Review

Women's Health

Factors to consider in gynecological surgery

Progress is evident in the whole concept of breast cancer treatment and in the assessment of the sentinel node in different cancers of the female in urogynecology, as well as in minimally invasive surgery. In this review we concentrate on the impact of endoscopic surgery. Minimally invasive surgery has evolved in a relatively short period of time to overtake the centuries old visionary and pioneering groundwork of outstanding colleagues in all surgical disciplines. This overview on the development of gynecological surgery highlights past achievements and describes present challenges of endoscopic surgery. It emphasizes future opportunities and possibilities to foster interdisciplinary collaboration and integrate emerging endoscopic, imaging and stereotactic surgical technologies to improve patient safety, enhance quality of care and advance surgical education.

Keywords: gynecology • hysterectomy • hysteroscopy • laparoscopy • microinvasive surgery

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Background & historical perspective

It has been a challenging journey since Georg Kelling presented the first endoscopic procedure, viewing the stomach of a dog, using Nitze's cystoscope and an air insufflation apparatus, at the Natural Scientists' Meeting in Hamburg, Germany in 1901. Departed innovative thinkers and visionary mentors, such as Raoul Palmer, Hans Frangenheim, Kurt Semm, Daniel Dargent, Patrick Steptoe, Jordan M Phillips, Robert B Hunt, Jochen Lindemann and our general surgical colleague Gerhard Buess, all struggled to introduce less disabling diagnostic and therapeutic technologies into daily clinical use for the betterment of our patients [1].

Considering that progress in medicine is incremental and requires the participation of numerous investigators to evolve, we shall mention just a few colleagues who set the technical basis for endoscopic surgery in general and in our field of gynecology in particular [1]:

- Philipp Bozzini (1773–1809) and the light guide [2]
- Antonin Jean Desormeaux (1815–1894) and his endoscopes [2]
- Georg Kelling (1866–1945) and his air insufflation apparatus [2]
- DC Pantaleoni performed the first hysteroscopy in 1869 [3]
- Max Nitze (1848–1906), an early urological endoscopist who developed cystoscopy [2]
- Heinrich Kalk (1895–1973) and his insufflation apparatus which allowed abdominal biopsies of the liver, etc. [2]
- Raoul Palmer (1904–1985), the European father of endoscopy with the lithotomy position [2]
- Hans Frangenheim (1920–2001) built his first abdominal insufflator in 1959 [2]
- Harold Hopkins (1918–1994) developed the rod lens system of modern endoscopes [2]
- Karl Storz (1911–1996) was responsible for the development of the cold light source in 1960 [2]

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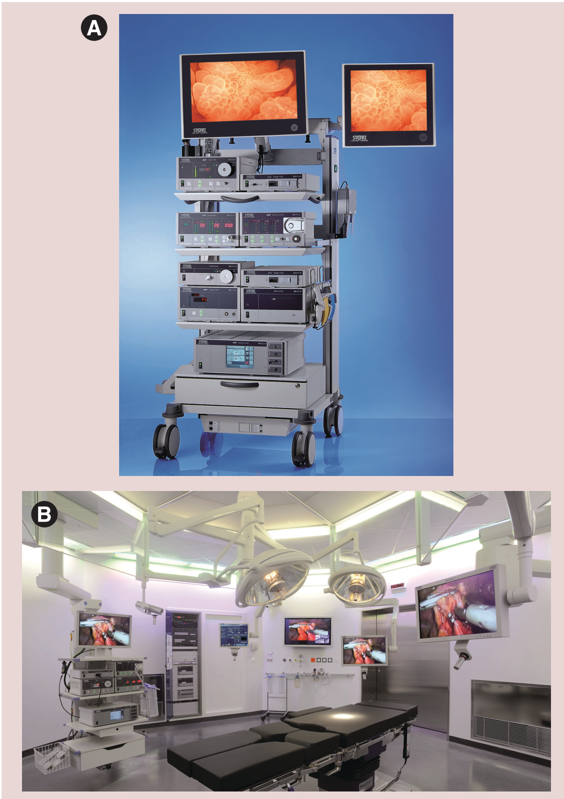

Figure 1. Essential equipment for laparoscopic surgery. **(A)** SMARTCART, **(B)** OR1 NEO with panoramic viewing possibilities.

- Patrick Steptoe performed many laparoscopies in Great Britain and developed the human *in vitro* fertilization (IVF) and embryo transfer (ET) technique together with Robert Edwards
- Hans-Joachim Lindemann (1920–2012) laid the groundwork for hysteroscopy based on the first book on hysteroscopy written by S Duplay and S Clado in 1898
- Jordan M Phillips (1923–2008) was a propagator and 'prophet' for gyne endoscopic worldwide
- Kurt Semm (1923–2003) was the father of operative gynecological endoscopy [4] and operative endoscopic surgery for all disciplines. He performed the first endoscopic appendectomy as a gynecologist in 1981
- Gerhard Buess (1943–2012) was an intensive promoter of minimal invasive new surgical techniques in the field of operative endoscopy worldwide

Evolution of endoscopic surgery

The development of endoscopic surgery began with Philip Bozzini's (died 1809) innovative approach to shed light into the vagina, rectum and oral cavity and was followed by Georg Kelling, who presented the first endoscopic procedure looking into the stomach of a dog in 1901. The rediscovery of endoscopic surgery occurred 150 years later by Hans Frangenheim and Kurt Semm. Hans Frangenheim developed diagnostic laparoscopy from 1960 to 1975 and the worldwide development and popularization of gynecologic endoscopy and endoscopic surgery in all medical disciplines began with Professor Kurt Semm. He became chief of the Department of Obstetrics and Gynecology at the University of Kiel (Kiel, Germany) in 1970.

With the introduction of laparoscopic cholecystectomy by Erich Mühe in 1985 [5] and Philipe Mouret in 1987 [6], the industry realized the importance and potential commercial benefits of this important development and became more interested in endoscopic surgery.

There are many milestones in the chronological development of minimal invasive surgery [7].

It is the aim of this review to primarily provide an overview of the possibilities of gynecologic endoscopic surgery today.

Technical prerequisites (materials & methods)

In cooperation with industry, there has been far-reaching development in technology and instrumentation, which today facilitates the performance of precise surgery [8].

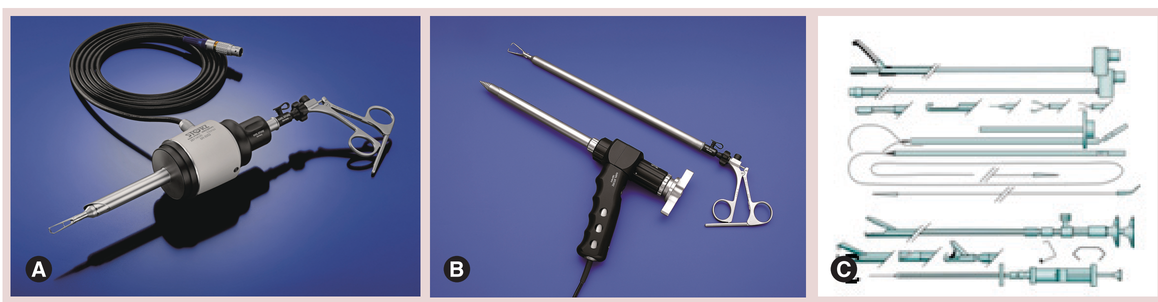

Figure 2. Morcellation and hemostatic instruments. **(A)** ROTOCUT GI morcellation tool, **(B)** SAWALHE II SUPERCUT Morcellator, **(C)** instruments for hemostasis, suture applicator needle holder and staples and ischemia set with applicator, syringe and long injection cannula.

(C) Reprinted with permission from [8,9].

Figure 3. Instruments for uterine manipulation. **(A)** Intrauterine manipulators produced by Karl Storz according to Koninckx, Clermont-Ferrand, Mangeshikar, Hohl, Donnez and Tintara. **(B & C)** LINA Loop at subtotal hysterectomy.
(A) © Karl Storz, Endoskope, Germany.
(B & C) Reproduced with permission from LiNA Medical.

All essential equipment for gynecological and general laparoscopic surgery is assembled on equipment trolleys, which have now been integrated into panoramic operating rooms (Figure 1).

A realistic, true to life 3D picture is now possible owing to various technological elements, such as digital simulation, a second camera system or the use of shutter lens. The ENDOCAMELEON laparoscope provides a viewing angle that can be adjusted continuously between 0° and 120° (Karl Storz GmbH & Co. KG, Tuttlingen, Germany; Figure 2).

Instruments for preparation, dilation, holding and grasping as well as screws and a large variety of cutting and irrigation instruments have been developed.

Morcellation instruments & instruments for hemostasis

The development of morcellation instruments was slow. In ovarian resection and enucleation of myoma, the tissue was cut with scissors and knives, depending on the size, and the specimen was removed using big-toothed forceps directly through the 11 or 15 mm trocar with the conical end. However, today, the so-called motor-driven morcellators in 10, 15 and 20 mm diameters are electrically powered and function well. The tissue is slowly cut electrically, nearly shaved from the surface, and pulled into the trocar sleeve (Figure 2).

Instruments for tying the blood vessels, such as the Roeder loop, the endoligature or the endosutures with extra or intracorporeal knotting, are widely known.

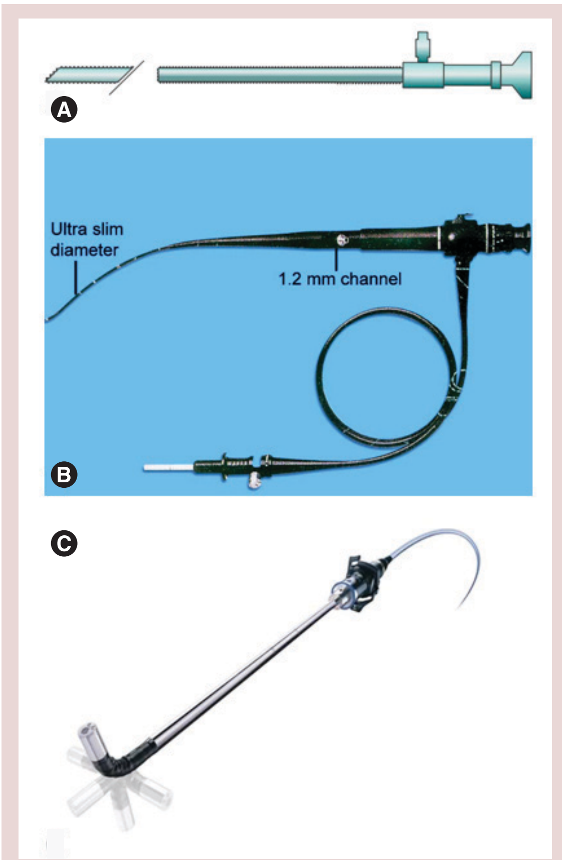

Figure 4. Lenses and endoscopes. **(A)** Rigid standard laparoscope, **(B)** Flexible endoscope, **(C)** EndoEYE video laparoscope (Olympus).
Reprinted with permission from [8].

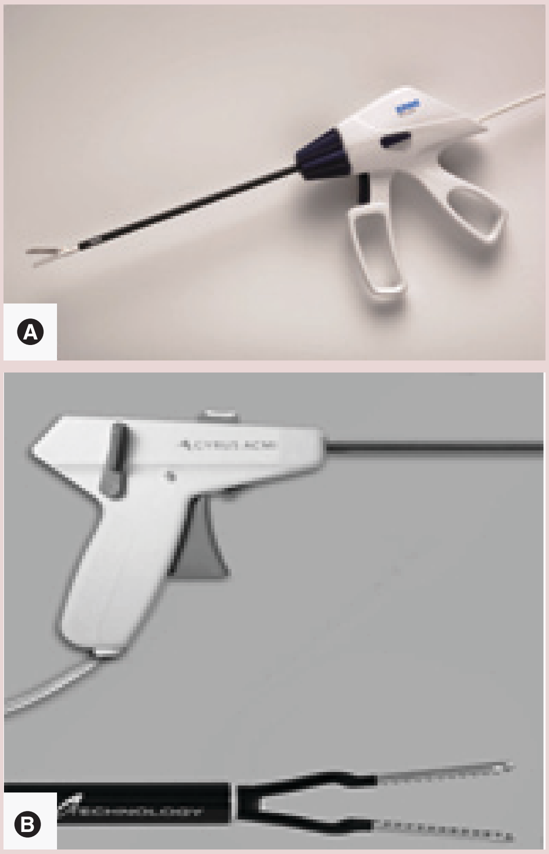

Figure 5. Coagulation and cutting devices. (A) BiCision coagulation and cutting forceps, **(B)** GyrusPK vessel sealing and cutting system.
(A) Reprinted with permission from Erbe.
(B) Reproduced with permission from Olympus.

Needle holders for straight, curved or ski needles are available in different variations.

Gynecologists prefer suturing and coagulation devices. However, clips and stapling devices, which are more frequently employed by general surgeons, are also used.

Instruments for uterine manipulation are depicted in Figure 3. Subtotal hysterectomy, as classic intrafascial supracervical hysterectomy or laparoscopic-assisted supracervical hysterectomy, is facilitated by

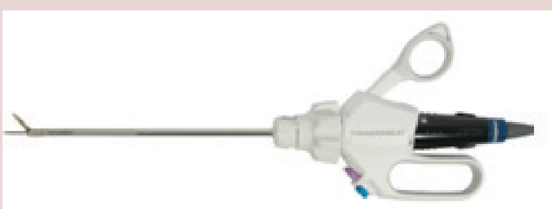

Figure 6. Thunderbeat coagulation and cutting device (Ethicon).
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the use of an electric loop or a monopolar driven hook.

Lenses & endoscopes

Scopes are available in rigid and flexible systems. The rigid system is based on Hopkins's experience with a rod lens system, which results in good resolution and depth of focus ratio. The 30° lens has the advantage of a wide panoramic view (Figure 4).

Energy systems for operative laparoscopy

Electrosurgery & thermofusion

We use monopolar current for cutting and bipolar instruments when coagulation is required before cutting large vessels. The majority of the systems have an auto stop to ensure that only the necessary tissue is denatured. They are not designed for a very large coagulation zone [10].

Bipolar vessel sealing, also described as thermofusion, combined with pressure between the branches of the instruments, is a new, easy to use technique that has been picked up by many companies in the production of disposable instruments with integrated cutting devices (examples in Figure 5).

Laser & harmonic scalpel (ultrasound energy)

Three forms of laser are used in endoscopic surgery: CO_2 laser, Nd:YAG laser and KTP lasers.

Ultrasonically activated laparoscopic instruments use mechanical energy to cut and coagulate tissues. The latest inventions combine thermofusion and ultrasound technology and increase surgical speed and precision, such as the Thunderbeat coagulation and cutting device (Figure 6).

Robotic endoscopic surgery

Among the currently available robotic systems and instruments, the da Vinci robot has proven to be the most advanced surgical system. Other robotic systems, such as the Telelap ALF-X, are not yet used in the treatment of patients.

Figure 7 shows the latest da Vinci surgical console and docking station, and the Endowrist instruments.

The Italian robotic system Telelap ALF-X (Figure 8) incorporates an eye-tracking system, force feedback characteristics, and is managed by one surgeon sitting unsterile at a computer console and an assistant interacting with the robotic arms of the second console, which can be easily moved around the table.

Precision-drive articulating instruments

A new motor-driven, handheld system that offers precision-driven articulating instruments, has recently been introduced on to the medical market in

Figure 7. Surgical instruments. **(A)** The da Vinci Surgical System Si, **(B)** Endowrist instruments.

Europe (Figure 9). The tip articulation is computer-assisted, and allows the surgeon to control the movements through individual yaw and roll controls on the handle's interface. The speed of the movements can be adjusted to suit each individual surgeon's preference.

The r2 DRIVE and the r2 CURVE are handheld instruments that offer all the degrees of freedom of a robotic system for single and multiple entries. Owing to the 90° deflectable and infinite rotatable tip in combination with the infinite rotatable shaft, surgical maneuvers can be confidently and precisely carried out even at difficult angles and in tight spaces.

Single port laparoscopic entry

With the improved technology of today, single port laparoscopic entry takes the idea of the early laparoscopy to new horizons. There are multitude single port laparoscopic entry ports available, such as the ENDOCONE (Figure 10).

Here we only mention the four ports most frequently used in Germany for ovarian cyst resection, adnexectomies, hysterectomies and myomectomies.

Instruments & apparatus for hysteroscopic surgery

The development of hysteroscopic instruments and techniques has been influenced by many factors, such as safety, convenience of use, possible treatment, the invasiveness of the procedure, the extent of anesthesia and hospitalization time.

Hysteroscopy

Clear vision in the cavity depends on a continuous flow of distention media. This was first described in 1956 by Norment [11].

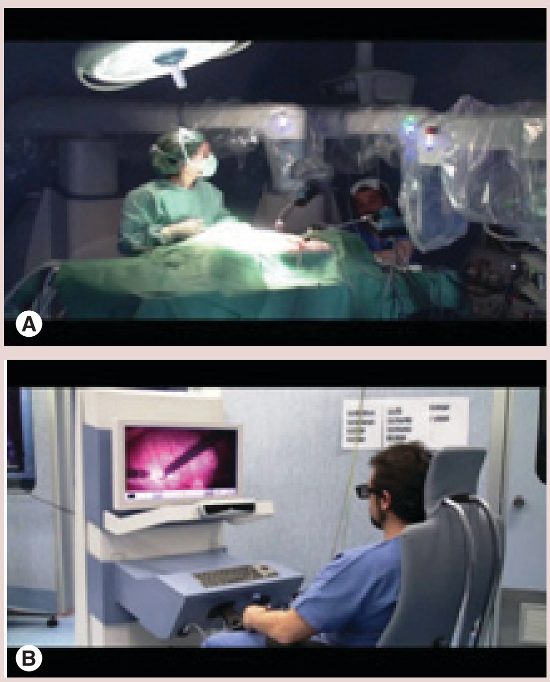

Figure 8. Telelap ALF-X robotic system. **(A)** Telelap ALF-X at the operation table (SOFAR) and **(B)** Telelap ALF-X control unit.
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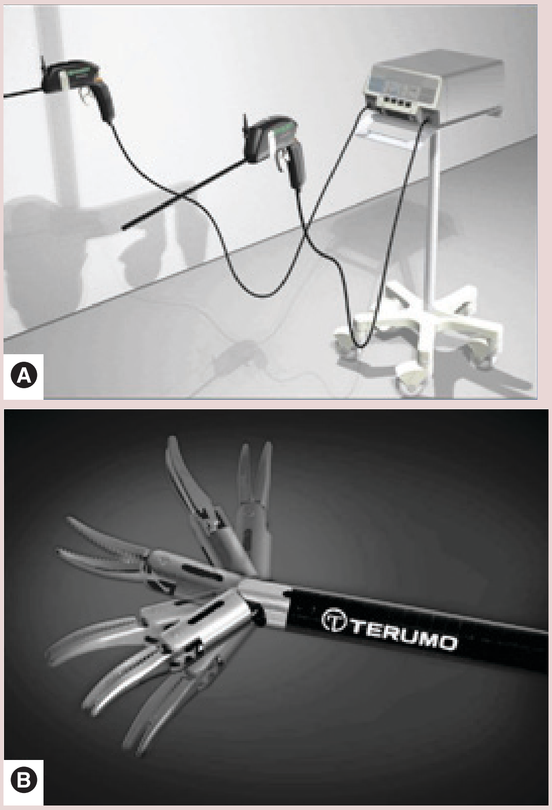

Figure 9. Precision-driven articulating instruments.
(A) Terumo Kymerax System with unit and bilateral articulated instruments, **(B)** possibilities of instrument rotation.
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Figure 10. ENDOCONE.
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Figure 11. EndoSee by Paul Indman.
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Since then changes and developments have taken place in different fields. The most important changes concerning equipment and utensils are described in the following sections.

Distention media

It was necessary to have a strict measurement of the deficit of fluid during resection. Therefore, different hysteroscopic pumps and devices for measuring the deficit were used.

Resectoscope & diathermy

Resectoscopes became more common and consequently so did the need for safer procedures. With the development of bipolar diathermy the whole hysteroscopic sphere changed. The risk of water intoxication disappeared owing to the use of NaCl instead of mannitol, sorbitol or glycine.

For all minimal invasive procedures, especially hysteroscopic procedures, the benefits of the use of natural orifices as entrance points will gain more importance in the future. This, together with new developments in smaller high-definition cameras and monitors, digital wireless transmission and telemedical communication, will make all hysteroscopic procedures easier to perform with less discomfort for the patient (Figure 11).

The big question is, when we discover the ultimate etiology of polyps, fibroids and abnormal uterine bleeding, will treatment be diminished to a pill? At present operative hysteroscopy includes: endometrial biopsy, resection of the endometrial polyp, resection of the submucous myoma, resection of the placenta remnants, lysis of intrauterine adhesions, extraction/management of the foreign body/intrauterine device, resection of the uterine septum (hysteroscopic metroplasty), endometrial ablation and hysteroscopic sterilization [9].

In the meantime, as technology advances, so do the skills of the gynecologists. In the future, IVF may be

Box 1. Organ-orientated catalog for gynecological endoscopic surgeries.

Conservative surgery for the adnexa

- Noninflammatory conditions of the adenexa
  - Ovariolysis
  - Ovarian biopsy
  - Puncture of ovarian cysts/ovarian drilling in cases of polycystic ovarian disease
  - Enucleation of ovarian cysts
  - Fimbriolysis
  - Salpingolysis
  - Fimbrioplasty
  - Salpingostomy
  - End to end anastomosis
  - Removal of Morgagni-Hydatid cyst
    - Pedunculated
    - Retroperitoneal
  - Enucleation of para ovarian cysts
  - Partial ovarian resection
  - Tubal sterilization
- Inflammatory conditions of the adnexa
  - Adnexitis in pyo-ovaries and pyosalpinx
  - Adhesiolysis in 'frozen pelvis'
  - Puncture or incision of an abscess

Radical surgery of the adnexa

- Oophorectomy
- Salpingectomy
  - Partial
  - Total
- Adnexectomy

Surgery in extrauterine pregnancies

- In the fallopian tubes
  - Total = salpingectomy
  - Conserving the tube = salpingotomy
- In the ovary
- In the cervix
- In the abdominal cavity
- Cornual pregnancy
- Biochemical local treatment by laparoscopy or by direct transvaginal injection under ultrasonic control

Endoscopic surgery in endometriosis

- Endoscopically visualized endometriosis can be located
  - On the peritoneum
  - In the region of uterosacral ligaments
  - On the surface of ovaries
  - In the ovaries
  - Inside the uterus
  - In the fallopian tube
  - On the bladder dome
  - On the intestines and in the intestinal wall
  - Retro cervical
- Therapeutically a three-stage treatment is offered
  - Stage 1: diagnosis, first operative cleaning
  - Stage 2: estrogen suppressive hormonal treatment for 3 to 6 months
  - Stage 3: second look pelviscopy with salpingostomy or any other correction as new operative treatment

Surgery for intra-abdominal adhesiolysis

- In upper abdomen
- In mid abdomen
- In lower abdomen

Box 1. Organ-orientated catalog for gynecological endoscopic surgeries (cont.).

Endoscopic surgery for intestinal adhesiolysis
- Intestinal adhesiolysis (parietal peritoneum)
- Intestinal adhesiolysis (visceral peritoneum)
- Lysis of intestinal and omental adhesions and resection

Laparoscopy for diagnosis & treatment of intra-abdominal tumors (cancer)
- As a substitute for exploratory laparotomy, conformation of diagnosis
- Second look pelviscopy
- Aspiration of ascites
- Tumor biopsy
- Debulking of tumor
- Tumor staging
- Lymphadenectomy
- Diagnosis and treatment of well-defined cases of carcinoma of the corpus, cervix of the uterus and ovarian cancer, in cases of radical surgeries such as laparoscopic-assisted radical vaginal hysterectomy by Wertheim and Schauta

Laparoscopic genital suspension operations
- Burch-colposuspension
- Sacrofixation of the vagina
- Correction of entero and rectocele, McCall culdoplasty
- Pectopexy [Noe G, Pers. Comm.]

Other indications
- Appendectomy
- Axillary lymphadenectomy in small carcinoma of breast
- Resection of rudimentary uterine horn
- Incision of lymphocele
- Laparoscopy during pregnancy

performed by hysteroscopic implantation of the conceived ovum and fetoscopic diagnosis and reimplantation of genes into the early foetus may become reality.

Laparoscopic robots will be used in the hysteroscopic field and remote cameras with a GPS transmitter will guide the surgeon. Computerized imaging and 3D modeling of organs will allow doctors to practice the procedures and train their skills.

Catalog of organ-oriented indications for operative laparoscopy/pelviscopy & hysteroscopy in gynecology

A variety of operating indications have been established during the last few decades, including surgery on the uterus and the adnexa for benign and for malignant reasons [9]. Many patients have benefited from the use of laparoscopy, particularly those with extra uterine pregnancies or endometriosis. Today, the field of endometriosis includes intensive cooperation with general surgeons, especially in the treatment of deep infiltrating endometriosis reaching into the bladder and bowels. There are less complications, shorter hospital stays and faster rehabilitation. Laparoscopic interventions are now possible for intestinal adhesiolysis, genital suspension operations, resection of rudimentary uterine horn, incision of lymphocele and during pregnancy. Furthermore, the endoscopic treatment of malignant disorders, including multiorgan procedures such as lymphonodectomies or exenterations, will dominate progress in the coming decades.

The catalog of organ-oriented indications for operative laparoscopy/pelviscopy and hysteroscopy in gynecology (pelviscopy is the already historical name that Kurt Semm used for gynecological laparoscopy) clearly shows what procedures are possible to be performed today (Box 1).

Selected examples

Total laparoscopic hysterectomy in benign indications

The hysterectomy procedure, as laparoscopic subtotal hysterectomy or as total laparoscopic hysterectomy (TLH), in benign tissue proliferations has undergone rapid development over the last 25 years.

The current TLH technique incorporates crucial worldwide developments [12]. The different steps of TLH in a case without adnexectomy are described as follows: the uterine manipulator and the trocars are inserted. Following a 360° view of the operative field, the small intestine is elevated from the small pelvis in order to begin the hysterectomy. The patient remains in a steep Trendelenburg position. The uterus is pushed to the left side and transection of the round ligament begins (Figure 12). This is followed by separation of the tubes.

Alternatively, the main parametrium is dissected in small steps down to the vaginal vault, with the ureters a safe distance away in the pelvic wall. After exposure and preparation of the uterine vessels, they are coagulated and dissected (Figure 12). The same procedure is performed contralaterally.

The key elements, pushing the bladder down from the anterior vaginal fornix prior to incision as well as distancing the ureters from the uterine vessels at cervico/vaginal level, are only safely facilitated by stretching the manipulator firmly cranially and to the contralateral side of the preparation (Figure 13).

The uterus is then separated from the vagina using a monopolar hook electrode, which is guided along the ceramic rim of the manipulator (Figure 13). The uterus is then extracted through the vagina or positioned in the vagina to prevent loss of intra-abdominal pressure (Figure 14). In cases of large benign uteri, distinguishable myomas can be enucleated or the large uterus cut into several smaller pieces so that the fragmented uterus can be extracted through the vagina. Alternatively, a 10–12 mm electromorcellator dissects the material which is then extracted through the abdominal wall.

After cautious coagulation of the vaginal edge [12], suturing of the vagina can begin. To avoid postoperative necrotic areas of the vaginal stump, coagulation is carried out very cautiously. Remaining slight bleeds are rectified by sutures incorporating the complete vaginal wall. Usually a curved needle and Polydiosanol 2–0 is used for single knot suturing with extracorporeal knots and intracorporeal safety knots [12].

Optionally, both sacrouterine ligaments may be attached to the posterior vaginal wall to prevent vaginal prolapse (McCall culdoplasty; Figure 14) [13,14]. Vaginal cuff dehiscence must be avoided [15].

Examples of hysteroscopic surgical procedures

Preoperatively, the polyp should be verified by saline infusion sonography, whereby the size, shape, origin of the stalk, the uterine cavity, the positioning of the cervix and the corpus can be assessed.

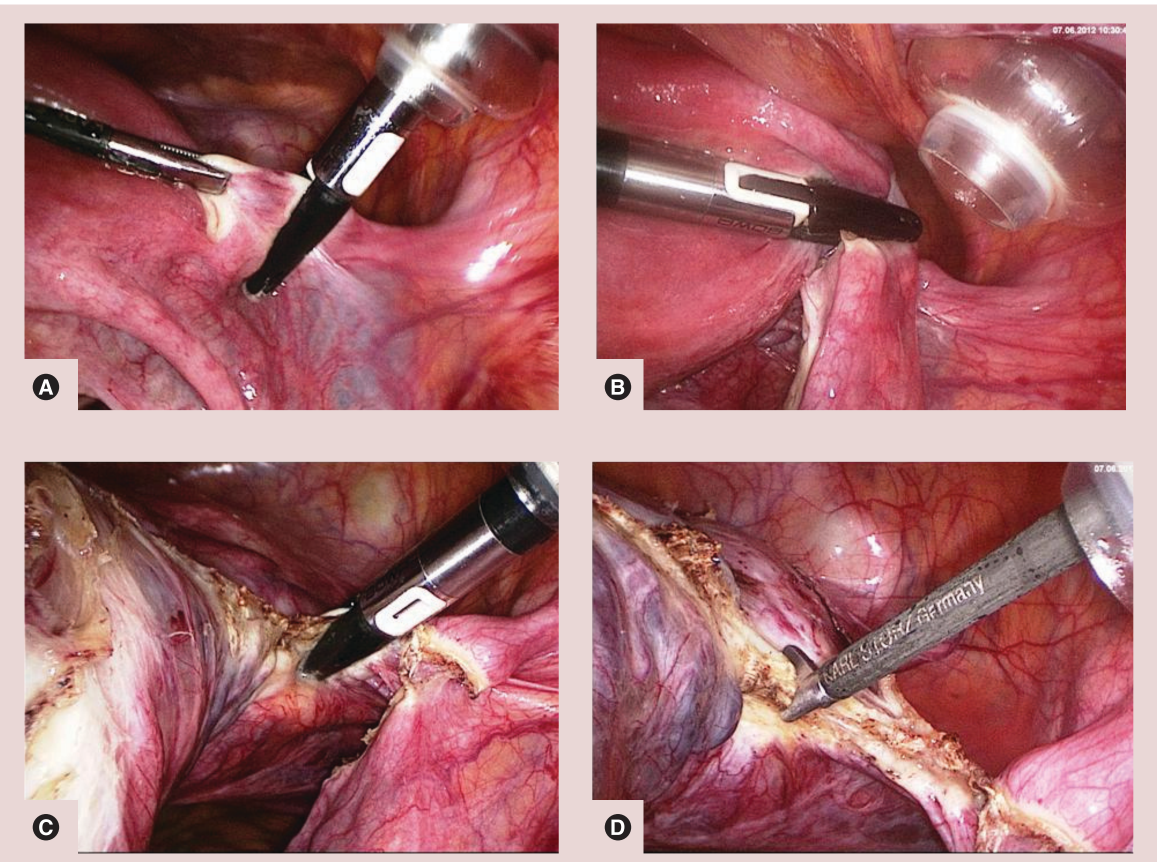

Figure 12. Initial stages of total laparoscopic hysterectomy in benign indications. (A) Separation of the round ligament with NightKNIFE® (BOWA, Gomaringen, Germany). **(B)** Division of the ovarian ligament. **(C)** Preparation of the uterine wall/broad ligament, parallel to the ascending branch of the uterine artery, with safe distance to the ureter (lying in the lateral pelvic wall retroperitoneally). **(D)** Cutting after coagulation of the skeletonized uterine artery.
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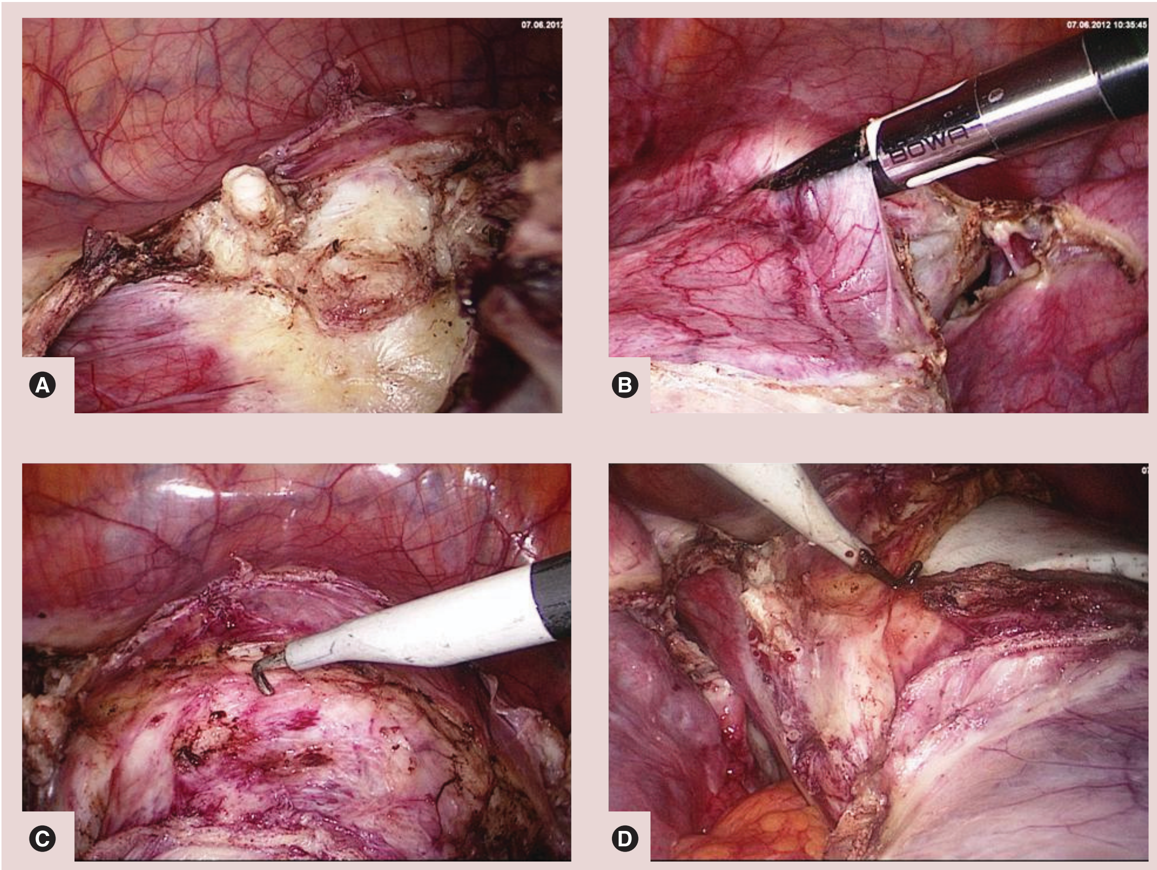

Figure 13. Continuing stages of total laparoscopic hysterectomy in benign indications. **(A)** Demonstration of the prominent vessel stump. **(B)** Opening of the bladder peritoneum. **(C)** Preparation of the bladder peritoneum with the aid of CO_2. Intra-abdominal pressure opens the right preparation layer between the vaginal wall and the bladder pillar. **(D)** Colpotomy with the monopolar hook on the Hohl manipulator.
Reprinted with permission from [1].

The vaginoscopic approach requires no gynecological instruments, such as speculum or depressor, and the use of a tenaculum is not necessary. Entry through the vagina and the cervical canal is performed under sight, and saline is used as the distention media. If the hysteroscopic pump is set to a maximum of 50–80 mmHg, there will be enough pressure to ensure good vision and not cause any pain.

The mini-hysteroscope should be 3.5–5 mm in diameter as this allows entry into the uterine cavity with no struggle or pain.

The polyp should be cut at the base, very close to the endometrium, with scissors, a polyp snare, twizzle or just grasped with forceps (Figure 15). Operative hysteroscopy includes myomectomy, polypectomy, septum resection and adhesiolysis [16].

Gynecological malignancies & endoscopic treatment

The first radical hysterectomy was performed by Wertheim in 1898 [18]. Since then radical hysterectomy has evolved into a simpler procedure and the surgical approach has evolved over a period of time into a highly specialized and minimally invasive modality. With technological advances, we now can perform radical hysterectomy with minimally invasive techniques, such as laparoscopy and robotics.

Here, we describe the 'Pune technique' of radical hysterectomy [19]. This technique has been developed over a period of 6 years in 600 consecutive patients. We have successfully managed to standardize the steps and the port positions.

Laparoscopic radical hysterectomy

Patient position

Patient is placed in modified Lloyd Davis position. A bolster is placed at the level of the anterior superior iliac spine, which causes elevation of the pelvis and results in a drop of the intestines cephalad. A gauze piece is kept in the vagina to prevent loss of pneumoperitoneum after colpotomy.

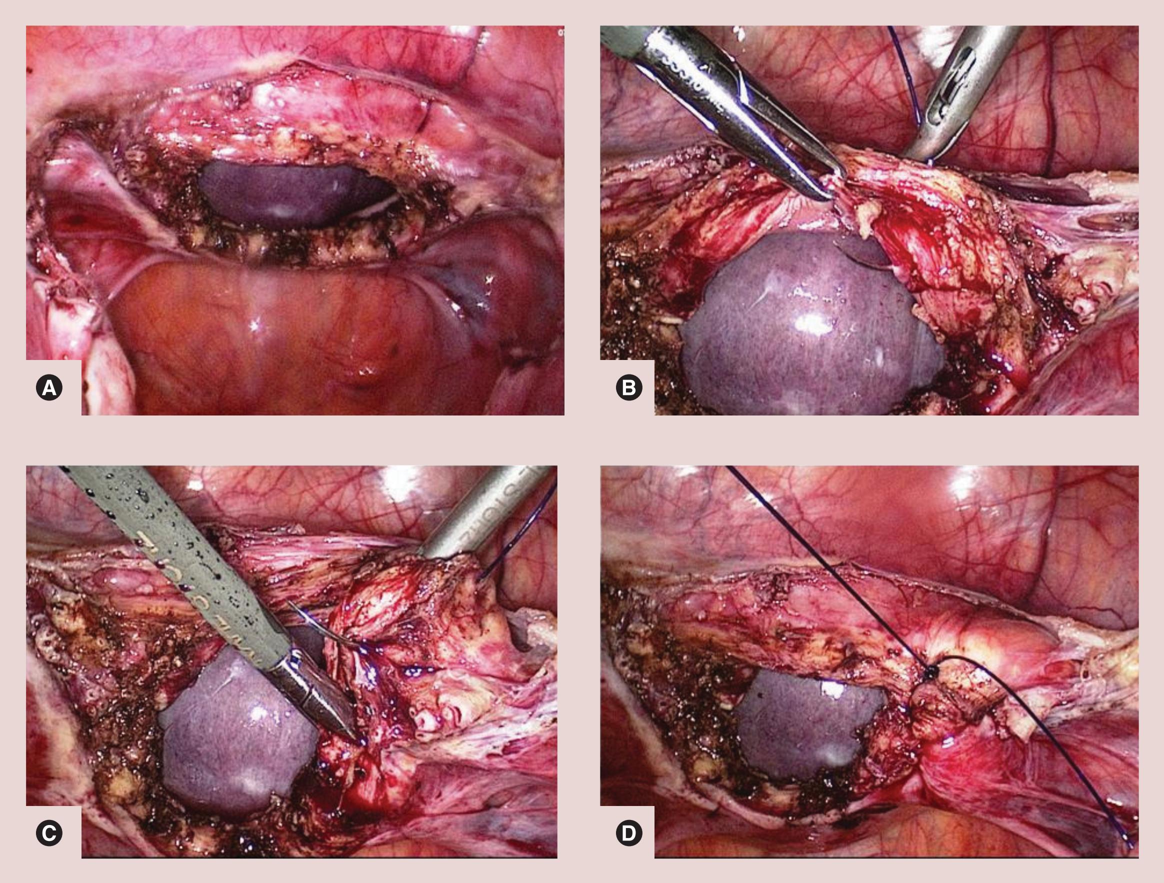

Figure 14. Final stages of total laparoscopic hysterectomy in benign indications. (A) Withdrawal of the uterus and deposition in the vagina. **(B)** First corner stitch on the right. **(C)** Second corner stitch on the right side through the medial part of the cardinal ligament. **(D)** Modified suture by van Herendael.
Reprinted with permission from [1].

Port positions

A total of five ports are used, as seen in Figure 16A:

- A 10 mm camera port at the umbilicus
- A 10 mm working port at the McBurney's point on the right side
- A 5 mm port pararectally on the right side at the midclavicular line at the level of the umbilicus
- A set of two 5 mm ports are inserted as a mirror image on the left side

Procedure

A myoma screw is introduced through the upper left port for uterine manipulation. In cases of pyometra, a tenaculum can be used for uterine retraction. Alternatively, the uterus can be hitched to the anterior abdominal wall.

Step 1: Posterior U-cut

The uterus is anteverted. The right ureter is identified under the peritoneum at the level of the sacral promontory. The peritoneum is excised using harmonic shears to expose the ureter (Figure 16B). This

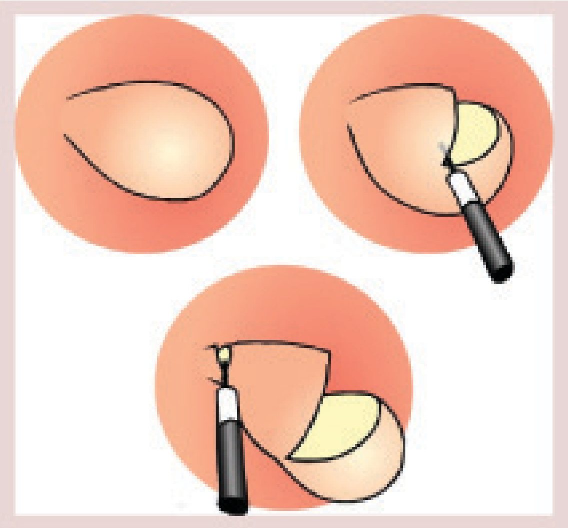

Figure 15. Removal of a larger polyp with the Twizzle electrode.
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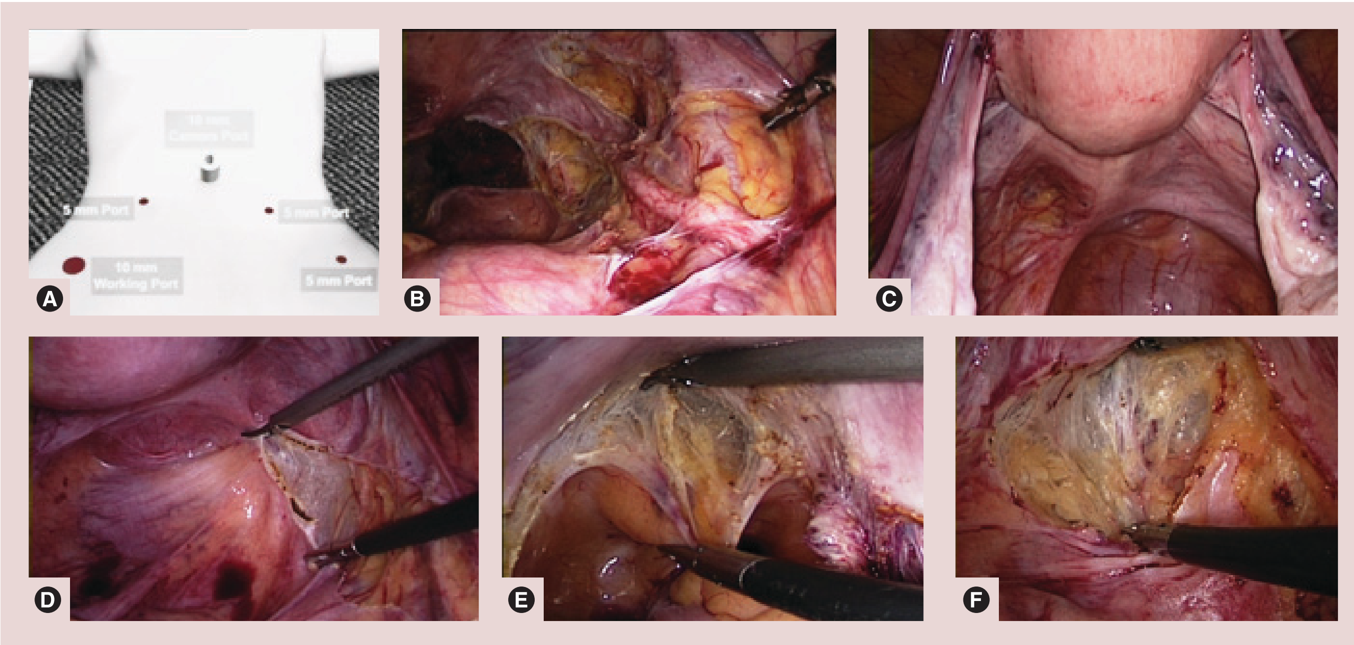

Figure 16. Laparoscopic radical hysterectomy, port positions and beginning steps. (A) Port positions. **(B)** Right ureter crossing the bifurcation of the common iliac at the level of sacral promontary. **(C)** Posterior U-cut. **(D)** Posterior cut extended towards the Pouch of Douglas. **(E)** Dissection in pouch of Douglas. Fat belongs to the rectum. Right plane and wrong plane. **(F)** Dissection in the pouch of Douglas. Two layers of the Denonvillers fascia.
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cut is extended into the pouch of Douglas maintaining the ureters laterally and constantly under vision. The same steps are repeated on the left side and both peritoneal cuts are joined in the pouch of Douglas forming the posterior U-cut (Figure 16C & D).

Step 2: Dissection of rectovaginal space

The peritoneum in the pouch of Douglas is pulled up. The dissection is carried out between the two layers of the fascia (Figure 16E). The plane between the fat and the posterior vaginal wall is dissected, keep-

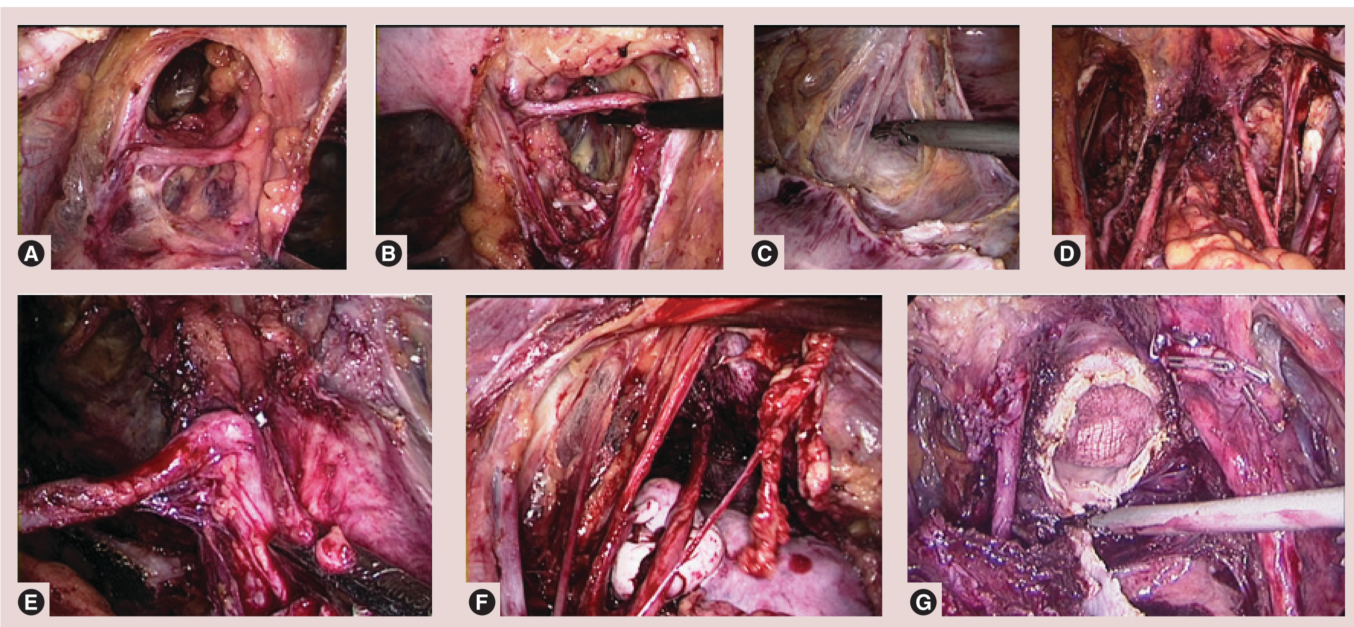

Figure 17. Laparoscopic radical hysterectomy final steps. (A) Left pararectal space in uterine artery and vein. **(B)** Right cardinal ligaments seen as single fan-shaped structure. **(C)** Anterior U-cut. Dissection up to the bladder pillar. **(D)** Road map after completion of dissection. **(E)** Left ureteric tunnel dissection. **(F)** Completed left ilio obturator lymph node dissection. **(G)** Completed colpotomy.
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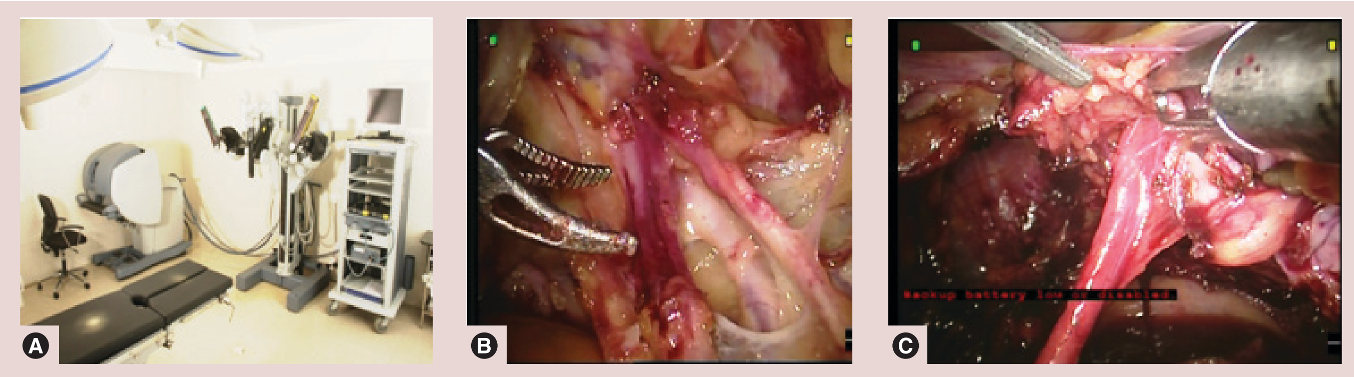

Figure 18. Robotic radical hysterectomy. **(A)** Robotic set-up, **(B)** right pararectal space, **(C)** left uretric tunnel dissection. Reprinted with permission from [1].

ing in mind the dictum "fat belongs to the rectum" (Figure 16F).

Step 3: Dissection of pararectal space

The left ureter is retracted medially and the posterior leaf of the broad ligament above the ureter is cut. The cut is extended downwards towards the bladder. The ureter forms the medial boundary of the pararectal space and the internal iliac artery forms the lateral boundary (Figure 17A). Both the artery and the vein are individually clipped or ligated and then cut. The ureter is retracted medially to expose the uteroscaral and Mackenrodt's ligaments, which are seen as a single fan-shaped structure (Figure 17B). The same steps are repeated on the right side.

Step 4: anterior U-cut

The peritoneum over the uterovesical fold is cut using the harmonic shears, starting from the round ligament on one side to the other, forming the anterior U-cut. The fascial plane between the bladder and the uterus is developed keeping in mind the dictum "fat belongs to bladder" (Figure 17C).

Step 5: dissection of ureteric tunnel

The uterus is pulled to the right and the left ureter is traced along its entire course towards the bladder. The bladder peritoneum is held and the bladder is retracted upwards. The ureter can be viewed as it enters the bladder at the uterovesical junction (Figure 17E). The bladder is pushed further down to achieve a good vaginal cuff, below the growth. Colpotomy is done above the trigonal level with the help of harmonic shears (Figure 17G). The infundibulopelvic ligaments are then cut and the entire specimen is separated and placed in an endo-bag.

Step 6: lymph node dissection

The lymph node dissection is started at the bifurcation of the common iliac artery. The dissection is done with the help of suction cannula as it is relatively atraumatic. The medial limit is formed by the internal iliac artery and the lower limit is the obturator nerve (Figure 17F). Similar dissection is done on both the sides. The entire nodal tissue obtained is put into the endo-bag.

After completion of the dissection, the final picture of the pelvis is shown in Figure 17D.

Robotic radical hysterectomy

As the modality of minimal access surgery in gynecological oncology is becoming increasingly popular, new technologies are emerging. Robotic surgery for cervical cancer is one such landmark that has changed the whole outlook of minimal access surgery. It overcomes the difficulties and the restriction of laparoscopic surgery while providing the benefit of open surgeries. Despite the fact that there are a few drawbacks, including limited range of motion intra-abdominally (only 4° of freedom), loss of tactile feedback, large bulky robotic arms, limited variety of instrumentation and cost, due to the 3D view, dexterity of instruments and more rapid learning, even without any prior experience in laparoscopy, many surgeons are quickly learning this minimally invasive technique. Robotic radical hysterectomy with the use of the 3-arm Da Vinci robot system (intuitive surgical; Figure 18A), applying the same Pune technique used for laparoscopic radical hysterectomy, is described in the following section.

Indications, contraindications and preoperative preparation of the patient remain the same as for laparoscopic radical hysterectomy.

Port positions

It is important to correctly place the trocars for the robotic arms as first planning at the beginning of the surgery:

- A 12-mm camera port is placed just above the umbilicus

- An 8-mm robotic port on the left side is placed 15 cm lateral and 10 cm caudal to the camera port
- The right-sided robotic port is a mirror image of the left robotic port
- Two assistant 10-mm ports are placed pararectally at the level of the camera port

Procedure

The robotic cart is docked in between the legs. In the case of cervical cancer, a myoma screw is used for uterine manipulation via the left upper assistant port, alternatively, a tenaculum can be used. Bipolar instruments and scissors are used. The steps remain the same as in the Pune technique (Figure 18B & C).

Laparoscopic anterior and posterior exenteration, in cases of advanced cervical cancer with involvement of bladder or rectum, is a morbid and extensive surgery that can be performed with good success today.

Complications & specific considerations

Although minimally invasive endoscopic surgery was generally pioneered and popularized by gynecologists over the last few decades, teaching institutions do not inspire and invest in endoscopic education and research with the same enthusiasm and dedication as our general surgical and other colleagues. How gynecologists embrace and tame this inevitable technosurgical metamorphosis and keep it in context of improved patient care will inevitably define our discipline for the foreseeable future.

Whereas before we trained and practiced in isolation, now a more integrated, interdisciplinary cooperative approach is extremely important. A contemporary endoscopic technology-dependent team requires

Executive summary

Historical perspective

- Minimally invasive surgery has evolved since the first endoscopy ever performed by Georg Kelling in 1901 from air insufflation to CO_2 insufflation with the development of multiple technical procedures including robotic surgery of today to an advanced surgical skill.

Technology of minimally invasive surgery

- Endoscopic surgery has certainly gained ground and promises to be practiced in gynecology. However, it is conceivable that in the near future, preoperative early recognition of pathological conditions with contemporary imaging technologies – the merger of imaging and endoscopy has already occurred – and better molecular-genetic recognition of disease – the human genome has already been described – will make extensive radical surgical procedures unnecessary.
- We are already experiencing the next generation of genetics and metabolomics. These fields will render extensive surgeries unnecessary in the future and we will rely on only minimal invasive surgery, which requires three fundamental components that are discussed below.
  - Skilled surgeon
    - Instruments and apparatus are the key features that enable a skilled surgeon to perform optimal, precise and indicated surgical procedures with minimal inflammation, adhesions and complications.
  - Exchange of knowledge
    - Owing to the ready exchange of knowledge between military institutions, aviation, space technology, informatics, engineering, mathematics, biology, genetics and medicine as well as human dedication to disease exploration, technological advancements are no longer bound in one field.
  - Technical developments
    - Practical advances with improved endoscopic instruments and suturing skills allow us endless choices and possibilities.
    - Precise, endoscopic, robotic surgery will be the only surgical tool in 2050. Bloodless surgery with articulated and robotic instruments with multiple degrees of liberty and precision coagulation will be possible. Computer-assisted instruments tips will allow the surgeon to position the angles to the desired tissue planes and give tactile feedback.
    - International gynecological endoscopic organizations, such as the Advancing Minimally Invasive Gynecology Worldwide (AAGL), Asian-Pacific Association for Gynecologic Endoscopy (APAGE) and European Society for Gynecological Endoscopy (ESGE), are opening up new horizons in our specialty. International Society for Medical Innovation and Technology (ISMIT) and Society for Laparoendoscopic Surgeons (SLS) have taken over the international field.

Selected examples

- Total, subtotal and radical hysterectomy is stepwise explained as example for all technical new procedures in the field of endoscopic gynecological surgery.

the assistance of several professionals, integrating horizontally to deliver optimal quality care.

This is indeed the dawn of endoscopic innovation and it is clear that we have to be prepared to mentor students to evolve and innovate in sync. We have to attune our teaching capabilities to prepare not only present clinicians, but also future gynecologic endoscopists [20].

We have to remain mindful that all medical advances need to remain patient-centered and intent on improving societal health. While we implement newer health methods and innovative surgical remedies, we have to maintain our commitment to clinical governance by evaluating practice patterns and adherence to clinical practice guidelines.

Consequently, teachers must remain committed to patient safety, quality health delivery and accountability. Dynamic, comprehensive and interdisciplinary risk management programs are intent on raising awareness across the endoscopy team to combat complacency and reinforce the overriding national unqualified dedication to quality health while supporting minimally invasive surgical endoscopic remedies. Complications such as vessel, bowel, ureter or bladder lesions have to be discussed preoperatively and our patients must know that they occur. Today they are shared and critically analyzed in our medical conversations.

Better health delivery will require attention to client needs and patient safety, and will necessitate practicing fiscally responsible care and ensuring accessible medicine. It will entail staying patient-centered and accountable, and will necessitate endoscopists to remain patient advocates.

In fact, evolving gynecologic endoscopy will bring many more new surgical technologies that the surgeon will have to learn; however, our commitment to patient well-being and safety remains.

Conclusion & future perspective: what are the goals of good surgery?

The future goals of good surgery are identical whether we perform laparotomy, laparoscopy or endoscopic procedures; regardless of the angle, location or means of access:

- Recognition of relevant pathology
- Possibility of radical treatment in endometriosis and cancer
- Minimal trauma, bleeding and tissue laceration
- Adhesion prevention
- Preservation of urogenital tract in women of reproductive age
- Utilization of the best instruments (with as many degrees of liberty as possible, robotic transmission, among others)

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References

1 Mettler L, Clevin L, Ternamian A, Puntambekar S, Schollmeyer T, Alkatout I. The past, present and future of minimally invasive endoscopy in gynecology: a review and speculative outlook. *Minim. Invasive Ther. Allied Technol.* 22(4), 210–226 (2013).

2 Schollmeyer M, Schollmeyer T. [Georg Kelling and the Saxonian rootes of laparoscopy]. . Verein Oschatzer Frauenärzte e.V., Siebenlehn, Germany (2001).

3 Pantaleoni D. On endoscopic examination of the cavity of the womb. *Med. Press Circ.* III, 582 (1869).

4 Jonat W, Andree C, Schollmeyer T. [Department of Obstetrics & Gynecology, Kiel and Michaelis-Midwifery-School, 1805 – 2005, a medical evaluation study for 200 years of existence]. Georg Thieme Verlag, Stuttgart, Germany (2005).

5 Reynolds W Jr. The first laparoscopic cholecystectomy. *JSLS* 5(1), 89–94 (2001).

6 Mouret P. From the first laparoscopic cholecystectomy to the frontiers of laparoscopic surgery: the future prospectives. *Dig. Surg.* 8, 124–131 (1991).

7 Mettler L. From air insufflation to robotic endoscopic surgery: a rocky road. *J. Minim. Invasive Gynecol.* 18(3), 275–283 (2011).

8 Mettler L. Instruments and Equipment for Laparoscopic Surgery. In: *Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery.* Schollmeyer T, Mettler L, Rüther D, Alkatout I (Eds). Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2013).

9 Mettler L. Manual for Laparoscopic and Hysteroscopic Gynecological Surgery. Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2006).

10 Alkatout I, Schollmeyer T, Hawaldar NA, Sharma N, Mettler L. Principles and safety measures of electrosurgery in laparoscopy. *JSLS* 16(1), 130–139 (2012).

11 Norment WB. The hysteroscope. *Am. J. Obstet. Gynecol.* 71(2), 426–432 (1956).

12 Schollmeyer T, Elessawy M. Total Laparoscopic Hysterectomy. In: *Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery.* Schollmeyer T, Mettler L, Rüther D, Alkatout I (Eds). Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2013).

13 Thompson JD, Warshaw J. Hysterectomy. In: *Te Linde's Operative Gynecology (9th Edition).* Rock JA, Thompson JD (Eds). Lippincott Raven, Philadelphia, PA and New York, NY, USA 771–854 (1996).

14 van Herendael B. Strategies to prevent vaginal vault descent during hysterectomy. In: *Manual of New Hysterectomy Techniques*. Mettler L (Ed). Jaypee Brothers Medical Publishers Ltd, New Delhi, India, 82–85 (2007).

15 Hur HC, Guido RS, Mansuria SM, Hacker MR, Sanfilippo JS, Lee TT. Incidence and patient characteristics of vaginal cuff dehiscence after different modes of hysterectomies. *J. Minim. Invasive Gynecol.* 14(3), 311–317 (2007).

16 Römer T. *Operative Hysteroscopy.* De Gruyter, Berlin, Germany (2011).

17 Clevin L. Diagnostic hysteroscopy and office hysteroscopy. In: *Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery*. Schollmeyer T, Mettler L, Rüther D, Alkatout I (Eds). Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2013).

18 Wertheim E. [The extended abdominal operation in a cervical uterine cancer]. Urban & Schwarzenberg, Berlin, Germany (1911).

19 Desai R, Galagali A, Puntambekar S, Agarwal G, Puntambekar S. Oncologic Surgery on the Uterus. In: *Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery.* Schollmeyer T, Mettler L, Rüther D, Alkatout I (Eds). Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2013).

20 Ternamian A. Risk Management in Gynecological Endoscopy. In:*Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery.* Schollmeyer T, Mettler L, Rüther D, Alkatout I (Eds). Jaypee Brothers Medical Publishers Ltd, New Delhi, India (2013).