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**ORIGINAL ARTICLE**

# Surgical techniques: robot-assisted laparoscopic hysterectomy with the da Vinci® surgical system†

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## Abstract

**Background** Advanced gynecologic pathology and the surgical limitations of conventional laparoscopy have often been cited as impediments to converting hysterectomy from a procedure predominantly performed by laparotomy to one accomplished by laparoscopy. Recently, the use of robotic technology as a means to facilitate the laparoscopic completion of a hysterectomy was introduced.

**Methods** Application of robotic-assistance with the *da Vinci* surgical system to complete a laparoscopic hysterectomy.

**Results** Advantages to this approach have been the improved dexterity and precision of the instruments coupled with three-dimensional imaging. Published preliminary data have shown feasibility and safety to this approach.

**Conclusion** The following paper demonstrates a safe and efficient surgical technique for completing a robot-assisted laparoscopic hysterectomy with the *da Vinci* Surgical System. Copyright © 2006 John Wiley & Sons, Ltd.

**Keywords** robotics; hysterectomy; laparoscopy

## Introduction

Approximately 600 000 hysterectomies are performed annually in the USA, with the majority due to benign conditions (1–3). Prior to the introduction of laparoscopic-assisted vaginal hysterectomy in the late 1980s, hysterectomies were approached by either a vaginal or an abdominal route (4). Since the 1990s, a definite trend toward laparoscopic hysterectomy has been seen.

Despite the increasing acceptance of laparoscopy, hysterectomy via laparotomy remains the most common route. One explanation for this slow acceptance is the learning curve with conventional laparoscopy and its associated complications. Another has often been advanced pathology, such as pelvic adhesions, of which the scarred or obliterated anterior cul de sac is one example, where the ability to complete a hysterectomy in a minimally invasive fashion is affected by the surgical anatomy field. This in turn is affected by the surgeon's skill level and the technical limitations of conventional laparoscopic instruments (5). The use of robot-assisted technology may provide a means to overcome both advanced pathology and the surgical limitations of conventional laparoscopy, by providing surgeons with improved dexterity and precision coupled with advanced imaging that allows for the completion of complex minimally invasive procedures in a fashion analogous to open surgery.

This paper describes the use of the da Vinci® surgical system (Intuitive Surgical), which is the only FDA-approved robotic device for use in gynaecological surgery as of April 2005. The surgical approach is based on the American Association of Gynaecological Laparoscopists (AAGL) classification system for laparoscopic hysterectomy: either AAGL type IVE (totally laparoscopic removal of the uterus and cervix, including vaginal cuff closure) or LSH III (totally laparoscopic supracervical hysterectomy with removal of the uterine corpus and division of the uterine arteries) (6). Both surgical technique and instrumentation are emphasized.

## The da Vinci surgical system

The da Vinci surgical system is a laparoscopic assist device comprising three components. The first component is the surgeon console, which is located remotely from the patient bedside. The surgeon seated at this console is able to control robot-assisted instruments within the patient with the aide of a stereoscopic viewer, hand manipulators and foot pedals. The second component is the InSite® vision system, which provides three-dimensional imaging through a 12 mm endoscope. A 5 mm endoscope is available. However, this only provides two-dimensional imaging. The third component is the patient-side cart, with robotic arms and EndoWrist® instruments. Currently the system is available with either three or four robotic arms. One of the arms holds the endoscope, while the other two or three arms hold the various EndoWrist instruments, which come in either 8 mm or 5 mm sizes. A newer model, the da Vinci® S™, functions on the same platform as its predecessor; however, it provides surgeons with additional range of motion from longer instruments and increased pitch.

The EndoWrist instruments are unique in that they possess a wrist-like mechanism that allows seven degrees of movement, thereby replicating the full range of motion of the surgeon's hand and in turn eliminating the fulcrum effect seen with conventional laparoscopy. A series of EndoWrist instruments, such as needle drivers and scissors, can be interchanged on either of the lateral robotic arms.

### Set-up

All patients are placed in low dorsal lithotomy position with arms padded and tucked at their sides after general endotracheal anesthesia has been administered (Figure 1). Anti-skid measures should be incorporated at this time, with either the proper use of shoulder braces or a foam egg crate mattress directly behind the patient's upper back in order to avoid patient slippage during the use of Trendelenburg.

The bladder is drained with a Foley catheter and the stomach is evacuated with a nasogastric tube. Preoperatively, patients should have undergone a mechanical bowel prep in order to adequately decompress the distal colon and rectosigmoid, for improved visualization of the pelvis. Based on surgeon preference, a variety of uterine manipulators can then be placed in order to facilitate the robot-assisted hysterectomy. This author utilizes either a RUMI® or ZUMI® uterine manipulator in conjunction with a Koh® colpotomy ring and vaginal pneumo-occluder balloon (all Cooper Surgical®, Trumbull, CT) (Figure 2).

**Figure 1. Proper positioning for robotic cases with patient in dorsal lithotomy and arms padded and tucked at sides**

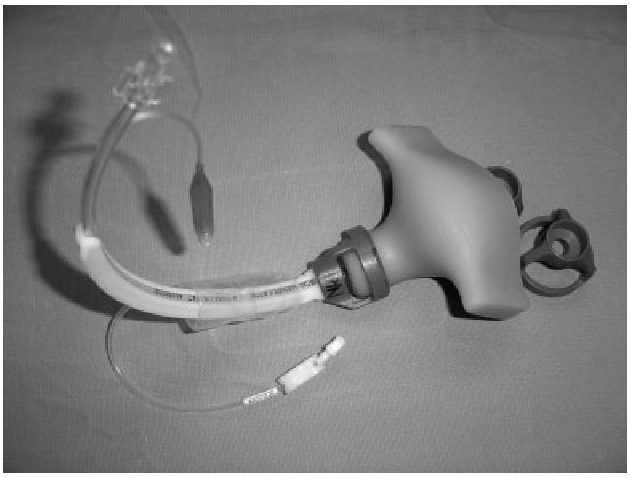

**Figure 2. ZUMI® uterine manipulator with Koh® colpotomy ring and vaginal pneumo-occluder balloon set-up pictured in uterine model (Cooper Surgical, Trumbull, CT)**

Pneumoperitoneum is obtained with a Veress needle technique, followed by placement of either four or five trocars, depending on whether or not the patient-side cart has three or four robotic arms. A 12 mm port is placed either at or above the umbilicus, depending on the size of the uterus. This port accommodates the dual optical endoscope. As a general rule, at least a hands-breadth distance, or approximately 8–10 cm between the endoscope and top of an elevated uterus during manipulation, is necessary in order to allow for an adequate working distance between the endoscope and



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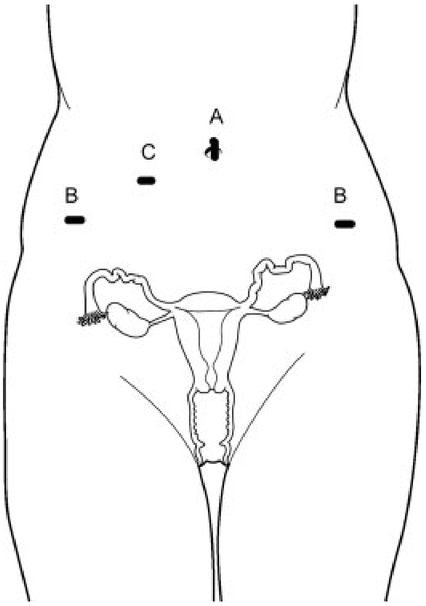


**Figure 3. Port placement (three-armed patient-side cart). The camera port (A) is 12 mm, either in the umbilicus or above, depending on size of the uterus. The lateral ports (B) are 8 mm da Vinci® ports in the lower quadrants of the abdomen. A 10–12 mm assist port is placed between the camera port and the right lower quadrant port**

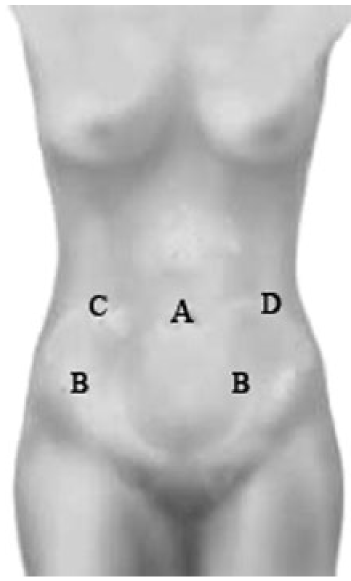


**Figure 4. Port placement (four-armed patient-side cart). The camera port (A) is 12 mm, either in the umbilicus or above, depending on size of the uterus. The lateral ports (B) are 8 mm da Vinci® ports in the lower quadrants of the abdomen. The fourth arm is represented by (D). A 10–12 mm assist port is placed between the camera port and the right lower quadrant port**

the uterine fundus. Two 8 mm ports that mount directly to the operating arms on the patient-side cart are placed in the left and right lower quadrants, respectively. As a general rule, these are located two finger-breadths from the anterior–superior iliac spines on a diagonal to the umbilicus. For larger uteri, these landmarks are moved further cephalad. A fourth port serves as an accessory port and can be placed between the camera port and either the left or right lower quadrant ports. This is typically a 10–12 mm port in order to facilitate introduction of suture as well as instruments used for retraction, suction/irrigation and specimen removal.

This author utilizes a three-armed patient-side cart with the accessory port placed on the patient's right side (Figure 3). Figure 4 illustrates the use of a four-armed patient-side cart. Depending on where the fourth arm is placed, the accessory port and bedside assistant are placed on the opposite side.

Once all desired ports are in place, the patient is placed in steep Trendelenburg. The patient-side cart with robotic arms is brought between the patient's legs and docked. Each port is attached to the assigned robotic arm, with the exception of the accessory port. The bedside surgeon is responsible for EndoWrist instrument exchanges and any accessory port activity, such as introduction of suture.

## EndoWrist instrumentation

A variety of EndoWrist instruments are available for use during a hysterectomy. Although traditional surgical instrumentation, such as a large needle driver, DeBakey forceps, permanent cautery hook (monopolar) and curved scissors are available on this platform, newer multi-functional EndoWrist instruments, such as the PK™ Dissecting Forceps® (bipolar), Hot Shears® (monopolar curved shears), Cobra Grasper and Mega Needle Driver® allow for safe and efficient completion of a hysterectomy with minimal instrument exchanges.

It has long been known that energized bipolar dissection systems greatly facilitate laparoscopic surgery, particularly as it relates to haemostasis. Unfortunately, traditional bipolar instruments, such as Kleppinger forceps, can introduce undesirable thermal collateral damage to adjacent critical structures, mainly by heat conduction. Additionally, over-desiccation due to a lack of tissue impedance feedback can result in partially ligated vascular pedicles. The latest generation of energized EndoWrist instrumentation has the potential to reduce the incidence of such problems through the use of active feedback control over the power output. This is exemplified by the bipolar PK Dissecting Forceps, which integrate with a Gyrus ACMI generator that incorporates PlasmaKinetic (PK) vapour pulse coagulation (VPC). This in turn results in an improved seal on vascular pedicles with minimal thermal spread, tissue sticking, heating of the instrument and surgical plume. This author utilizes the factory default settings on the Gyrus ACMI generator, which are applicable across all gynaecological procedures. Critical to the successful use of this instrument is a tension-free application to the tissue being treated. Excessive traction or force on the tissue being treated will result in a poor application of the radio frequency current effects.



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## Robot-assisted laparoscopic hysterectomy technique

This author's following surgical technique is analogous to an open surgical approach, while also keeping consistent with either the AAGL type IVE or LSH III laparoscopic hysterectomy, as described earlier. Critical to the safe and successful completion of a robot-assisted hysterectomy is adherence to the principles of open surgery, which include proper development of avascular planes and skeletonization of vascular pedicles prior to ligation, either by suture or radio frequency current. The approach to hysterectomy will be based on a three-armed patient-side cart.

Each case is begun with bipolar PK Dissecting Forceps on the left arm and monopolar Hot Shears on the right arm. It is important to note that the monopolar current provided to the Hot Shears is in coagulation mode, therefore the power settings on the radio frequency generator are typically kept to a minimum at 35, in order to avoid the risks of excessive energy delivery. Factory default settings on the Gyrus ACMI generator are used for the PK Dissecting Forceps.

Regardless of whether or not the adnexae are going to be removed in conjunction with the hysterectomy, the adnexae are initially detached from the uterus in order to avoid both an obstructed view of the broad ligament and unnecessary retraction by the bedside assistant. This is accomplished by first skeletonizing the fallopian tube and utero-ovarian ligament on each side. The bipolar PK Dissecting Forceps are then used to coagulate and seal these pedicles, followed by 'cold' transection with the monopolar Hot Shears (Figure 5). Energized cutting with the monopolar Hot Shears carries the risk of disrupting the seal created on the pedicle by the bipolar PK Dissecting Forceps. Careful attention must be paid to ensure that the ureters are identified bilaterally and well out of harm's way. The monopolar Hot Shears are then used to transect the round ligaments bilaterally followed by incision of the anterior and posterior leaves of the broad ligament. These two EndoWrist instruments are then used to create a vesico-uterine reflection and skeletonize the uterine vasculature bilaterally (Figure 6). This entire dissection is facilitated by cephalad uterine movement that is provided by the bedside assistant on the uterine manipulator.

Alternatively, a fourth arm configuration could allow introduction of either a Cobra Grasper or Tenaculum for upward uterine traction. These steps allow the Koh colpotomy ring to become clearly delineated as a dissection landmark and for the ureters to be identified and fall laterally out of harm's way. Proper bilateral skeletonization of the uterine vascular pedicle will allow for a much better tissue effect from the radio frequency current applied through the bipolar PK Dissecting Forceps and minimize any risk of lateral thermal spread to adjacent structures, such as the ureter and bladder (Figure 7). This technique of vascular pedicle skeletonization prior to ligation is consistent with that seen in an open hysterectomy. A tension-free application


**Figure 6. Vesico-uterine reflection is being developed with the aid of the monopolar Hot Shears®**

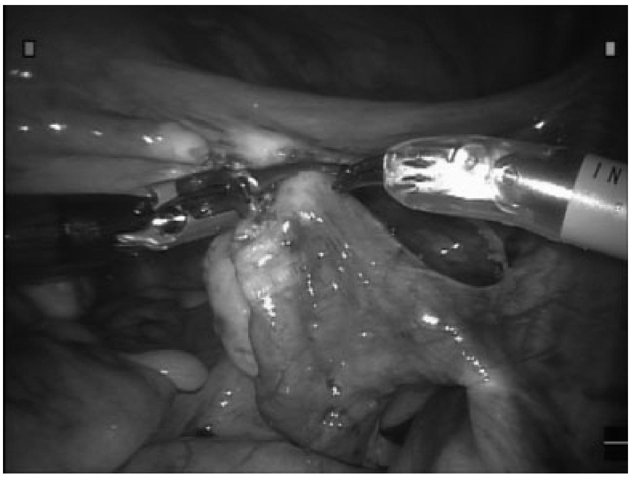

**Figure 5. Bipolar PK Dissecting Forceps® are being applied to a skeletonized fallopian tube and utero-ovarian ligament on the right**

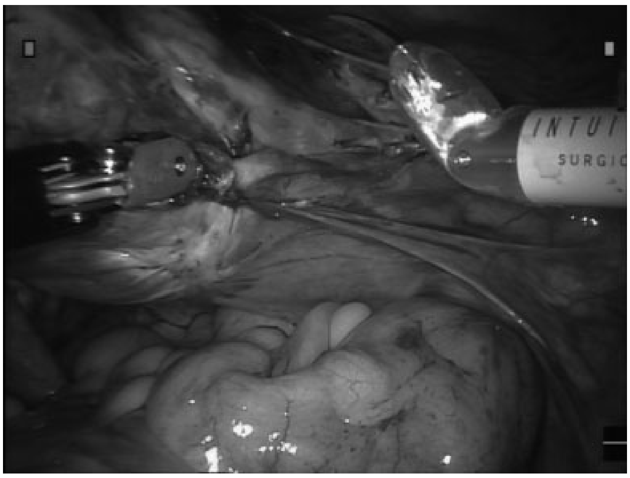

**Figure 7. Bipolar PK™ Dissecting Forceps® are being applied to a skeletonized uterine vasculature on the right during upward movement of the uterine manipulator**



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of the bipolar PK Dissecting Forceps is utilized during coagulation and dessication of the uterine vasculature. Should the surgeon find it necessary to perform multiple applications, this must be balanced with the risk of excessive instrument and tissue heating, with possible lateral thermal spread to critical adjacent strucutures.

Once the uterine vasculature is coagulated bilaterally, the uterus should become ischaemic in appearance. These pedicles are not transected until the colpotomy is performed. The ascending branches of the uterine vasculature are also coagulated bilaterally in order to minimize any back-bleeding during either total or supracervical hysterectomy.

In cases where a total laparoscopic hysterectomy is intended, the monopolar Hot Shears are utilized to divide the cardinal and uterosacral ligament complexes bilaterally in a manner consistent with an intrafascial hysterectomy. Completion of both the anterior and posterior culdotomy is facilitated by the Koh colpotomy ring, while upward uterine traction is provided by the bedside assistant (Figure 8). Pneumo-peritoneum is maintained by inflation of the vaginal pneumo-occluder balloon placed at the onset of the case. If adnexae are to be removed as part of the hysterectomy, then this can be accomplished prior to colpotomy, with specimens placed in the posterior cul-de-sac for retrieval after delivery of the uterus into the vagina. After proper skeletonization of the infundibulo-pelvic ligaments (ovarian vasculature) and identification of the ureters in the retroperitoneum bilaterally, the bipolar PK Dissecting Forceps are then used to coagulate and seal these pedicles, followed by 'cold' transection with the monopolar Hot Shears (Figure 9). Again, a tension-free technique is critical to successful ligation of the pedicle. Additional applications may be utilized if the surgeon finds it necessary; however, caution must be exercised in order to avoid excessive instrument and tissue heating, with possible lateral thermal spread to critical adjacent structures.

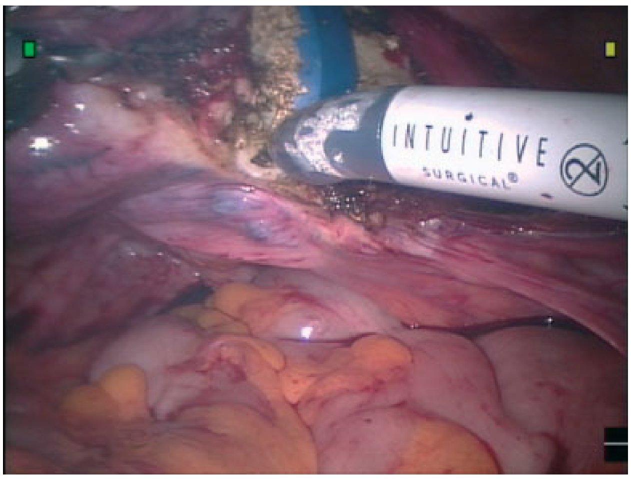


**Figure 8. Colpotomy with incision of cardinal and utero-sacral ligament complexes is accomplished with the monopolar Hot Shears®; blue Koh® colpotomy ring is visible**

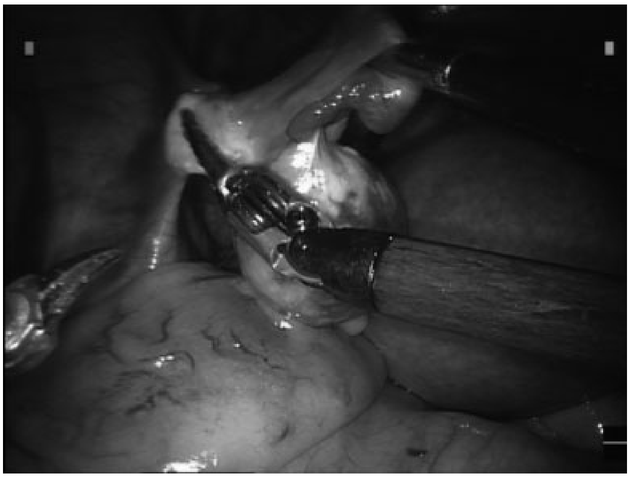

**Figure 9. Bipolar PK™ Dissecting Forceps® being applied to a skeletonized left infundibulo-pelvic ligament (ovarian vasculature)**

**Figure 10. A Mega Needle Driver® drives a CT-2 needle with 0-Vicryl™ suture through the vaginal cuff while the edges are nicely everted with the PK™ Dissecting Forceps®, thereby ensuring incorporation of vaginal mucosa in the closure**

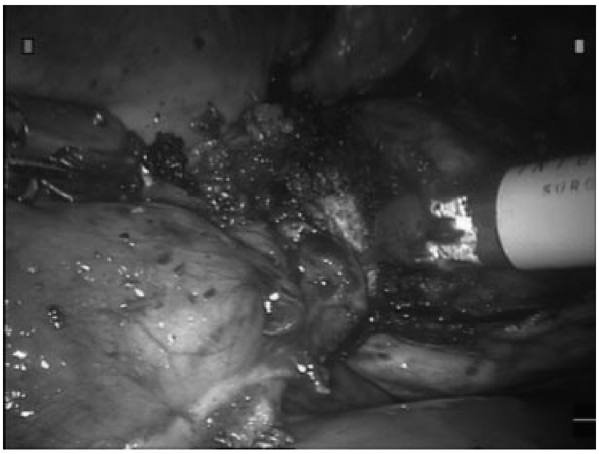

**Figure 11. A supracervical hysterectomy is accomplished with the monopolar Hot Shears® at a level just below the internal os, while the PK™ Dissecting Forceps® provide traction on the uterine corpus during amputation**



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**Table 1. Robot-assisted laparoscopic hysterectomy**

| Reference | No. of patients | Age (years) | BMI (kg/m$^2$) | EBL (ml) | Uterine weight (g) | OR time (min) | Hospital stay (days) | Type of hysterectomy | Indication | Complications |
|---|---|---|---|---|---|---|---|---|---|---|
| Advincula and Reynolds (7) | 6 | 40 | 26 | 87.5 (50–150) | 121.7 (70–166) | 254 (170–368) | 1.3 | IVE (5) III (1) | Endometriosis, abnormal uterine bleeding, symptomatic fibroids | Vaginal cuff haematoma (1) |
| Reynolds and Advincula (8) | 16 | 41 | 27.8* | 73 (50–300) | 131.5 (30–327) | 242 (170–432) | 1.5 | III (4) IV E (12) | Chronic pelvic pain, fibroids, AUB (failed medical Rx) | Thermal bowel injury (1) Vaginal cuff haematoma (1) Pneumonia (1) |

*Median reported.

**Table 2. Robot-assisted laparoscopic hysterectomy during staging of gynaecological malignancies**

| Reference | No. of patients | Age (years) | EBL (ml) | OR time (min) | Hospital stay (days) | Type of hysterectomy | Indication | Node counts | Complications |
|---|---|---|---|---|---|---|---|---|---|
| Reynolds *et al*. (9) | 7 | 48 | 50 | 257 (174–345) | 2 | IV E (4) Staging (3) | Endometrial CA Ovarian CA Fallopian tube CA | 15* (4–29) | Sinusitis (1) |

*Median reported.



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Once the uterus and cervix are completely detached, the specimen, with or without adnexae, is delivered into the vagina. In cases where the uterus is too large to pass through the colpotomy, a tissue morcellator can be used to debulk the specimen. The uterine fundus can be used to maintain pneumo-peritoneum during the closure of the vaginal cuff or the vaginal pneumo-occluder balloon can be replaced. A sterile glove stuffed with Ray-Tecs™, tied and placed in the vagina can also help maintain pneumo-peritoneum during this portion of the procedure. Either interrupted sutures of 0-Vicryl™ on CT-2 needles cut to 6 inches, or a running suture of 0-Vicryl on a CT-2 needle cut to 11 inches, can be used. Care must be taken to ensure that adequate bites are taken far enough back from the cut edge of the vaginal cuff, where radio frequency current was applied, in order to avoid a pull-through of suture and potentially a vaginal cuff dehiscence. All knots are tied intracorporeally. The vaginal cuff closure can be readily accomplished with the PK Dissecting Forceps' ability to grasp and evert the edges of the vaginal cuff, while the Mega Needle Driver's high-force grip is able to securely hold CT-1 or CT-2 needles as they pass through the thick vaginal cuff (Figure 10). These two EndoWrist instruments are placed on the left and right robotic arms, respectively. Alternatively, based on surgeon preference, a large needle driver can be used in place of the PK Dissecting Forceps to help facilitate vaginal cuff closure. Once the vaginal cuff is closed, the specimen is removed from the vagina along with any pneumo-occlusive device.

In cases where a laparoscopic subtotal hysterectomy is intended, the monopolar Hot Shears are used to amputate the uterine corpus below the internal os, followed by extraction of the specimen through the accessory port with a tissue morcellator (Figure 11). The cervical stump can either be left open if haemostatic or closed with interrupted sutures of 0-Vicryl on CT-2 needles cut to 6 inches. Again, the Mega Needle Driver nicely facilitates this suturing task, given the density of the cervical stump and need to securely hold a large needle.

During the course of either a total or supracervical hysterectomy, if the surgeon is uncomfortable coagulating large vascular pedicles with energized EndoWrist technology, then traditional suture ligation can be performed with intracorporeal knot tying.

Prior to the conclusion of the procedure, all operative sites are irrigated, a low insufflation pressure check is performed to ensure haemostasis, and the robot-assist device is undocked. All instruments are then removed from the patient's abdomen and pneumo-peritoneum released. Port sites are closed accordingly.

## Conclusion

As can be seen from the above surgical technique description, an almost sutureless hysterectomy can be performed as a result of improvements in energized robotic instrumentation, the exception being vaginal cuff closure during a total laparoscopic hysterectomy. This approach to robot-assisted hysterectomy has been used successfully by this author for both total and supracervical hysterectomy (AAGL type IVE or LSH III laparoscopic hysterectomy). This experience has also spanned the range of benign and malignant pathology (Tables 1 and 2) (7–9).

Critical to the success of this technique has been a thorough understanding of all facets of robotic instrumentation involved with today's platform of surgical robotics, the da Vinci surgical system, in addition to an adherence to open surgical principles. This is by no means the only way to perform a robot-assisted hysterectomy, but represents a safe and efficient way of approaching gynaecological pathology.

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