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METHODOLOGY

Hysterectomy for Uterine Disease in 2010: from Past to Future

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Abstract: Hysterectomies were unknown in the field of obstetrics and gynaecology until the 19th century. In the 20th century they were perhaps too frequently performed whereas the 21st century has witnessed a steep decline in hysterectomy numbers. It is therefore an opportune time to review the indications for hysterectomies, hysterectomy techniques and the present and future status of this surgical procedure. There is a widespread consensus that hysterectomies are primarily to be performed in cancer cases and obstetrical chaos situations even though minimal invasive surgical technologies (MIS) have made the procedure more patient friendly than the classical abdominal opening. Today, minimally invasive hysterectomies are performed as frequently as vaginal hysterectomies and the vaginal approach is the first choice if the correct indications are given. It is no longer necessary to open the abdomen; this procedure has been replaced by laparoscopic surgery. Laparoscopic and robotic-assisted laparoscopic surgery can also be indicated for hysterectomies in selected patients with gynaecological cancers. For women of reproductive age, laparoscopic myomectomies and numerous other uterine- preserving techniques are applied in a first treatment step of meno-metrorrhagia, uterine adenomyosis and submucous myoma. These interventions are only followed by a hysterectomy if the pathology prevails.

Keywords: laparoscopic and conventional hysterectomies, comparison

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Introduction

In contrast to the 20th century, hysterectomy is no longer the major gynaecological surgical procedure. How has this change come about? Historical data on the first hysterectomy vary from country to country.

Probably the first documented medical opening of the abdomen took place on December 25th 1809 by Ephraim McDowell (1771–1830). Data relating to the first vaginal hysterectomy go back to the times of Soranus of Ephesus in Greece in the year 120 AD. The first successful abdominal hysterectomies in Europe were performed by Charles Clay on January 3rd 1863 and Eugen Köberle on April 3rd 1863 in Strasbourg. Both surgeons claimed to have performed the first successful hysterectomy but this took some time to prove as Clay's first patient in 1863 died soon afterwards. A hysterectomy performed by Conrad Langenbeck on a mentally deficient/retarded patient could not be proved until 26 years later after a post-mortem examination.

There are multiple reports on the standardization of hysterectomies by Wilhelm Alexander Freund, Czerny and Conrad Langenbeck. Radical hysterectomy for cervical cancer was introduced by Schuchardt and later refined by Ernst Wertheim. Vaginal radical hysterectomy was popularized by Friedrich Schauta. The end of the 19th century and the beginning of the 20th century witnessed the introduction of specially modified instruments, anaesthesia and antisepsis. The death rate for vaginal hysterectomy in 1886 was still approximately 15%, by 1890 it had dropped to 10% and by 1910 it had decreased to 2.5%. The success rates for abdominal hysterectomies were much slower. In 1880 a death rate of 70% was still reported. You can only wonder how women at that time consented to such an operation.

In the early 20th century, up until 1945, the subtotal hysterectomy as an abdominal procedure was the universal approach. This type of hysterectomy was associated with less pelvic infections, ureter lesions and other complications in the pre-antibiotic period. After these problems had been overcome by the development of antibiotics, total hysterectomy was introduced. The main concern was to prevent the occurrence of cervical stump cancer, even though only 0.4% of 6600 cases were reported in the USA[1] and 0.1% in Finland Kilkku[2] Kurt Semm[3] and Tom Lyons[4] published similar data of vaginal cancer following abdominal hysterectomy, yet nobody considered removal of the vagina at hysterectomy as prophylaxis against this.

The Pfannenstiel-incision introduced by Johannes Pfannenstiel from Breslau in 1900 proved to be the only real change in the abdominal procedure. This change was from the lower longitudinal abdominal incision to the lower horizontal abdominal incision. The universal acceptance of this incision occurred only after 1970. The increased safety of abdominal and vaginal hysterectomy led to an explosion in the number of hysterectomies performed, with over 650,000 being performed annually in the US and similar numbers in Europe. These procedures cost annually between 1980 and 1990 approximately 3 billion dollar in the United States of America and resulted in Europe and America in almost 50% of women over the age of 45 no longer in possession of their uterus. Technical progress, such as endometrial ablation, an increase in the endoscopic operations as well as a better understanding of organ preservation has led to a clearer understanding of the indications for hysterectomy today.

Which Techniques to Resect the Uterus in Malignant and Benign Indications are Available?

Throughout the world in the US, Germany, Asia, Africa and Australia, gynaecologists have had ample opportunity over the last 40 years to become acquainted with all surgical methods of hysterectomy. What conclusion do you draw after 40 years? Let us first of all discuss the different techniques:

Vaginal hysterectomy

The first hysterectomy performed at the time of Soranus of Ephesus and the newest technique, performed in the 21st century under the name of NOS—Natural Orifice Surgery, use the vagina as the entrance and exit point. For all gynaecologists and surgeons there are many ways to perform an operation, but the lex parsimoniae of William Ockham (1235–1350) is always valuable: "If we have different ways to solve a problem, the simplest way is the right one." Surgery is no exception.

When Langenbeck first performed a vaginal hysterectomy in 1813, the discipline of gynaecology was founded. Since then vaginal access has been the privilege of the gynaecological surgeon.

In 1939, according to the French surgical expert Doyen, no one could call himself a gynaecologist if he had not performed a vaginal hysterectomy. Vaginal hysterectomy is still a central feature of gynaecological discussion.

The gynaecologist only considers other access routes for the exploration of the minor pelvis if vaginal access can not give a clear diagnosis and possibility of treatment. He may then have to select, as others surgeons (general surgeons, oncologists, urologists, gastroenterologists and plastic surgeons), the abdominal route.

In Germany approximately 100,000 hysterectomies are performed annually. Statistics still show that 60%–70% of all hysterectomies are performed by the abdominal approach with the exception of uterovaginal prolapse. In Sweden more then 95% of all hysterectomies that are not performed in conjunction with a descensus operation are performed abdominally. In contrast, Western Australia has 40% hysterectomies by the abdominal route. The vaginal route is the primary route for hysterectomy and the superior one, dependent upon the following questions:

1. What is the best surgical route for the patient?
2. Are there any contraindications?
3. Can the clinical complaint of the patient be identified by the vaginal route?

Vaginal hysterectomies are effective in function, costs and time. In an interesting analysis Johnson et al evaluated 27 trials for 3643 hysterectomies.[5] They concluded that where vaginal hysterectomy is not possible, laparoscopic hysterectomy is preferable to abdominal opening. Twenty randomized controlled trials (RCT) comparing total abdominal hysterectomy, vaginal hysterectomy and laparoscopic hysterectomy and 16 RCT comparing laparoscopic hysterectomies with total abdominal hysterectomies clearly stated that laparoscopic hysterectomy requires greater surgical skill. Laparoscopic hysterectomy is associated with a faster return to normal activity for the patient and a shorter hospital stay. Vaginal hysterectomy leaves behind no scars and is the faster operative technique. Vaginal hysterectomy should be performed for the following indications:

1. Uterine prolapse
2. Dysfunctional uterine bleeding
3. Adenomyosis
4. Carcinoma in situ CIN3 of cervix
5. High risk with endometrial cancer
6. Cervical fibroids and polyposis uterine.

Operative steps

Vaginal hysterectomy can be performed in six to ten steps according to the situs of the patient.[6]

1. Circumcision of the cervix with the scalpel, after grasping the cervix with two sutures or cervical clamps. According to Joel-Cohen 1972[7] and Stark 2006[8] in patients with uterine prolapse the incision of the vaginal wall can also start below the orificium urethrae externum. If the cut is deep enough, the vaginal wall can be pushed back with the finger and mobilisation is easy. If necessary, the vaginal wall can be separated from the cervix with scissors.
2. Separation of bladder from uterus and opening of the spatium vesico uterinum or the spatium recto uterinum. If the spatium vesico uterinum cannot be opened easily, it is easier to open the spatium recto uterinum with scissors until the sacrouterine ligaments are visible.
3. Clamping, dissection, suturing or coagulation of the sacrouterine ligaments. The sacrouterine ligaments and paracervical tissue must not bleed. In patients with uterine prolapse the uterine vessels are directly visible.
4. Identification of the uterine vessels, separation by knife or scissors, suturing or often today the use of the biclamp, followed by sharp dissection. If the peritoneum in the area of the vesico uterine space was not opened, it is now opened by sharp dissection.
5. Extraction of the uterus through the vagina after separation from the round ligaments, the ovarian ligaments or from the infundibulo pelvic ligaments. This step is sometimes performed with clamps, dissection and suturing or with the Biclamp® (thermofusion).
6. The peritoneum is left open and only the vagina is closed with individual sutures. If necessary, a reconstruction of the pelvic floor is performed to prevent consecutive vaginal prolapse or formation of a Douglas-cele by placing an extra suture between the two sacrouterine ligaments and the vaginal stump.

According to the data collected by the Center for Disease Control in the USA[9,10] the mortality rate for a vaginal hysterectomy—excluding cancer patients or obstetrical chaos situations—is 2.7/10,000 compared to 8.6/10,000 for an abdominal hysterectomy. The lowest mortality rate per 10,000 surgical interventions was for laparoscopic hysterectomies and the highest for abdominal hysterectomies. It is still open to discussion whether the peritoneum should be closed or left open.[11]

Abdominal hysterectomy

After the first unintended abdominal supracervical hysterectomies of Charles Clay[12] and Ellis Burnham,[13] the first deliberate hysterectomy, with the patient surviving, was carried out in 1855 by Kimball. This was an abdominal supracervical hysterectomy. After the introduction of anaesthesia by William Morton on October 16th 1846, there were several reports of abdominal hysterectomy but with a mortality of 25%. Charles Clay performed his first successful hysterectomy with a patient surviving on January 3rd 1863 and Eugen Köberle on April 3rd 1863. Both of these doctors are considered the fathers of abdominal hysterectomy.

In 1880 T.G. Thomas reported on 365 collected cases of abdominal hysterectomy which revealed a staggering mortality of 70%. In comparison, vaginal hysterectomy had a mortality rate of 15% in 1886. Nevertheless, Mikulicz and in 1878 Wilhelm Alexander Freund[14] provoked progress in abdominal hysterectomy. They placed three ligatures on the broad ligaments and through the introduction of new techniques for sub-total hysterectomy the mortality rate went down in the period 1896 until 1906, from 22% to 3.4%.

In the early 20th century abdominal hysterectomy was performed mainly as sub-total hysterectomy with the reduced chance of pelvic infections and ureter complications. It is important to remember that this was still the pre-antibiotic era. After the development of antibiotics, E.H. Richardson performed the first total hysterectomy in 1929 in America. The main concern was to prevent the occurrence of cervical stump cancer, even though only 0.4% of 6600 cases were reported in the USA[1] and 0.1% in Finland Kilkku.[2]

In the middle of the 20th century, apart from the change from sub-total to total hysterectomy, the only change in the abdominal procedure was the almost universal adoption of the less disfiguring suprasymphysary incision introduced by Johannes Pfannenstiel.

Abdominal hysterectomy today is a safe technique. There is no more fear of infection, thrombosis or other morbidities. In the last 40 years of the 20th century an explosive increase in the number of hysterectomies took place. Even in Germany the method of choice for bleeding abnormalities, myomas and other pathology was always laparotomy and hysterectomy. Vaginal interventions for hysterectomies increasingly took place in individual centres, such as in Vienna, Austria, and at our centre in Kiel, Germany.

Operative steps

The procedure of abdominal hysterectomy is tailored to the indication. The uterus has to be visualized and freed in the first step. In the second step the round ligaments are separated from the uterus. In the third step the adnexa are separated from the uterus or from the pelvic wall. In the fourth step the parametrium is opened and the bladder is pushed down in the fifth step. The uterine vessels are clamped, separated and sutured. In the sixth step the uterus is separated from the vagina trying to preserve the uterine ligament connection. In the seventh step the vagina is closed and the sacrouterine ligaments are fixed to/through the vagina to prevent Douglas-cele (Moskowitsch technique). In the eighth and last step, after rinsing of the minor pelvis, the visceral peritoneum is left open.

Minilaparotomy hysterectomy

The minilaparotomy procedure may be considered a time saving technique for total hysterectomy for benign uterine pathology. It offers some of the advantages of a minimally invasive procedure (low morbidity, short hospital stay, good cosmetic results) and the benefits of open access (for example, shorter learning curve than laparoscopy). It is a minimally invasive, feasible option, particularly in countries where laparoscopic hysterectomies are not available. In many reports minilaparotomy hysterectomy has been compared to laparotomy and laparoscopic assisted vaginal hysterectomy.[15,16]

Laparoscopic hysterectomy

This technique was developed over the last 25 years. As early as 1984 our teacher, Kurt Semm, was already

using laparoscopic assistance in difficult vaginal hysterectomies.[17] He called this technique laparoscopic assistance for vaginal hysterectomies. In fact, many vaginal hysterectomies were performed in Kiel with laparoscopic assistance, to dissect the uterus from the round ligaments, the adnexa, the sacrouterine ligaments and the cardinal ligaments. However, worldwide discussion on laparoscopic hysterectomy began after the first published laparoscopic assisted vaginal hysterectomy by Harry Reich in 1989.[18] We began to perform supracervical laparoscopic hysterectomy in 1989, but the first publication did not appear until 1991.[13] Prior to this, a few journals had turned down our submitted papers, referring to the absurdity of such a surgical technique.

The Nezhat brothers in the United States described their first radical hysterectomy in 1991, but a publication did not appear until 1992.[19]

Laparoscopic hysterectomies in their different forms have been a provocation for gynaecologists for the last 20 years. Gynaecologists favour the vaginal technique and today the only indications remaining for abdominal operations are of a malignant nature. If the operative indication for laparoscopic hysterectomy is given and the surgeon is an experienced laparoscopist, the majority of patients can be spared a laparotomy. Figure 1 gives an overview of the combination possibilities for laparoscopic and vaginal surgery, including parailical and paraaortic lymphadenectomies. In comparison to conventional abdominal hysterectomy and

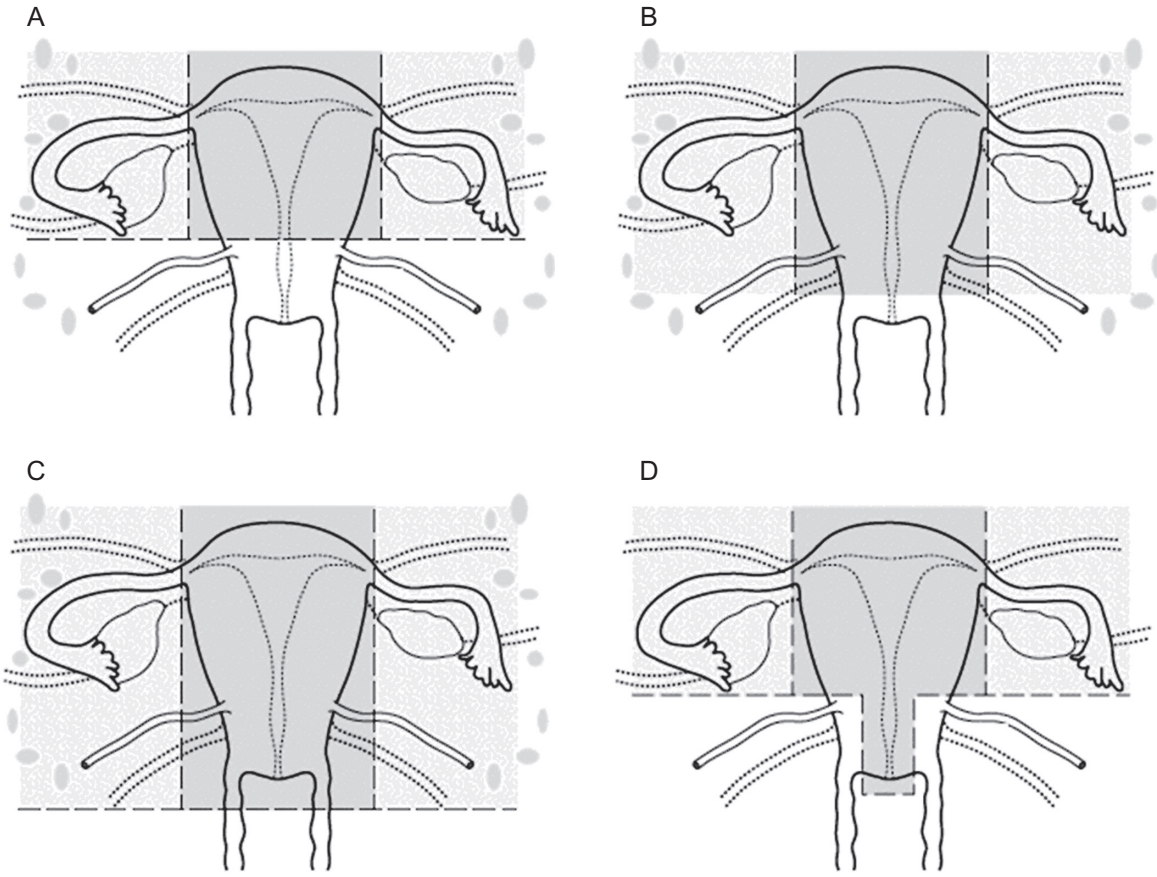

Figure 1. Variation of laparoscopic assisted hysterectomy—LAVH.
A) LAVH—Laparoscopic-assisted vaginal hysterectomy: Laparoscopic resection of the uterus in the region of round ligaments, adnexa and infundibulopelvic ligament from the pelvic side wall above the cardinal ligaments with or without lymphadenectomy. **B**) TLH—Total laparoscopic hysterectomy: Laparoscopic resection of the uterus starting from round ligament up to the infundibulopelvic ligaments. Cutting the uterine vessels and mobilisation of the cervix down to the vaginal vault with or without lymph nodes, opening the paracervical and pararectal spaces. **C**) RLH—Radical laparoscopic hysterectomy: Laparoscopic resection of the uterus from the round ligaments and infundibulopelvic ligaments and uterine vessels, opening of paravesical and pararectal spaces with mobilisation of the uterus including the upper third of the vagina with or without lymphadenectomy, along with the parametria. **D**) Subtotal laparoscopic hysterectomy (SLH) as CISH: Classic Intrafascial Subtotal Hysterectomy with coring of the inner cervix and endoscopic resection of the uterus up to above the cardinal ligaments. Tying of only the ascending branches of the uterine vessels without lymphadenectomy (for hysterectomy in benign lesions).

vaginal hysterectomy, the following laparoscopic hysterectomy techniques are currently practised:[6,20–22]

1. Laparoscopic assisted vaginal hysterectomy—LAVH
2. Total laparoscopic hysterectomy—TLH or LH
3. Intrafascial supracervical hysterectomy—CISH, subtotal or supracervical hysterectomy—SLH or LASH
4. Laparoscopic radical hysterectomy—LRH according to Wertheim or Schauta, with further specifications according to different schools
5. Robotic assistance in oncologic hysterectomy.

Robotic laparoscopic radical hysterectomy is a variation of laparoscopic radical hysterectomy.

A trachelectomy is performed in lymph node-free cases, whereby the total cervix is dissected and the vagina attached to the uterus.

Operative steps

Laparoscopic assisted vaginal hysterectomy—LAVH

In this case the uterus is mobilised laparoscopically and resected transvaginally. The dissection is carried down to but excluding the uterine vessels which are secured vaginally. Similarly, uterosacral and cardinal ligaments are clamped and transfixed ligated transvaginally. LAVH is performed in four laparoscopic and three vaginal surgical steps.[21,23]

Total laparoscopic hysterectomy—TLH or LH

Indications for TLH include benign gynaecological alterations such as fibroids, endometriosis and dysfunctional uterine bleeding in patients for whom vaginal surgery is contraindicated or cannot be performed. TLH may be performed for possible malignant indications such as early endometrial cancer, early localised small cervical cancers (trachelectomy) and also in the early stages of ovarian cancer with lymphadenectomies. The laparoscopic part consists of the preparation of the uterus and the cervix and the complete dissection of the vaginal stump. The individual steps of this procedure are detailed in Figure 2.

The intrafascial supracervical hysterectomy—CISH and the subtotal laparoscopic hysterectomy—LASH

In recognition of the CISH technique, performed at the Kiel university hospital from 1991 to 1995,[24] and still practised with interesting modifications in many countries, we would like to describe the CISH technique and the currently more frequently used LASH technique.

CISH technique

Sub-total hysterectomy represents the method of choice in every form of benign uterine disease that affects only the uterus with no cervical abnormality. Annual cervical cytological surveillance is recommended to detect intracervical neoplasia which can occur if the cervix remains intact. Kurt Semm performed sub-total hysterectomy with coring of the inner cervix to totally resect the cylindrical cervical epithelium.[3] The operative steps are detailed in Figure 3, in a sequence from A till L. The cervix is dissected from the uterine corpus with a LINA loop[6] and the uterus is morcellated transabdominally. It is also now possible to morcellate the uterus transcervically with the Rotocut (Storz), after coagulation of the ascending branches of the uterine arteries but without the positioning of Roeder loops.

Laparoscopic assisted sub-total or supracervical hysterectomy—LASH

The advantage of the LASH procedure is that it can be performed on nulliparous patients, patients who have not previously had a vaginal delivery and patients who have had previous abdominal surgery. In these cases the uterus is morcellated but no colpotomy is performed. The technique is used mainly for fibroids, therapy resistant dysfunctional uterine bleeding and adenomyosis. This technique is now practised routinely in Kiel according to the standardised safe minimally invasive technique.[25,26] In a retrospective study on the clinical significance of adhesions, the effect of SprayShield as an adhesion prophylaxis has been evaluated.[27]

Laparoscopic radical hysterectomy—(LRH) (Wertheim or Schauta technique)

Following the lead of earlier surgeons, a few skilled European and American gynaecologic surgeons have further refined the technique of radical hysterectomy, partly using robotic assistance. In addition to the Nezhat brothers[19] and Jo Childers,[28,29] who have been propagandists for radical endoscopic surgery worldwide, European colleagues such as Daniel Dargent,[30] Denny Querleu,[31] Achim Schneider and Mark Possover[32] have also put intensive work into oncologic endoscopic surgery. However, it is a colleague of the third world, Shailesh Puntambekar, who has successfully brought world attention to the possibility of radical oncological surgery via laparoscopy.[33]

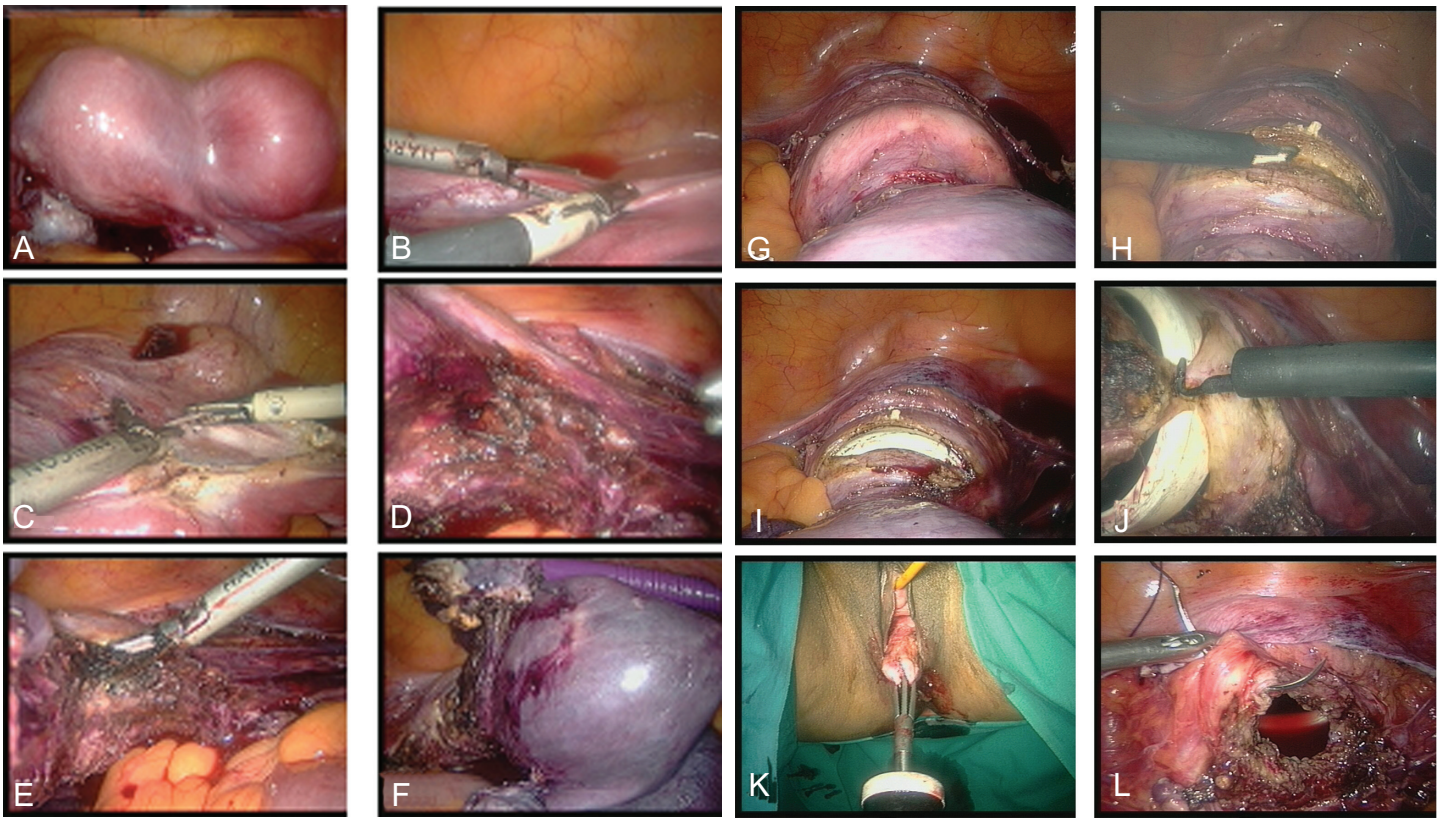

Figure 2. Total Laparoscopic Hysterectomy—TLH.
A) Multifibroid uterus. **B**) Dissection of the left round ligament. **C**) Preparation of left uterine vessels. **D**) Presentation of right uterine vessels. **E**) US-coagulation and separation of right uterine vessels. **F**) Ischemic uterus elevated by the uterine manipulator according to Mangeshikar. **G**) Vaginal delineation line on the ceramic cap of the Mangeshikar manipulator. **H**) Separation of cervix from vagina using the monopolar hook sound. **I**) The cap becomes visible in the vaginal fornix. **J**) Continuous dissection of uterus from vagina. **K**) Extraction of a 210 g uterus from vagina. **L**) Reinsertion of the manipulator tube with ceramic cap to keep the pneumoperitoneum, closure of vaginal stump with a continuous suture and two corner sutures. To prevent enterocele formation the sacrouterine ligaments are attached to the vaginal stump.

In 1986 Dargent already began to perform laparoscopic trachelectomy in cases of small cervical cancers with no iliac lymph node metastases.[30] Shailesh Putambekar performs laparoscopic radical hysterectomy not only in endometrial and early cervical cancers, but also for anterior exenteration.[34,35] A few of us have had the opportunity to work with Shailesh Putambekar in India and in Germany. He performs excellent anterior exenterations endoscopically and proves repeatedly that radical hysterectomies are possible via the endoscopic approach.

The results of radical laparoscopic[36] and radical robotic cancer surgery[37] compare well with the outcome of radical abdominal and vaginal cancer surgery. Radical laparoscopic vaginal hysterectomy according to Schauta is successfully practised in Germany by Schneider et al and Possover et al. The Wertheim radical abdominal hysterectomy technique is implemented in New York, Atlanta and in Pune, India by Shailesh Putambekar in cancer cases. Especially parailiac and paraaortic lymph nodes can be prepared more precisely as there is a larger augmentation than at laparotomy. Trachelectomy allows patients with early cervical cancer, who still want to have children, the possibility to preserve their fertility.

Endoscopic surgery for malignant alterations has the same chance of success as open surgery, with less surgical trauma. It depends as much on subsequent chemo or radiation therapy as open surgery does. Molecular genetic progress in the therapy of malignant disease will show the real role endoscopic surgery can take.

Robotic assistance in oncologic hysterectomies

The first robotic camera assistant used in endoscopic surgery was the automated endoscopic system for optimal positioning (AESOP; Computer Motion, Goleta, California, USA). This hand, foot or voice-controlled

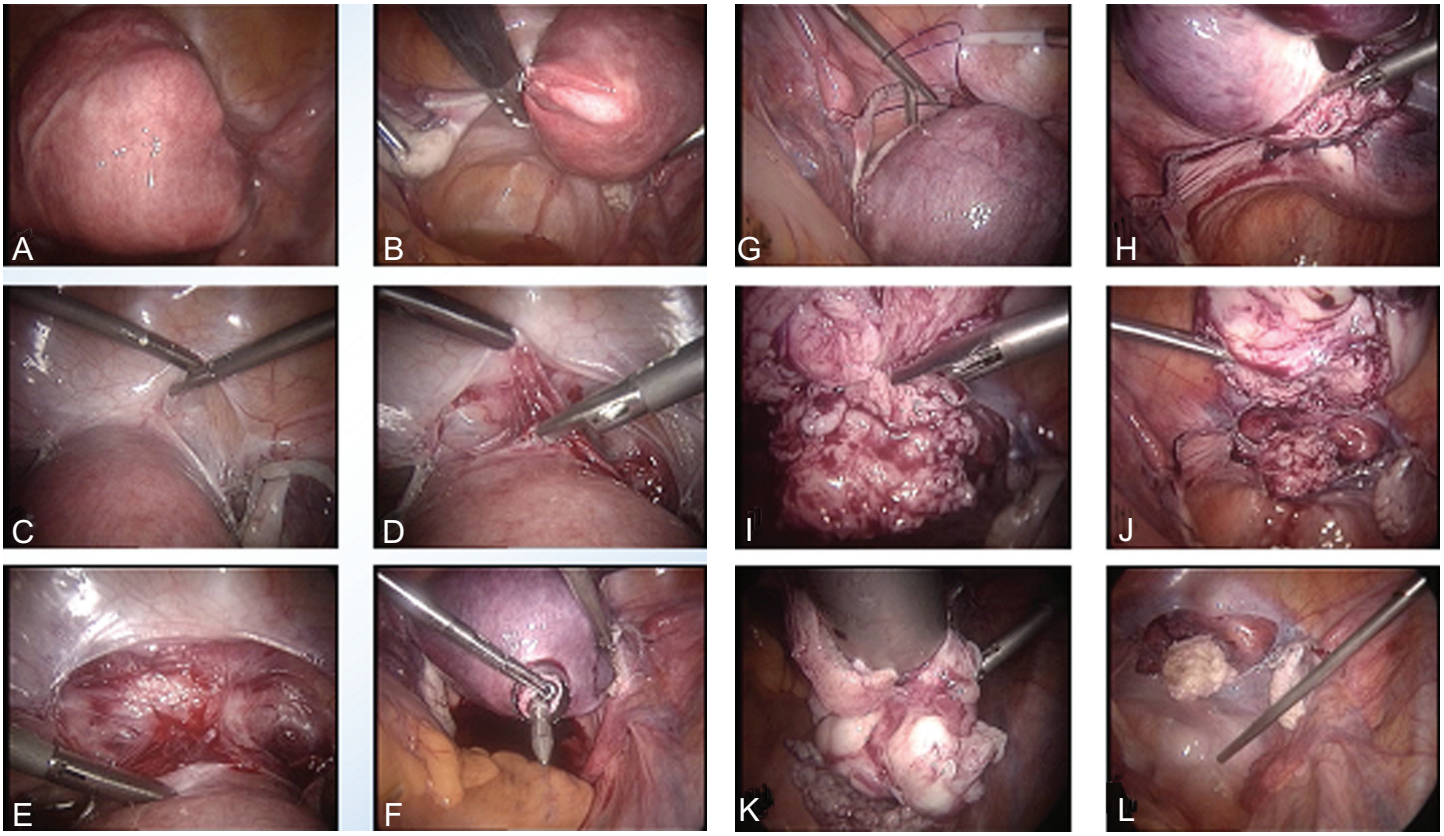

Figure 3. Classic Intrafascial Subtotal Hysterectomy—CISH.
A) Multifibroid uterus. **B**) Dissection of left adnexa from the uterus with a stapler. **C**) Opening of the vesico-uterine space. **D**) Preparation of the bladder. **E**) Demonstration of the pericervical fascial ring. **F**) Transcervical and transuterine resection of a 15 mm tissue cylinder including the "transformation zone around an axial guide rod". **G**) Positioning of a "Roeder loop" as tourniquet to tie the ascending branches of the uterine arteries. **H**) Sharp dissection of cervix from the uterine corpus with a scissor (or a monopolar loop as LINA Loop or STORZ cervical loop). **I**) Further cervical dissection. **J**) Separation of uterine body from the cervix. **K**) Morcellation of the uterus. **L**) Irrigation leaving the visceral peritoneum open.

arm allows the surgeon to perform complex laparoscopic surgery faster than with an assistant holding the camera. The next surgical robot was a voice-controlled robot ZEUS (Computer Motion) that consists of AESOP to hold the camera and two additional AESOP-like units, which have been modified to hold the surgical instruments. The modern robot generation named da Vinci surgical system is based on the technologies of Computer Motion and developed by Intuitive Surgical (Mountain View, California, USA). It was approved by the US Food and Drug Administration (FDA) in May 2005 for clinical use in gynaecology and was first used in reproductive gynaecology for tubal surgery.[38] There are four main components of the da Vinci surgical system:[37]

1. Surgeon's console: the surgeon sits viewing a magnified three-dimensional image of the surgical field (Figs. 4a–c).
2. Patient side-cart: this system consists of three instrument arms and one endoscope arm (Fig. 4d).
3. Detachable instruments (endowrist instruments and intuitive masters): these detachable instruments allow the robotic arms to manoeuvre in ways that simulate fine human movements. There are seven degrees of freedom, which offer considerable choice of rotation in full circles. The surgeon is able to control the amount of force applied, which varies from a fraction of a gram to several kilos. Tremor and scale movements are filtered out. The movements of the surgeon's hand can be translated into smaller ones by the robotic device (Fig. 4e).
4. Three-dimensional vision system: the camera unit or endoscope arm provides enhanced three-dimensional images with the result that the surgeon knows the exact position of all instruments in relation to the anatomical structures (Fig. 4f).

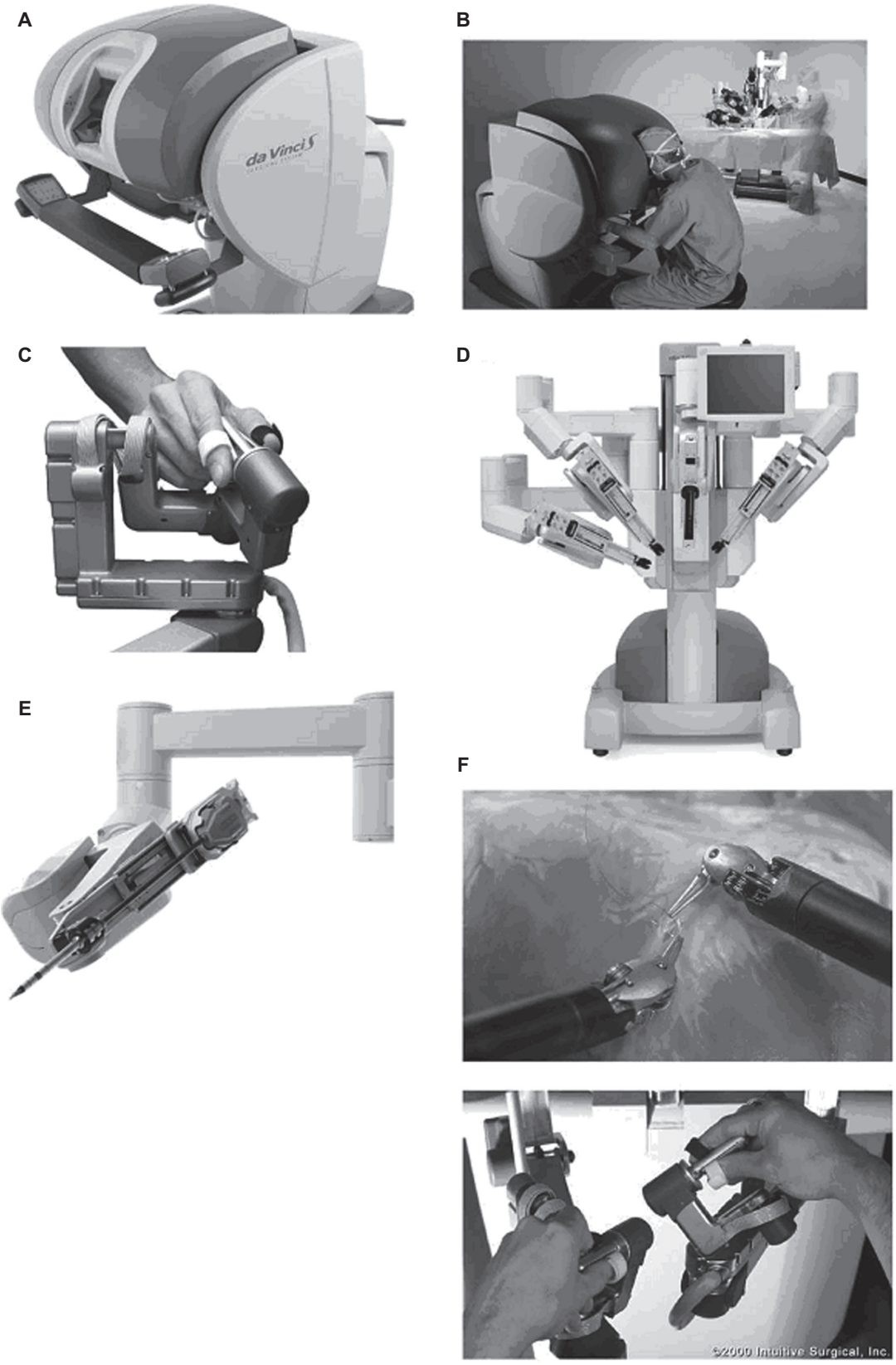

Figure 4. da Vinci Robotic System (Intuitive Surgical).
A) da Vinci 2005 steering unit = surgeon's console. **B**) Working position of surgeon = surgeon's console. **C**) Finger movements for robotic action of instruments. **D**) 3D rapid robotic arms ready to be connected to the 3 active instruments = patient-side cart. **E**) Robotic arms connected to instruments within the 3 working channels = detachable instruments. **F**) Intra-abdominal situs at pelvic lymphadenectomy: one holding arm grasping the lymph node in the centre and two working arms left and right = 3D vision system.

The patients lie in a horizontal position with both arms tucked alongside their body. Four trocars are placed next to the optic trocar. The surgeon sits at the console and the first surgical assistant is seated in most cases on the patients' left side. This assistant controls the left accessory ports into which the instruments that are used for vessel sealing, retraction, suction, irrigation and suturing are inserted. The middle robotic arm is attached to the optical trocar, with two lateral working arms to the right and one to the left. The robotic arms are connected at the beginning of the procedure and disengaged from the trocars at the end of the operation. The incisions are stitched and the incision lines are reapproximated.

A three-dimensional vision allows the surgeon to perform ultra precise manipulations with intraabdominal articulated instruments while providing the necessary degrees of freedom.[38] Compared with the ZEUS system, the da Vinci system is considered to have a shorter learning curve. Operative times and intraoperative technical movements appear inherently more intuitive.[39] The da Vinci robotic surgical system also provides the surgeon with an immersive, ergonomic surgical experience. The surgical technique of a robot-assisted laparoscopic hysterectomy with the da Vinci surgical system has been well described and detailed in step-by-step reports.[40–42] It has also been evaluated as a safe and feasible procedure.[43–45] The da Vinci surgical system is large, expensive and has a steep learning curve. It is, however, well on the way to being fully integrated into existing healthcare systems.

Results of robotic-assisted procedures in gynaecological oncology (noncomparative studies)

The first robotic-assisted hysterectomy and salpingo-oophorectomy on humans was published in 2002 by Diaz-Arrastia and colleagues from the University of Texas.[46] In one woman, the authors performed a staging procedure for ovarian cancer, including pelvic and paraaortic lymph node biopsies and infracolic omentectomy, which required the repositioning of the da Vinci robot from pelvic to upper abdominal surgery.[40,46–55]

The robot setup time became much shorter with practice (45 min for the first case, 8 min for the 11th case). They suggested that robotic surgery is a safe and effective alternative to conventional laparoscopic surgery.[46] A few years later, the same team reported on a retrospective study using 'computer-enhanced' robotic surgery in patients with early stage IA–IIA cervical (14 cases), endometrial (three cases) and ovarian (three cases) cancer. The setup time from the beginning of surgical skin preparation to the start of the surgery was a mean of 31.7 min. The operative time was a mean of 5 h 2 min. Intraoperative complications mentioned were a robot failure, which required the instrument to be changed, redraping of the surgical chart and rebooting of the robot and bradycardia from pneumoperitoneum, which resolved once the pneumoperitoneum was released. Postoperative complications included shoulder palsy, which resolved in 2 days and colostomy with repair without long-lasting squeals.[52]

In France, Marchal and colleagues performed a study on robotic-assisted radical hysterectomy with and without pelvic lymphadenectomy in endometrial and cervical cancer. The procedure was safely performed in five endometrial adenocarcinomas and seven cervical carcinomas with no increase in complication rates. Operating times from all cases resulted in a mean of 181 min. The mean number of pelvic lymph nodes removed was 11.[40,47–49,51,53–55] Estimated blood loss was 0–900 ml (mean, 83 ml). Seventy-seven percent of hysterectomies were vaginally assisted and six were performed with the robot alone. The complication rate for robotic hysterectomies is in the same range as for classical laparoscopic procedures. No port-site metastasis or recurrences were found at a mean follow-up of 10 months (range 2–23 months). There was no morbidity related to the robotic system.[51]

Advincula and colleagues at the University of Michigan performed a study on robotic-assisted hysterectomies with lymphadenectomies for endometrial (four patients), ovarian (two patients) and fallopian tube (one patient) cancer. The median lymph node count was 15, operating time, 257 min and only one complication was described namely, sinusitis. The surgical techniques and experiences described demonstrated the feasibility of applying robotic assistance to laparoscopic cancer staging without an increase in complication rates or compromise to surgical technique.[40]

A Norwegian group described their first robotic-assisted radical hysterectomy (Piver type III) and bilateral pelvic lymphadenectomy for cervical cancer

(stage Ib1) as a case report. Four months after the operation, the patient presented with asymptomatic bilateral lymphocysts but otherwise the patient was well.[56] In further reported 15 cases, no conversions or technical incidents were observed.[53]

Boggess and colleagues from the University of North Carolina presented seven cases of total robotic type III radical hysterectomy with pelvic lymphadenectomy and oophoropexy for cervical cancer stage Ib1 at the Annual Meeting of the Society of Gynecologic Oncology in 2006. The mean operative time was 252 min and the mean blood loss was 143 (25–300) ml. There were no intraoperative complications. None of the patients required intravenous pain medication or blood transfusion. All surgical margins were negative and a mean of 35 extracted pelvic nodes was reported. All patients were discharged on the day following operation. Ninety percent of patients resumed their daily activities in 1–2 weeks.[48] One year later, Boggess et al[47] reported 43 cases of radical hysterectomy with pelvic and paraaortic lymphadenectomy for endometrial cancer performed in the mean operative time of 163 min.

Magrina and colleagues performed robotic radical hysterectomy reported first on eight patients with a total operating time of approximately 218 min, of which 174 minutes console time,[57] and further on 27 patients with a mean total and console time of 189.6 and 150.4 min, respectively.[55] With increasing experience is a learning curve for robotic operations transparent.

A team from Seoul evaluated the feasibility and surgical outcome of robotic radical hysterectomy with pelvic lymphadenectomy. They showed in a retrospective study on 10 patients with International Federation of Gynaecology and Obstetrics (FIGO) stage IA2 to IBI cervical cancer that robotic radical surgical treatment for cervical cancer is feasible, promising and associated with a low morbidity. All operations were completed robotically with no conversions to laparotomy and there were no urethral injuries or fistula complications. The mean operative time was 207 min; mean docking time, 26 min; mean estimated blood loss, 355 ml; and mean number of resected pelvic lymph nodes, 27.5.

Molpus et al[50] demonstrated the utility of the da Vinci in preserving ovarian function before scheduled adjuvant pelvic radiation, when they described the first clinical case of robotically assisted endoscopic ovarian transposition.

Results of robotic-assisted procedures in gynaecological oncology (comparative studies)

The team from University of North Carolina reported on 43 robotic-assisted laparoscopic hysterectomies with pelvic and paraaortic lymph node dissection for women with endometrial cancer as a simple case report. There were no conversions to laparotomy in the robotic group compared with 3% in the laparoscopy group. There were significantly more nodes recovered in the robotically staged patients (29.8 versus 23.2). The mean blood loss in the robotic group was 63 ml (25–300) with 45% of patients having no measurable blood loss compared with 142 ml (50–700) in the laparoscopy group. Mean operative time was 163 min compared with 213 and hospital stay was 1.0 compared with 1.2 days. There were 4.6% major complications in the robotic group compared with 12.8% in the laparoscopy group.[47]

The team from Mayo Clinic in Scottsdale compared robotic-assisted surgery, laparoscopic surgery and open laparotomy in patients undergoing radical abdominal hysterectomy with bilateral lymphadenectomy for cervical cancer. They operated on 27 patients robotically with a mean operative time of 189.6 min, 31 patients laparoscopically with a mean operative time of 220.4 min and 34 patients had an open laparotomy with a mean operative time of 166.8 min; the mean blood loss was 133.1, 208.4 and 443.6 ml, respectively. In this team, robotic lymphadenectomy in 27 patients resulted in a mean of 25.9 excised lymph nodes and this appeared to be equal to that observed in laparoscopic lymphadenectomy in 31 patients, in which a mean of 25.9 lymph nodes was excised. These results compare well with open abdominal lymphadenectomy, with the mean number of excised lymph nodes being 27.7. There were no significant differences in intraoperative or postoperative complications among the three groups, no fistula formation in any patient and no conversions in the robotic or laparoscopic groups. Thus, in this matched comparison of radical and modified radical hysterectomies by robotics, laparoscopy and laparotomy, the extent of lymphadenectomy was similar for the three groups, but blood loss and the length of hospital stay were significantly reduced as compared

with laparotomy, indicating reduced tissue trauma. The robotic and laparotomy operating time was significantly shorter as compared with laparoscopy in the subgroup of patients undergoing the modified radical but not the radical technique.[55] In contrast, Boggess and colleagues reported that open abdominal pelvic lymphadenectomy in 48 patients resulted in a mean of 22.3 lymph nodes being excised, which was significantly less than the mean of 38.4 lymph nodes when robotic lymphadenectomy was used in 31 patients. As compared with laparoscopy, patients having robotically assisted surgery experienced reduced blood loss (176 versus 328 ml) and reduced hospitalization (1.9 versus 2.9 days), though the lymph node count was higher for the laparoscopy group. There were no intraoperative or major postoperative complications in either group.[49]

In a Norwegian study, 15 pilot cases of robotic-assisted laparoscopic radical hysterectomy were compared with 15 cases of conventional laparoscopic total radical hysterectomy as controls. Median operation time was statistically significantly lower for robotic surgery (241 min) than for laparoscopy (300 min). Significantly less bleeding and shorter hospital stays were also observed in the robotic-assisted group. The histopathological results concerning the number of lymph nodes, the parametrial tissue and vaginal cuff size were similar in both groups. In the robotic group, complications were as follows: one patient with cystotomy, two patients with postoperative lymphoceles, one patient with deep venous thrombosis, one with obturator pain and one with urinary tract infection.[58] This team concludes that the robotic-assisted laparoscopic radical hysterectomy in early stage cervical carcinoma cases can achieve better results than traditional total laparoscopic radical hysterectomy technique.[53]

Recent Focus on Hysterectomies Including Uterine Manipulators

At the 2007 International Hysterectomy Symposium in Kiel,[6] colleagues from Europe, Australia, South America, Africa, Taiwan (Chyi Long Lee), Japan (Masaaki Andou) and the United States (Farr, Camran and Ceana Nezhat) reported on their experience of performing radical endoscopic surgery. A live radical hysterectomy, performed by Shailesh Puntambekar (India), was transmitted to the Kiel meeting and again in 2008 to the Biannual German Congress of Obstetrics and Gynaecology in Hamburg.

At the November 2008 Meeting on Controversies in Obstetrics, Gynaecology and Infertility in Paris, the pros and cons of subtotal hysterectomy were debated by L. Mettler and F. Nezhat. Today, in the era of N.O.T.E.S = Natural Orifice Transluminal Endoscopic Surgery or N.O.S. = Natural Orifice Surgery,[59] discussion also focuses on purely transvaginal or transgastric hysterectomy, as discussed at the 2008 NESA Meeting in Naples, Italy.

The many variations and combinations of laparoscopic and vaginal hysterectomy show that colleagues all over the world are interested in the further development of these surgical techniques with individual preferences. For example, our student Ramakrishna Purohit developed the pre-laparoscopic vaginal extraperitoneal ligation of the uterine vessels applying the LAVH technique in the first step. In order to keep the pneumoperitoneum in the second laparoscopic step, he developed a type of Tourniquet suture and an intrauterine manipulator.

Uterine manipulators

A large variety of intrauterine manipulators, rotators and flectors are used as a so called third arm of the surgeon for laparoscopic hysterectomy.[60] However, in malignant indications one has to avoid intracervical or intrauterine manipulation and traction must be performed through an additional entry. The TLH Uterine Manipulator—Dr. Mangeshikar (Fig. 5) offers good manipulation and fixation possibilities for hysterectomy. Other manipulators which may improve the surgical technique of total laparoscopic hysterectomy are described by Mueller et al 2005.[61]

Alternative Techniques

Over the last ten years, the techniques of uterine artery embolization (UAE) and MRI guidance of focused ultrasound for uterine leiomyoma treatment have been developed. Descriptions of MRI-guided focused ultrasound therapy treatment of fibroids indicate that it is an effective treatment for uterine leiomyomata and results in sustained symptomatic relief.[62–64]

Uterine artery embolization is an alternative to hysterectomy in women seeking treatment for symptomatic uterine myomas.[65,66] It is associated with a good success rate in properly selected patients, with

Figure 5. TLH Uterine Manipulator—Dr. Prashant S. Mangeshikar (PEE BEE India).

few major complications. The overall rate of serious complications after UAE, including infection and thrombotic events, is approximately 5%,[67] most often occurring within three months of the procedure when patients are still being closely monitored for symptoms.[68]

Because of the high risk of infection, women who have had UAE and present with necrotic myoma adjacent to the endometrium should not undergo endometrial biopsy. Routine evaluation of the myoma in relation to the endometrium by means of imaging is recommended.

In any discussion between endometrium ablation and hysterectomy, endometrium ablation has to be given first priority. It is no longer a question of endometrium ablation versus hysterectomy but of finding the right method for endometrium ablation and the right method for hysterectomy. It is difficult to keep pace with the fast progressing technologies that come on the market and to select the best endometrium ablation technique, most of which are quite costly. We will look at only a few techniques from the view of their historical development.

In Germany, we still perform approximately 150,000 hysterectomies per year. Only 10%–15% are performed for malignant disease and about 5%–15% for fibroids or gynaecological alterations, such as incontinence and uterus prolapse. The majority of hysterectomies are still performed for dysfunctional bleeding disorders which nowadays can be treated by endometrium ablation.

1. Endometrium ablation techniques of the first generation = hysteroscopic endometrial resection and coagulation.
   In long-term studies, a success rate of 80% was achieved in reducing, but not eradicating, dysfunctional bleedings. Hysteroscopic endometrial techniques, such as the YAG laser, the resectoscope and rollerball technique (also a combination of both techniques), cryoablation and microwave techniques are available.
2. Second generation methods of endometrial ablation include a number of global ablation techniques. One of the most effective appears to be the NovaSure™ System which was introduced to Germany in 1998 by A. Gallinat. It consists of a bipolar ablation device and a radio-frequency controller that enables endometrial ablation in an average of 90 seconds. No endometrial pre-treatment (mechanical or pharmaceutical) is required. Once the uterine length has been sounded, after intrauterine localization of the gold-tipped probe, the width of the uterine cavity is measured. These values are entered into the controller which automatically calculates the power output necessary to ensure an optimal ablation. The endometrium is vaporized and evacuated from the uterine cavity by continuous resection. Once the myometrial layer is reached, the system automatically terminates the ablation. In a five-year follow-up[69] only three patients had to undergo hysterectomy. The NovaSure treatments were performed as outpatient procedures. The only disadvantage is the still relatively high price.

Limits for Hysterectomies

Are there limits for hysterectomies or for which indications are hysterectomies still recommended?

According to present medical standards, malignant disease of the ovaries, tubes and uterus is to be treated by hysterectomy. According to Dargent, trachelectomy can replace hysterectomy in younger women with early cervical cancer (smaller than 2 cm and without lymph node lesions in the cervix).

Contraindications for vaginal hysterectomy are a very large uterus that can not be vaginally morcellated and non-descent of uterus. In these cases laparoscopy, in combination with vaginal hysterectomy, can be performed. Abdominal hysterectomy has become less important and is mainly performed for cancer cases. The size of the uterus, multiple adhesions, endometriosis and obstetrical chaos situations can limit the feasibility of laparoscopic hysterectomy. In cases of massive bleeding, abdominal access is still the chosen route. Natural Orifice Surgery, with one instrument panel applied transvaginally, may open new doors for vaginal surgery (NESA Days 2008, Naples).

Hysterectomy for benign indications, irrespective of surgical technique, increases the risk for stress-urinary-incontinence which may occur through damage to nerves, vascular supply or uterine descent.[70] It is also associated with an increased risk for subsequent pelvic organ prolapse leading to enterocele prolapse.[71]

Future Aspects

Considering how long Homo sapiens has inhabited the planet earth, the history of hysterectomy is a short one. This surgical technique began with a high mortality rate and a high morbidity rate, but with technological advances in the 20th and 21st century, particularly after antisepsis and antibiotic prophylaxis eradicated infections and safe anaesthesia and infusion therapy decreased the high mortality rates, the procedure has now become very safe with a mortality rate of approximately 12 per 10,000.[72] Hysterectomy, with a few exceptions (cancer cases), is increasingly performed to improve quality of life, rather than to save life.

It is difficult to foresee the future, but almost certainly other alternatives to hysterectomy will continue to evolve. For example, a better understanding of endometriosis has already produced a new therapy basis for this disease. The development of a HPV vaccine, early cervical cancer detection and the effective recognition of endometrium carcinoma also influence therapy. No surgical alternative for ovarian cancer has so far been found and hysterectomy, in addition to lymphadenectomy and omentum resection, prevails. These techniques, however, can be performed laparoscopically.[32,73]

Conclusion

In the 21st century, abdominal hysterectomy as a surgical intervention for benign indications belongs in the past. With appropriate indications and modern morcellation techniques, even large uteri up to 1 kg and more can be surgically removed with laparoscopic assistance transvaginally or totally laparoscopically. Vaginal hysterectomy is still the favoured route. It should only not be used if symptoms of the patient, the expected morbidity or the inexperience of the surgeon with the vaginal technique demand laparoscopic assistance.

Malignant disease of the vagina, cervix, uterus, tubes or ovaries is the primary indication for abdominal hysterectomy as centres which are able to perform laparoscopic and robotic-assisted laparoscopic techniques for malignant disease are still rare. The further development of laparoscopic vaginal surgery in oncology, as developed by Dargent, remains a challenge for the endoscopic surgeon in the 21st century.

Alternative techniques to hysterectomy, such as endometrium ablation, have emerged and should always be considered before a hysterectomy is performed. For benign indications with an intact cervix, no endometriosis and no previous cervical surgery, laparoscopic subtotal hysterectomy leaving the cervix in place (LASH, CISH) provides a minimally invasive alternative to all other methods of total hysterectomy in benign conditions. However, if the patient cannot have regular controls postoperatively, laparoscopic total hysterectomy is preferable as with subtotal hysterectomy regular pap or thin-prep controls are necessary.

Disclosures

The authors report no conflicts of interest.

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