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TECHNIQUES AND INSTRUMENTATION

Robotic vaginally assisted NOTES hysterectomy: the first case series demonstrating a new surgical technique

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Abstract The objective of this case report is to demonstrate a new hysterectomy technique via transvaginal natural orifice transluminal endoscopic surgery (NOTES) using robotic surgery. Previous experience with the Da Vinci Xi (Intuitive Surgery) for gynaecological oncology, and with NOTES for adnexal surgery and hysterectomy, led to the decision to combine the advantages of these techniques, namely to reduce the invasiveness of robotic surgery and improve the ergonomics of NOTES. A robotic vaginally assisted NOTES hysterectomy (VANH) was performed in five patients with a myomatous uterus. The circumcision of the cervix, the opening of the anterior and posterior peritoneum and the transection of both sacro-uterine ligaments were performed by classical vaginal surgery. A NOTES port was constructed by assembling a surgical glove, a wound protector, 4 Da Vinci 8-mm trocars and 1 reusable 5-mm trocar. The ring of the wound protector was then inserted transvaginally into the peritoneal cavity to create a pneumoperitoneum. The hysterectomy was performed via transvaginal NOTES using the surgical robot. Subsequently, a bilateral adnexectomy was performed in the same way. Once the hysterectomy and bilateral adnexectomy were completed, the robot and gloveport were removed. When the uterus was too large to extract in toto, it was manually morcellated so that it could be removed vaginally. The colpotomy was closed as in classical vaginal surgery. This is the first case report demonstrating that vaginal robotic surgery is possible and that it can be used to perform a hysterectomy. Robotic vaginally assisted NOTES hysterectomy (RVANH) makes use of the advantages of robotic surgery to broaden the indications for vaginal hysterectomy and can help overcome its limitations, while the NOTES approach avoids abdominal wall wounds and trocar-related complications. Further developments in robotic technology will help overcome the problem of robotic arm collision. Robotic hysterectomy via vaginal access is a novel approach that requires further validation. The extra cost and setup time of RVANH will also need to be assessed in comparison to the advantages it provides over a vaginally assisted NOTES hysterectomy or total laparoscopic hysterectomy.

Keywords Hysterectomy · Vaginal · Notes · Robotic · Vanh · Rvanh · Vamis

Background

Aiming to minimise surgical morbidity, the evolution from laparotomy to laparoscopy has now extended into the area of even less invasive surgery such as robotics, single incision laparoscopic surgery (SILS) and natural orifice transluminal endoscopy (NOTES). Minimally invasive surgery not only improves cosmetic outcome but also reduces surgical injury. This in turn decreases the inflammatory and neuroendocrine responses resulting in less postoperative pain and quicker recovery [1, 2].

NOTES attempts to reach the abdominal cavity by scar-free means, i.e. numerous surgical procedures are performed via a natural body orifice. This technique has gained popularity amongst general surgeons, gynaecologists, urologists and gastroenterologists over the past few years, and its feasibility and safety have been approved [3].

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NOTES can be performed via a variety of approaches including stomach, oesophagus, bladder, and rectum, but the majority of NOTES procedures have been performed transvaginally [4]. The vagina can easily be decontaminated and provides direct access. Culdotomy has been used widely for several surgical procedures (not only by gynaecologists but also by general surgeons for extraction of large specimens), and it has been approved as safe and easy to close [5].

In *hybrid* NOTES, the surgical procedure is performed through a natural body orifice with transabdominal assistance. The term *pure* NOTES refers to procedures that involve only transluminal access.

Hysterectomy via NOTES, after performing an anterior and posterior colpotomy and transection of sacro-uterine ligament via classical open vaginal surgery, has been described [6, 7]. We refer to this technique as vaginally assisted NOTES hysterectomy (VANH) as the first part of this procedure is performed by conventional vaginal surgery, and in the second part of the procedure, the hysterectomy is performed via NOTES. Previous experience with the Da Vinci Xi (Intuitive Surgery) for gynaecological oncology, and with NOTES for adnexal surgery and hysterectomy, led to the decision to combine the advantages of these techniques, namely to reduce the invasiveness of robotic surgery and improve the ergonomics of NOTES.

Material and methods

Patients

A single surgeon (BJ) performed 5 robotic VANH to evaluate the feasibility of the technique. All patients were selected for hysterectomy due to myomatous uterus. Patients were selected based on the following criteria: no contraindication for general anaesthesia, pneumoperitoneum or Trendelenburg position; no fixed uterus, strong pelvic adhaesions or nodularity in the Pouch of Douglas on clinical examination; no history of pelvic inflammatory disease; and no suspicion for malignancy. Obesity (BMI > 30) was not considered to be an exclusion criteria.

The following patient and perioperative data were collected and retrospectively analysed: patient age, body mass index (BMI), parity, mode of delivery, previous surgery, type of surgery, operating time, serum haemoglobin (Hb) drop (change between the preoperative Hb and postoperative Hb 1 day after surgery), perioperative complications, postoperative pain score, hospitalisation time, and weight of the uterus. The duration of surgery was defined as the time from the placement of the Foley catheter to the end of vaginal closure. It was measured in three stages: vaginal time, docking time and console time. Vaginal time was the time when the surgeon was operating by classical vaginal surgery: from placement of the Foley catheter until the sacro-uterine ligaments were ligated and after undocking the robot until the end of vaginal closure. Docking time was the time for docking and undocking the robot. Console time was the time when the surgeon was operating at the robotic console.

Bowel, bladder, ureteral or vascular injuries, as well as blood loss >300 ml were considered as intraoperative complications. Short-term postoperative complications were identified to be urinary tract infection, postoperative ileus, vaginal vault bleeding or infection, or hematuria.

Postoperative pain was assessed using the visual analogue pain scale (VAS) (scoring from 0 = no pain to 10 = worst imaginable pain). The VAS score was evaluated at 6 and 24 h postoperatively. All patients received the same intraoperative analgesia: intravenous paracetamol 1000 mg and ketorolac trometamol 20 mg. Postoperative pain was managed by paracetamol 1000 mg and ketorolac trometamol was administered on patient's demand.

Prophylactic intravenous antibiotic therapy, cefazoline 2 g and metronidazol 500 mg, was administrated during surgery.

No vaginal intercourse was allowed for 6 weeks after the procedure. Each patient was re-assessed at the postoperative consultation 6 weeks after surgery.

Surgical technique (video)

A robotic VANH was performed. The patient was placed in a lithotomy position as for a classical vaginal hysterectomy. The circumcision of the cervix, the opening of the anterior and posterior peritoneum and the transection of both sacro-uterine ligaments were performed by classical vaginal surgery. A NOTES port was constructed by assembling a surgical glove, a wound protector, 4 Da Vinci 8-mm trocars and 1 reusable 5-mm trocar (Fig. 1). The ring of the wound protector was then inserted transvaginally into the peritoneal cavity to create a pneumoperitoneum (Fig. 2). A Da Vinci Xi surgical robot was sidedocked between the legs of the patient (Fig. 3). Three arms were connected to the trocars in the gloveport. The fourth arm was not used. Using a 30° optic, a fenestrated bipolar grasper, and a vessel sealer, the hysterectomy was performed via transvaginal NOTES using the surgical robot. Subsequently, a bilateral adnexectomy was performed in the same way. Once the hysterectomy and bilateral adnexectomy were completed, the robot and gloveport were removed. When the uterus was too large to extract in toto, it was manually morcellated so that it could be removed vaginally (Fig. 4). The colpotomy was closed as in classical vaginal surgery. No abdominal incisions were made.

Results

Five robotic VANHs were successfully performed without perioperative complications. No conversion to standard multi-incision laparoscopy or laparotomy was necessary.

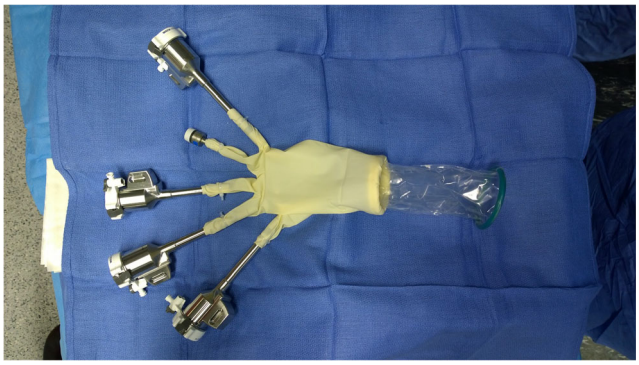

Fig. 1 A NOTES port was constructed by assembling a surgical glove, a wound protector, 4 Da Vinci 8-mm trocars and 1 reusable 5-mm trocar

Fig. 3 The Da Vinci Xi surgical robot is sidedocked between the legs of the patient

Table 1 presents an overview of patient and perioperative data. Individual patient details are presented in Table 2. Mean vaginal time was 18.2 min, mean docking time was 17.8 min, and mean console time was 33.6 min. Three patients had had previous surgery. There were no intraoperative complications. One patient had a postoperative superficial thrombophlebitis in her leg. The mean drop in haemoglobin level was 1.2 g/dl. Most patients scored a low postoperative pain score (range 2–3) 6 and 24 h after surgery. All uteri were benign upon pathological examination (specimen weight 70–575 g). All patients had previous vaginal deliveries and one patient had had a previous Caesarean section (Table 3).

Each patient was examined 6 weeks after surgery. There was no vaginal wound infection or dehiscence, and none of the patients complained of pain during pelvic examination. All patients were in good health and were back at work.

Discussion

These first five cases of robotic VANH were performed successfully. The procedures were completed within a reasonable operation time and without major complications. No conversion to laparotomy, transabdominal robotic surgery or standard laparoscopy was necessary. The duration of hospitalisation was similar to the hospitalisation time for a laparoscopic or vaginal hysterectomy in our department.

To the best our knowledge, this is the first report on RVANH (robotic vaginally assisted NOTES hysterectomy) and on the use of a Da Vinci surgical robot via vaginal access. As the Da Vinci Xi surgical robot is designed for multiport access, we experienced significantly more robotic arm collision during these transvaginal NOTES procedures than we normally experience during multiport transabdominal

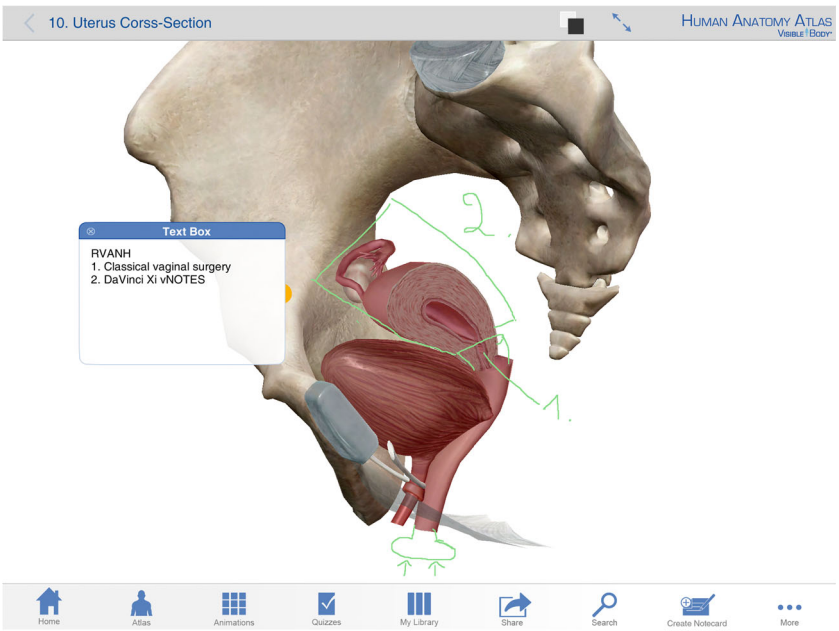

Fig. 2 Both sacro-uterine ligaments are transected by classical vaginal surgery (1). The ring of the gloveport is placed transvaginally into the peritoneal cavity (position indicated by 1.) The rest of the procedure is performed by Da Vinci Xi (2)

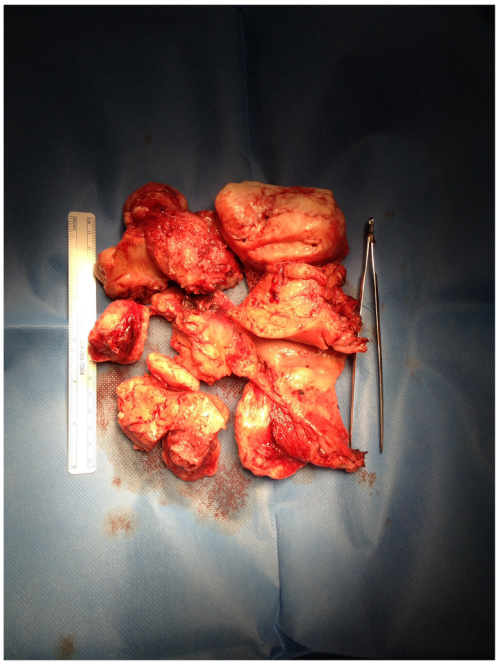

Fig. 4 The uterus was manually morcellated so that it could be removed vaginally

procedures. Particularly in the second more obese patient with the larger uterus, the arms had to be repositioned more frequently during the final stage of the hysterectomy. Having longer robotic instruments would have better facilitated this part of the procedure. Overall, the arm collision problem was smaller than we had anticipated.

Conventional transvaginal surgery has significant advantages compared to laparoscopic surgery, such as the absence of abdominal scarring and faster recovery from surgery [8]. It is the preferential approach to hysterectomy [9]. Most medium-sized uteri (mean uterine weight in this case series was 329 g) can be removed vaginally by an experienced

Table 1 Overview of patient and perioperative characteristics

Data	Mean	Range
Age (years)	53.2	46–60
BMI (kg/m^2)	24.3	21.2–30.5
Operating time (min)		
Vaginal time	18.2	15–26
Docking time	17.8	15–20
Console time	33.6	12–65
Serum haemoglobin drop (g/dl)	1.2	0.5–2.6
Postoperative pain score		
6 h	2.4	2–3
24 h	2	2
Uterine weight (g)	329	70–575

Table 2 Patient and perioperative characteristics of consecutive patients

Patient no.	Age (years)	BMI (kg/m^2)	Parity	Delivery mode	Previous surgery	Type of surgery	Operating time (min)			Serum haemoglobin drop (g/dl)	Perioperative complications	Postoperative pain score		Hospitalisation (days)	Weight uterus (g)
							Vaginal	Docking	Console			6 h	24 h		
1	52	23.7	1	NVD	Laparotomy for spinal surgery Abdominoplasty	RVANH + BSO	15	20	45	0.6	/	3	2	2	363
2	54	30.5	2	NVD	/	RVANH + BSO	20	20	65	0.8	Superficial thrombophlebitis	3	2	3	575
3	60	22.7	2	NVD	Appendectomy Laparotomy for ovarian torsion	RVANH	15	19	12	2.6	/	2	2	3	70
4	54	23.4	3	NVD	/	RVANH	15	15	26	0.5	/	2	2	3	506
5	46	21.2	4	CS ×1	LLETZ	RVANH	26	15	20	1.6	/	2	2	2	132

NVD normal vaginal delivery, *CS* caesarean section, *LLETZ* large loop excision of transformation zone, *RVANH* robotic vaginally assisted NOTES hysterectomy, *BSO* bilateral salpingo-oophorectomy

Table 3 Types of hysterectomy

Abbreviation	Name	Description
VH	Vaginal hysterectomy	Total hysterectomy performed entirely through vaginal access under direct vision using conventional surgical instruments
LAVH	Laparoscopic-assisted vaginal hysterectomy	Total hysterectomy where first the cranial part of the uterus is dissected via transabdominal laparoscopy and afterwards the caudal part of the uterus is dissected under direct vision using conventional instruments
TLH	Total laparoscopic hysterectomy	Total hysterectomy where the entire uterus is dissected via transabdominal laparoscopy
VANH	Vaginally assisted NOTES hysterectomy	Total hysterectomy where first the caudal part of the uterus is dissected vaginally under direct vision and afterwards the rest of the hysterectomy is performed via transvaginal NOTES using an endoscopic camera and endoscopic instruments
RVANH	Robotic vaginally assisted NOTES hysterectomy	Total hysterectomy where first the caudal part of the uterus is dissected vaginally under direct vision and afterwards the rest of the hysterectomy is performed via transvaginal NOTES using a surgical robot

vaginal surgeon. By performing transvaginal NOTES, the technical drawbacks of transvaginal surgery, including limited visualisation to attempt good haemostasis and difficulty in performing adnexectomy in case of adhesions between the adnexa and the uterus, can be overcome. Additionally, NOTES eliminates the risk of trocar related complications and induces less postoperative pain [10]. It has been demonstrated that very large uteri can be removed via VANH and that ligating the uterine vessels transvaginally before dissecting the rest of the uterus results in less blood loss compared to a transabdominal laparoscopic approach where there is more manipulation before occlusion of the feeding vessels [6, 7].

When comparing RVANH with our previous experience of VANH performed with conventional laparoscopic instruments, we found the vessel sealer to be very useful. It permitted us to perform the entire robotic part of the procedure using just two instruments: a vessel sealer and a fenestrated bipolar grasper. We have tried using different non-articulating and articulating sealing devices in VANH but always found the handles too bulky, causing collision between the surgeon's hands and the assistant's hands holding the camera. Therefore, we mostly use a bipolar grasper and cold scissors during VANH, which requires more port transfers, as one always needs to change instruments between coagulating and transecting. Using the Da Vinci robot and the vessel sealer solves this problem of hand collision and need for frequent instrument changes. The other advantages of robotic surgery over laparoscopic surgery also apply to vaginal robotic surgery such as better ergonomics and camera control.

One could argue the possibility of pelvic infection after vaginal surgery; however, no patient presented with this complication after the RVANH procedure. Previous studies have also shown that postoperative pelvic infection is unlikely, especially when prophylactic antibiotics are administered [7, 11]. As the vaginal vault is closed in the same way as in a classical vaginal hysterectomy, no differences in incidence of dyspareunia are to be expected. Sexual abstinence should be recommended for 6 to 8 weeks, as is the recommendation for conventional transvaginal surgery [7].

As previously mentioned by Lee et al. [12], the major limitation of transvaginal NOTES is the inability to overview the pelvic area, in particular the vesico-uterine pouch, and thus lesions such as bladder endometriosis can be missed. Innovation of endoscopes is desirable to overcome this limitation and to have the ability with NOTES to explore the entire abdominal cavity.

Further technical innovations in surgical robots will also help overcome the problem of robotic arm collision and will therefore reduce the time of surgery. As with all robotic surgery, the cost of a RVANH hysterectomy will need to be assessed in comparison to the advantages it provides over a VANH or a total laparoscopic hysterectomy.

Conclusion

These are five case reports demonstrating that vaginal robotic surgery is possible and that it can be used to perform a hysterectomy. RVANH makes use of the advantages of robotic surgery to broaden the indications for vaginal hysterectomy and can help overcome its limitations, while the NOTES approach avoids abdominal wall wounds and trocar-related complications. Further developments in robotic technology will help overcome the problem of robotic arm collision. Robotic hysterectomy via vaginal access is a novel approach that requires further validation. The extra cost and setup time of RVANH will also need to be assessed in comparison to the advantages it provides over a VANH or total laparoscopic hysterectomy.

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Author's contributions Jan Baekelandt recruited and operated all patients. He collected the data, performed the literature review, wrote and submitted the article, and made the video.

Compliance with ethical standards

Funding No funding was received for this study.

Conflict of interest The author declares that he has no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all patients included in the study.

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