	1.326
Surgical transfer	-14.396	(-28.98,0.19)	0.053	1.129
Duration of surgery	0.061	(0.01,0.11)	0.016	1.809
Intraoperative bleeding Volume	-0.029	(-0.05,-0.01)	0.001	1.347
Pelvic adhesion	-0.164	(-4.16,3.82)	0.935	1.191
Surgeon	-4.202	(-8.61,0.20)	0.061	1.121

BMI: body mass index, v-NOTES: vaginal natural orifice transluminal endoscopic surgery, VIF: variance inflation factor

overall recovery status of patients. The results of influencing factors of postoperative flatus time through multivariate linear analysis are shown in Table 5. Flatus time decreased by 0.6 h for every 1 kg/m² increase in BMI(95% CI-1.19, -0.02, $P = 0.043$), and increased by 0.06 h for every 1-minute increase in operation duration (95%CI 0.01, 0.11, $P = 0.016$). Each 1 ml increase in intraoperative blood loss decreased the flatus time by 0.02 h (95%CI -0.05, -0.01, $P = 0.001$).

Among the 192 patients included, 11 patients had intraoperative blood loss more than or equal to 400 ml (average 504.55 ± 145.70 ml). Among these 11 patients, 9 were diagnosed with uterine fibroids before surgery, and 1 was diagnosed with adenomyosis. Six patients were in the LESS group and five were in the vNOTES group. The mean age was 49.45 ± 5.09 years, the mean BMI was 24.12 ± 2.22 kg/m², the mean longest diameter of uterus was 9.07 ± 3.07 cm, and the mean duration of operation was 166.18 ± 60.38 min.

A total of 3 patients in the vNOTES group had surgical conversion (4.29%), and 12 patients in the postoperative

LESS group had postoperative fever (9.84%), compared with 2 patients in the v-NOTES group (3.33%). At 1 month of postoperative outpatient follow-up, 3 patients re-admitted due to postoperative complications were all in the LESS group. 1 patient was re-admitted with upper abdominal mass 1 week after surgery, 1 patient was re-admitted due to fever on the 8th day after surgery, and 1 patient was re-admitted due to pelvic encapsulated effusion. All three patients recovered after conservative treatment and were not re-operated.

Discussion

Due to surgeons' pursuit of more non-invasive, more beautiful and faster recovery, the vagina, as a unique natural channel for women to communicate with the outside world, has made v-NOTES develop rapidly in the field of gynecology. Previous studies have shown that for hysterectomy, it combines the advantages of single-site laparoscopy and traditional vaginal surgery, so that it has better clinical and postoperative recovery indicators [19]. In order to further prove the safety and effectiveness of vNOTES in hysterectomy, we used a prospective cohort study to compare vNOTES with LESS in 192 patients who underwent hysterectomy from May 2023 to October 2023 in Chengdu Women's and Children's Central Hospital.

Intraoperative blood loss, conversion rate, and perioperative complications are important indicators for evaluating the safety and efficacy of a surgical procedure. There were no statistically significant differences between the LESS and vNOTES groups for these measures. This suggests that the safety and efficacy of the vNOTES approach for completing a hysterectomy are not inferior to those of LESS, which is consistent with previous studies [1]. In this study, the vNOTES group showed advantages in terms of operation time, hospital stay and flatus time. In addition, although there was no significant statistical significance in postoperative pain in our study, vNOTES also significantly reduced postoperative pain in patients in previous studies [20–22]. The reason for consideration is that vNOTES surgery enters the body cavity through the natural orifice of the vagina, without the need for body surface incision, and the soft tissue dissection is relatively less, which has less interference on the human body and gastrointestinal tract, which is conducive to reducing the surgical injury and promoting the recovery of postoperative gastrointestinal function. Moreover, the vaginal fornix nerve innervation is minimal, the trauma is small, the recovery is fast, and the patients can get out of bed earlier after the operation, reducing the time of postoperative observation and recovery. In the era of ERAS and minimally invasive concepts, there is no doubt that vNOTES is very consistent with the current trend of surgical development, and the

results of this study further verified the safety and feasibility of hysterectomy using vNOTES as an approach.

Our results suggest that after excluding 11 patients with intraoperative bleeding greater than or equal to 400 ml, the amount of blood loss in the vNOTES group (72.5 ml) was still higher than that in the LESS group (62.0 ml). The reasons for the analysis may be as follows: vNOTES surgery enters the abdominal cavity through the vagina, a natural cavity. Although the body surface trauma is reduced, the vaginal tissue is soft and rich in blood vessels, and the intraoperative operation may cause damage to local blood vessels, resulting in increased blood loss. vNOTES, as a relatively new surgical method, requires high skills and experience of the surgeons, and the surgeons may need longer time to adapt and master this surgical method during operation, which may lead to increased intraoperative blood loss. Surgical position is also a possible influencing factor. In LESS, patients need to keep head low and feet high, and part of the bleeding is deposited in the upper abdomen, while the blood accumulation in vNOTES surgery is limited to the pelvic cavity, which is more convenient for record, and the vNOTES statistics on intraoperative bleeding are higher than those in LESS [23]. In addition, individual patient differences may also affect the amount of intraoperative blood loss. For example, the patient's age, weight, uterine size, blood vessel distribution, and other factors may affect the amount of blood lost during surgery. In summary, the reasons for more intraoperative blood loss in vNOTES than LESS may involve the differences in surgical paths, surgical skills and experience, and individual differences of patients [18, 24]. When choosing the surgical approach, these factors should be fully considered, and the most suitable surgical method should be selected according to the specific situation of the patient and the experience of the surgeon. However, our explanation for the increased blood loss in the vNOTES group is speculative, as we lack robust data to substantiate these claims. The difference in blood loss between the two groups may also be attributed to the surgeons' level of expertise, rather than the inherent advantages or disadvantages of the surgical technique itself. This interpretation is further supported by our findings, which demonstrate that surgical experience can significantly influence the duration of the procedure, subsequently affecting intraoperative blood loss. Therefore, further research involving surgeons with varying levels of experience is necessary to validate these findings.

In this study, there were 11 patients with blood loss more than or equal to 400 ml, including 6 patients in the LESS group and 5 patients in the vNOTES group. After reviewing the surgical records, it is considered that the causes of massive bleeding may be as follows: The wound was active bleeding due to the large and tight adhesion

during the separation of adhesion; Large uterus may lead to limited visual field and insufficient exposure during surgery, resulting in increased operation difficulty, and potential bleeding points may not be found and hemostatic in time. Although uterine size is not an absolute contraindication for vNOTES, the existing literature has confirmed that the probability of bleeding increases with the increase of the uterus [25–27].

In this study, three patients in the vNOTES group had surgical conversion (4.29%), which was mainly due to serious adhesion at the posterior fornix, resulting in difficult access and increased risk of damage to neighboring organs, and these patients became LESS. However, 26 (37.14%) of the patients in this study completed vNOTES hysterectomy with a history of pelvic surgery. This indicates that the history of pelvic surgery is not a contraindication of vNOTES. Therefore, before surgery, the surgeon needs to fully evaluate the pelvic adhesion of patients. Physical examination with history of dysmenorrhea or previous pelvic surgery indicated difficulties in uterine movement, tenderness of uterus and adnexa, and tubercles of sacral ligament, etc. Ultrasonography and other means can provide important clues for screening severe pelvic adhesions [28, 29]. Through these methods, after fully evaluating patients before surgery, the risk of intraoperative conversion and the harm it brings to patients can be reduced to a certain extent.

According to our study, three patients were readmitted to the hospital within two weeks of surgery for reasons of epigastric mass, pelvic encapsulated effusion, and fever. The three patients were all in the LESS group, and all had special manifestations during the course of the disease. One patient had 800 ml intraoperative bleeding, one patient had postoperative infection, and one patient had postoperative fever. Therefore, more attention should be paid to patients with large amount of intraoperative blood loss, postoperative infection, fever and other special conditions, close observation and follow-up, in order to avoid postoperative readmissions.

The advantages of this study lie in the prospective design and standardized procedures. At the same time, the researchers screened the patients according to the strict criteria of drainage, and all the operations were carried out according to the standard procedures. This study compared the perioperative information of LESS and vNOTES, two relatively advanced surgical approaches, and proved the safety and feasibility of vNOTE in hysterectomy. In addition, our hospital has been implementing gynecological surgery with vNOTES approach since 2018, with an average of 2,000 cases per year in the past two years, accumulating considerable expertise and relatively standardized vNOTES procedures.

There are still some limitations in this study. First, compared to similar studies using porous laparoscopy

and LESS, the sample size of this study was relatively small and the number of patients included was small. Second, vNOTES, as a relatively new surgical approach, is not widely understood by surgeons at all levels, so a standardized operating procedure should be followed to complete the learning curve. Third, although this study is a prospective cohort study, there are still certain biases, such as differences in the surgical experience of surgeons between groups. Further randomized controlled trials would provide a more robust validation of our findings. Finally, the postoperative follow-up in this study only lasted until 1 month after surgery, and there was a lack of information collection and research on long-term complications and quality of life after hysterectomy. Therefore, in order to promote the development of vNOTES in the field of gynecology, larger multi-center studies with more patients and longer follow-up should be conducted.

Conclusions

In conclusion, vNOTES is safe and feasible for hysterectomy. vNOTES offers advantages such as shorter operation times, reduced flatus time, better cosmetic outcomes, and faster postoperative recovery. However, vNOTES has a higher rate of surgical conversion and greater intraoperative blood loss compared to LESS. To ensure patient safety and advance the use of vNOTES in gynecological surgery, surgeons must continually refine their technical skills and optimize preoperative evaluation mechanisms to mitigate individual patient variability, reduce intraoperative bleeding, and lower conversion rates.

Abbreviations

LESS	Transumbilical laparoendoscopic single-site surgery
v-NOTES	Transvaginal natural orifice endoscopic surgery
BMI	Body mass index
LovNOTESS	Longitudinal Vaginal Natural Orifice Transluminal Endoscopic Surgery Study
ERAS	Enhanced recovery after surgery

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Author contributions

XW and XL designed the research protocol; XW and XL conducted the study; XW and AX analyzed the data; XW and XL drafted the manuscript; JL, AJ and XL critically revised the manuscript; LH, YL and XG provided funding resources. All authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.

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the design of the study, collection, analysis, and interpretation of data, and in writing the manuscript.

Data availability

The datasets generated and analyzed during the current study are not publicly available due to our ongoing prospective study but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study is based on a Longitudinal Vaginal Natural Orifice Transluminal Endoscopic Surgery Study (LovNOTESS) conducted in Chengdu (China Clinical Trials Registry ChiCTR2200059282, April 28, 2022) and approved by the Ethics Committee of Chengdu Women and Children's Central Hospital (No. 202130). This study was conducted strictly in accordance with the Declaration of Helsinki. Before the surgery, all patients were well-informed of the potential risks and advantages of vNOTES and other alternative surgical treatments, including TU-LESS or multi-port laparoscopy, and expressed their preference for vNOTES. Written informed consent obtained from all the participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

- Chaccour C, Giannini A, Golia D'Auge T, Ayed A, Allahqoli L, Alkatout I, Lagana AS, Chiantera V, D'Oria O, Sleiman Z. Hysterectomy using Vaginal Natural Orifice Transluminal endoscopic surgery compared with Classic Laparoscopic Hysterectomy: a new advantageous Approach? A systematic review on Surgical outcomes. *Gynecol Obstet Invest.* 2023;88(4):187–96.
- Wu JM, Wechter ME, Geller EJ, Nguyen TV, Visco AG. Hysterectomy rates in the United States, 2003. *Obstet Gynecol.* 2007;110(5):1091–5.
- Nieboer TE, Johnson N, Lethaby A, Tavender E, Curr E, Garry R, van Voorst S, Mol BW, Kluivers KB. Surgical approach to hysterectomy for benign gynaecological disease. *Cochrane Database Syst Rev* 2009(3):Cd003677.
- Stone R, Carey E, Fader AN, Fitzgerald J, Hammons L, Nensi A, Park AJ, Ricci S, Rosenfield R, Scheib S, et al. Enhanced Recovery and Surgical optimization protocol for minimally invasive gynecologic surgery: an AAGL White Paper. *J Minim Invasive Gynecol.* 2021;28(2):179–203.
- Kaloger E, Glaser GE, Kumar A, Dowdy SC, Langstraat CL. Enhanced recovery after minimally invasive gynecologic procedures with bowel surgery: a systematic review. *J Minim Invasive Gynecol.* 2019;26(2):288–98.
- Zhang W, Deng L, Yang F, Liu J, Chen S, You X, Gou J, Zi D, Li Y, Qi X, et al. Comparing the efficacy and safety of three surgical approaches for total hysterectomy (TSATH): protocol for a multicentre, single-blind, parallel-group, randomised controlled trial. *BMJ Open.* 2024;14(1):e074478.
- Feng D, He L. Regarding transvaginal natural orifice transluminal endoscopic surgery (vNOTES) in gynecologic surgeries: a systematic review. *Asian J Surg.* 2020;43(8):842.
- Sandberg EM, la Chapelle CF, van den Tweel MM, Schoones JW, Jansen FW. Laparoscopic single-site surgery versus conventional laparoscopy for hysterectomy: a systematic review and meta-analysis. *Arch Gynecol Obstet.* 2017;295(5):1089–103.
- Jallad K, Walters MD. Natural orifice transluminal endoscopic surgery (NOTES) in gynecology. *Clin Obstet Gynecol.* 2017;60(2):324–9.
- Lerner VT, May G, Iglesia CB. Vaginal natural orifice Transluminal endoscopic surgery revolution: the Next Frontier in Gynecologic minimally invasive surgery. *Jsls* 2023, 27(1).
- Mereu L, Pecorino B, Ferrara M, Siniscalchi M, Garraffa G, D'Agate MG, Scollo P. Cumulative Sum analysis of learning curve process for Vaginal Natural Orifice Transluminal endoscopic surgery hysterectomy. *J Minim Invasive Gynecol.* 2023;30(7):582–6.
- Giannini A, D'Oria O, Bogani G, Di Donato V, Vizza E, Chiantera V, Lagana AS, Muzii L, Salerno MG, Caserta D et al. Hysterectomy: Let's Step Up the Ladder of Evidence to Look Over the Horizon. *J Clin Med* 2022, 11(23).
- 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.
- Housmans S, Noori N, Kapurubandara S, Bosteels JJA, Cattani L, Alkatout I, Deprest J, Baekelandt J. 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).
- Kim MS, Noh JJ, Kim TJ. Hysterectomy and Adnexal procedures by Vaginal Natural Orifice Transluminal endoscopic surgery (VNH): initial findings from a Korean surgeon. *Front Med (Lausanne).* 2020;7:583147.
- Zhang J, Dai Y, Leng J, Zhu L, Lang J, Sun D. Hysterectomy and bilateral adnexectomy using transvaginal natural orifice transluminal endoscopic surgery: the role of multichannel abdominal PORT and vaginal support ring. *J Obstet Gynaecol Res.* 2021;47(7):2521–8.
- Hou Q, Li X, Li Y, Zhang Q, Liu T, Huang L, Gong Z, Feng D, Gu D, Lin Y, et al. Analysis and suggestions on the complications in 2000 cases of transvaginal natural orifice transluminal endoscopic surgery: can it be a conventional surgery? *Int J Gynaecol Obstet.* 2024;164(2):541–9.
- Huang L, He L, Huang L, Gan X, Lin Y, Xiong Z. Learning curve analysis of transvaginal natural orifice transluminal endoscopic hysterectomy combined under the standard operating procedure. *Int J Gynaecol Obstet.* 2022;159(3):689–95.
- Baekelandt JF, De Mulder PA, Le Roy I, Mathieu C, Laenen A, Enzlin P, Weyers S, Mol B, Bosteels J. Hysterectomy by transvaginal natural orifice transluminal endoscopic surgery versus laparoscopy as a day-care procedure: a randomised controlled trial. *BJOG.* 2019;126(1):105–13.
- Xie A, Li X, Huang J, Wang H, Liu Y, Wang L, Liao J, Yu J, Yan Z, Zhang J, et al. Transvaginal natural orifice endoscopic surgery for ovarian cystectomy: a more suitable surgical approach for the day-care procedure. *Front Med (Lausanne).* 2023;10:1164970.
- Liu Y, Li X, Liu T, Xie A, Wu X, Jia Y, Liao X, Cheng W, Wang H, Zhong F, et al. Transvaginal natural orifice endoscopic surgery for tubal ectopic pregnancy: a more suitable surgical approach for enhanced recovery after surgery. *Heliyon.* 2024;10(2):e24945.
- Cheng W, Li X, Liu T, Xie A, Wu X, Liao J, Liao X, Jia Y, Zhou X, Liu Y, et al. Transvaginal natural orifice transluminal endoscopic surgery for myomectomy: a more suitable surgical approach for enhanced recovery after surgery. *Eur J Obstet Gynecol Reprod Biol.* 2024;295:143–9.
- Li X, Liu T, Hou Q, Zeng X, Xiong Y, Yang Y, Li Z, Li Y, Lin Y, He L. Comparison of Prone with Lithotomy position in removal of posterior myoma in Transvaginal Natural Orifice Endoscopic surgery: a prospective cohort study. *J Minim Invasive Gynecol.* 2024.
- Kaya C, Yildiz Ş, Alay İ, Aslan Ö, Aydinler İE, Yaşar L. The comparison of Surgical outcomes following laparoscopic hysterectomy and vNOTES hysterectomy in obese patients. *J Invest Surg.* 2022;35(4):862–7.
- Temtanakitpaisan T, Wu KY, Huang CY, Jaiswal A, Yen CF, Lee CL. The outcomes of transvaginal NOTES hysterectomy in various uterine sizes. *Taiwan J Obstet Gynecol.* 2018;57(6):842–5.
- Uccella S, Casarin J, Marconi N, Cromi A, Morosi C, Gisone B, Pinelli C, Ghezzi F. Laparoscopic Versus Open Hysterectomy for Benign Disease in Women with Giant Uteri (≥ 1500 g): feasibility and outcomes. *J Minim Invasive Gynecol.* 2016;23(6):922–7.
- Uccella S, Morosi C, Marconi N, Arrigo A, Gisone B, Casarin J, Pinelli C, Borghi C, Ghezzi F. Laparoscopic Versus Open Hysterectomy for Benign Disease in Uteri weighing > 1 kg: a retrospective analysis on 258 patients. *J Minim Invasive Gynecol.* 2018;25(1):62–9.

28. Hui M, Schwartzenburg C, Bhalwal A. Utility of Vaginal Natural Orifice Transluminal endoscopic surgery for permanent sterilization after failed attempt at Bilateral Tubal Ligation at the Time of Previous Cesarean Section. *J Minim Invasive Gynecol.* 2022;29(10):1138–9.
29. Guan X, Bardawil E, Liu J, Kho R. Transvaginal Natural Orifice Transluminal Endoscopic Surgery as a rescue for total vaginal hysterectomy. *J Minim Invasive Gynecol.* 2018;25(7):1135–6.

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