Basics on Laparoscopic Instrumentation and Apparatuses

Liselotte Mettler
University of Kiel

In the early years of gynaecological endoscopy there were only 5-10 industrial companies worldwide producing instruments and equipment for laparoscopic surgery. Today, there are over 200 companies offering equipment for laparoscopic surgery. Here, we report on the products of some reliable industrial partners whose products we use or are known to us without any claim to the completeness of the content.

All essential equipment for gynaecological and general laparoscopic surgery is assembled on an equipment trolley (Fig. 1).

Figure 1 :
SMARTCART: Equipment cart for gynaecologic endoscopic surgery (laparoscopy and hysteroscopy) with electrosurgical unit, CO_2 pneuautomatic with heated gas, light source and HDTV monitor (Karl Storz 3D System)as well as control unit for hysteroscopic surgery (Karl Storz)

For efficient endoscopic work it is necessary to ensure that the surgeon can check the equipment and settings at a glance. Newer, improved, user-friendly developments are the touch sensitive panels that are directly operated by the surgeon and the voice-controlled units. Industry is continually developing new technologies to meet surgical requirements.

The first voice-controlled camera-holding arm, AESOP (Automated Endoscopic System for Optimal Positioning)[1], has long been replaced by smaller voice-controlled compact motorized endoscope holders, such as the ViKY® EP Endo Control System (Endocontrol Inc, Dover, USA). More complex robot systems have gained ground mainly in oncologic surgery.

The da Vinci system of Intuitive Surgical, Inc. (Sunnyvale, CA, USA) has undergone a remarkable development during the last ten years enabling a surgeon sitting at a console, a few feet from the patient, to perform delicate and complex operations through a few tiny incisions with increased vision, precision, dexterity and control.

The da Vinci Surgical System consists of several key components, including: an ergonomically designed console where the surgeon sits while operating, a patient-side cart where the patient lies during surgery, four interactive robotic arms, a high-definition 3D vision system, and proprietary EndoWrist® instruments. The robot does not replace the surgeon but robotic-assisted surgery is seen as a possible method of overcoming the technical challenges of conventional laparoscopy. Another telesurgical system is the Telelap ALF-X (Sofar S.p.A., Milan, Italy).

Routine endoscopy trolleys with the units of the late twentieth century have been replaced by panoramic operating room (OR) endoscopic settings, such as the OR1™NEO (Karl Storz GmbH & Co. KG, Tuttlingen, Germany)(Fig. 2).

Figure 2:
OR1™NEO (Karl Storz) with panoramic viewing possibilities, integrated commanding functions for all operative procedures and documentation

The newly designed OR1™NEO allows all surgical and technical functions to be controlled and monitored from the user interface within the sterile area. The trolley includes all necessary apparatuses to be selected and controlled by the surgeon: endoscopic camera, light sources, insufflators, suction and irrigation pumps, electrical energy systems, AIDA compact NEO documentation systems and OR1™ AV system NEO solutions. AIDA compact NEO uses the highest digital resolution specified for HD of 1920 x 1080 pixels, equal to 5 times the image information available from today's PAL standard. A new, nearly 3D panoramic view monitor combines the depth of focus with enhanced colour brilliance for improved ergonomic viewing. These systems are compatible with third party devices, such as OR lights, energy units (e.g. Erbotom), lasers and modern thermofusion systems.

Other panoramic OR systems are the ENDOALPHA or Visera-Elite of Olympus with the Endo Eye, a fascinating camera system with the camera at the tip of the scope without heat production and the STRIKER unit with the digital documentation system SDC Ultra.

The idea of warming and humidifying the CO_2 gas to avoid damage to the peritoneum has been propagated by Douglas Ott and Philippe Koninckx. The HumiGard™ of Fisher & Paykel Healthcare (Auckland, New Zealand) provides heated, humidified and filtered gas to a patient at a predetermined temperature. Today every CO_2 pneuautomatic provides up to 37°C heated CO_2 gas which is controlled by a pressure regulator and within the machine by applying the Quadro-test. In the Quadro-test the volume of gas flowing through the Veress needle during insufflation, intra-abdominal pressure, total volume and preset filling pressure are measured. Cold light is provided by Xenon lamps. The video camera systems are equipped with three-chip camera or HD-cameras and can be used for laparoscopy as well as hysteroscopy.

High-resolution video monitors guarantee optimal picture quality. The technological development allows the use of larger monitors in HD quality that facilitate a relaxed working atmosphere for the surgeon.

A realistic, true to life three-dimensional picture is possible due to various technological elements such as digital simulation, a second camera system or the use of shutter lens. Digital devices for the video camera control the picture quality and facilitate automatic white balancing. The Karl Storz company already offers the TRICAM 3D imaging system that allows the surgeon to view crisp,clear images through a pair of lightweight polarizing glasses. The ENDOCAMELEON® laparoscope provides a viewing angle that can be adjusted continuously between0° and 120° (Fig. 3).

Figure 3:
ENDOCAMELEON® laparoscope (Karl Storz)

Various techniques permit safe cutting as well as coagulation. The earlier thermocoagulator entirely avoided the flux of current through the target tissue and made haemostasis safe by heating it up to 100-120^{0}C [2]. Today, modern electronic high frequency systems with mono- and bipolar currents are widely used. The equipment for other techniques, such as the argon beamer, laser and ultrasonic cutting equipment, is put on an ancillary trolley. Efficient suction irrigation apparatuses remove body fluids as well as abdominal lavage with a warm irrigation solution and are standard equipment for laparoscopy as well as laparotomy.

The universal perturbation apparatus is used for the CO_2 insufflation of the fallopian tubes in gynaecology. A cervical adapter can be simultaneously inserted for intraoperative manipulation as well as for hydro and chromopertubation. The hysteroflater facilitates gas or fluid hysteroscopy with control of both inflow and outflow.

Video recorder, photo printers and especially equipped computers are used for documentation. The combination of highly modern charged coupled device (CCD) cameras and full HD technology capture and document the surgical procedures.

Depending on habit and use, the majority of the equipment is placed either near the head or foot end of the patient vis-a-vis the surgeon. The use of a flexible instrument rack extending from the drapes, which can likewise hold the monitors, is very practical. A voice-controlled camera holder facilitates a fatigue-free positioning of the camera and thus offers a safe working condition.

Instruments (Basic equipment)

Until 1960 palpation probes were the only endoscopic instruments available. From 1960-1970 the diagnosis and treatment of female infertility and later tubal sterilization were the only procedures performed by gynaecological laparoscopy.

Therefore, atraumatic forceps and scissors for transsection of tubes were the first instruments to be developed for laparoscopy.

From 1970 onwards, the demand for thermal coagulation began. Electrical units were not able to catch aberrant electric currency as is possible today. In 2012 all electro-surgical units - once the different and indifferent electrodes have been correctly applied – recapture aberrant electricity.

Cave*: There has to be total coverage of the indifferent electrode to the skin of the patient.*

Of the multitude of laparoscopic instruments known today, we describe here only a selected few which are absolutely necessary for gynaecological operative laparoscopy and which should be available in duplicate or triplicate on the instrument trolley. Multiple use instruments for cutting, grasping, dissection, pushing, traction, coagulation, irrigation and suction are very helpful.

Instruments for perforation

- The **Veress needle [3]** is blindly introduced into the abdomen after lifting the anterior abdomen wall. Trocars of 3 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 24 mm diameter are used for guiding the endoscopes and operative instruments, irrigation, coagulation and during employment of needle holders and morcellators.
- The simple **automatic flap valves** can leak because of soiling with blood or tissue particles. Therefore they are to be used for single use only. **Trumpet valves** are stable, but must be always opened and closed. They hinder the introduction of needles and thread.
- **Endoscopic lenses** must be frequently washed and removed because of soiling during the operation. Therefore, for such trocars we reluctantly use automatic valve, but prefer trumpet valve.
- **Primary trocars** can be inserted by the Z-puncture technique to prevent dehiscence of aponeurosis and late prolapse of the omentum. The decision, however, depends on the surgeon. We recommend the conical trocars; but are aware that the pyramidal trocars, especially in the so-

called safety trocars, are employed as optical trocars. They carry the advantage of a sharp cutting edge (Fig. 4).

Figure 4:
Optics, trocars, needle holder and RoBi® instruments – rotating bipolar grasping forceps and scissors (Karl Storz)

- Optiview[R] by Ethicon (Ethicon Endo-Surgery, Cincinnati, USA) , Visiport[R] by Covidien (Mansfield, MA, USA) and XCel by Ethicon (Fig. 5) offer **insertion under vision**. At present, only 10 mm to 11 mm trocars are available through which the 10 mm laparoscope can be passed under direct vision.

Figure 5: Xcel, a disposable, viewing trocar for laparoscopic entry under sight (Ethicon)

- **Optical Veress needles** can be inserted under vision. The insertion under vision can be done below left costal margin also; a suitable trocar can inserted through the umbilicus under vision.
- The linear **expansion trocars** help controlled widening of a narrow canal by serial dilatation.
- The **Endo-Tip.**

Dilatation Instruments

It is possible to dilate up to 10mm, 12mm, 15mm and 20mm through an introduced rod and a suitable 5mm threaded trocar (Fig. 6).

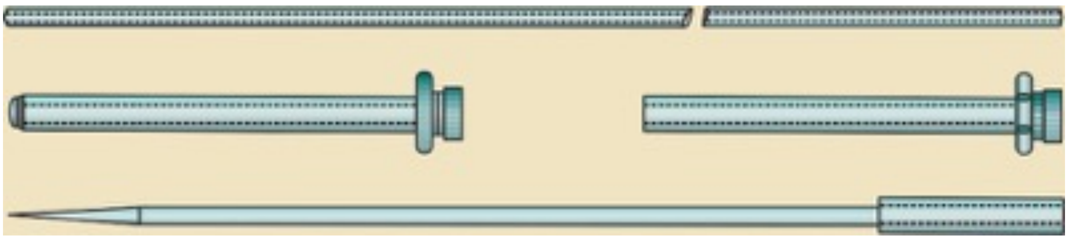


Figure 6: Dilatation instruments:
a) Central introduction rod
b) Dilators
c) Mandrin, when the dilator is introduced as trocar

Holding, Grasping Instruments and Screws

Various types of traumatic and atraumatic forceps are used as endoscopic grasping tools for operations (Fig. 7).

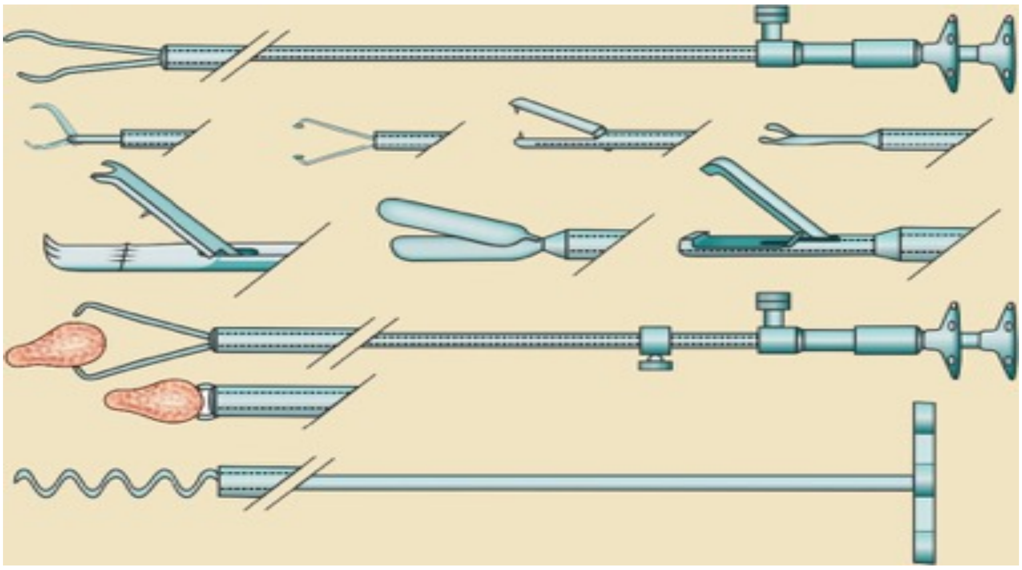


Figure 7: Holding, grasping and drilling instruments:

a) Atraumatic forceps

b) Various tips of forceps (left to right): 2 intestinal forceps, lymph node holding forceps, 2 biopsy forceps, spoon forceps and toothed forceps

c) Swab holder, before holding and with the swab

d) Myoma screw

They are in 5 to 20mm sizes. In 10mm size we recommend the big toothed forceps and lymph node holding forceps to hold the tissues firmly. The 10mm swab holding forceps are suitable for holding tissues lightly and for pushing. The 5mm and 10mm swab holders are used in tissue dissection. The 5 and 10mm myoma screw is used for traction on the myoma. The handles shown in Fig. 7 are round grip handles; however, the handles of the Robi instruments of the Karl Storz company are easier and more ergonomic to use (Fig. 4).

Cutting Instruments

5mm curved scissors and the 5 and 11mm saw-toothed scissors as well as different micro knives with changeable disposable blades are available as doubled-edged models (Fig. 8).

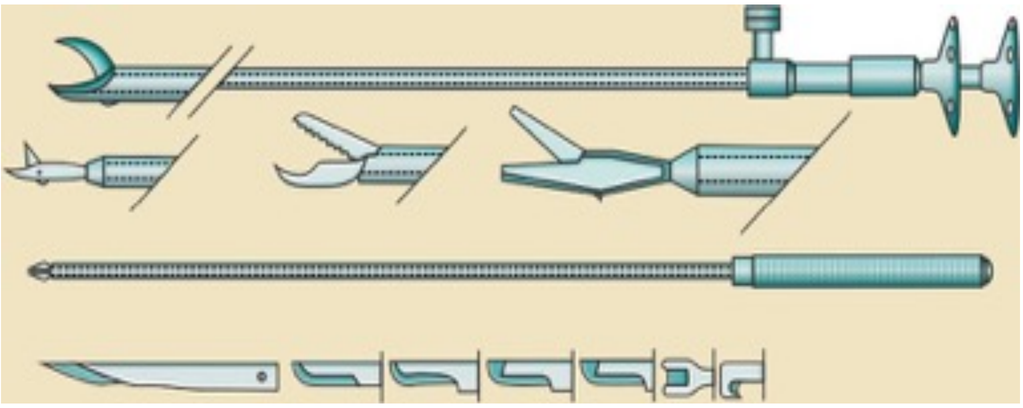


Figure 8: Cutting instruments:
a) Dissection scissors with round handle, as macro and microscissors (with 2 mm span)
b) Scalpel
c) Changeable cutting blades (single use) of the scalpel

Mostly, curved scissors are used, but round scissors with electric connection are frequently employed because of their extreme safety. The latter one is often used as a disposable instrument. Blunt round scissors are especially suitable for retroperitoneal dissection.

Suction and Irrigation Instruments

The suction irrigation devices of Karl Storz and Wisap GmbH (Sauerlach, Germany) are well known. The system of Wisap has 5mm and 10mm suction and irrigation tubes (Fig. 9).

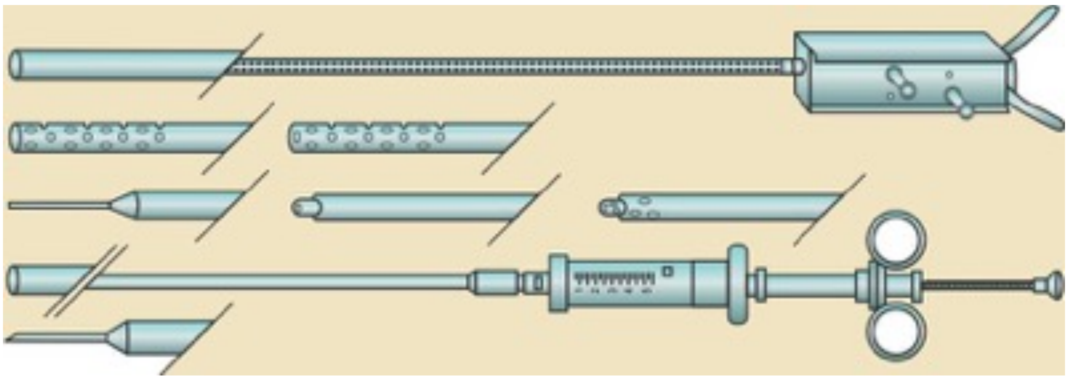


Figure 9: Suction and irrigation instruments:
a) 5 mm suction irrigation cannula with open end
b) 5 mm suction irrigation cannula with perforated end
c) Aspiration cannula for cysts
d) Manual aspiration system for Douglas exudates

The suction cannula is used either with an open tip or with a perforated tip. Large volumes of fluids in ovarian tumors and ascites are aspirated with these suction irrigation cannula (Fig. 10).

Figure 10:Suction irrigation system (R. Wolf, Knittlingen, Germany)

It is set at an irrigation pressure of up to 300mm Hg and an aspiration force of up to 1 bar. The normal suction force is maximum 800 mbar; irrigation pressure is 300mm Hg. With extra-long (50cm) suction irrigation tubes, it is possible to suck even under the dome of diaphragm from the pelvic region. Many disposable systems are also available.

Morcellation Instruments

The development of morcellation instruments was slow. In ovarian resection and enucleation of myoma, the tissue is cut with scissors and knives, depending on the size. The specimen can be removed either with big-toothed forceps directly through the 11mm or 15mm trocar with conical end. However, the so-called motor drive morcellators in 10mm, 15mm and 20mm diameters are electrically powered and function well. The tissue is slowly cut electrically, nearly shaved from the surface, and pulled into the trocar sleeve. It is particularly suitable for horizontal operations as in vertical use a laceration of bowel or vessels can easily occur. Karl Storz produces the Steiner morcellator[R], the Rotocut and a new development, the Sawalhe II Supercut morcellator, all with a tissue protection shield (Figs. 11 & 12).

Figure 11: ROTOCUT GI (Karl Storz), morcellation tool with protective shield, available in 2 sizes (12 and 15 mm)

Figure 12: SAWALHE II SUPERCUT Morcellator (Karl Storz)

Many companies have disposable morcellators. The WISAP electric morcellator was the first on the international market. Alternatively, the surgical specimen from the abdominal cavity is put in an endobag (small plastic bags) with forceps. Morcellation is only advised at present for benign specimens. However, I foresee the transformation of fibroid-like material into powder, which can then be aspirated and examined by the molecular pathologist for malignancy.

Instruments for Hemostasis

Instruments for tying the blood vessels such as the Roeder loop, the endoligature or the endosutures with extra or intracorporeal knotting are widely known (Fig. 13). Needle holders for straight, curved or Ski needles must be available in different variations. Further details are given in a separate chapter on sutures in this manual.

For hemostasis, endocoagulation, [4] heat denaturation at 100-120^{0}C, bipolar coagulation in various forms (see section on energy sources in this chapter) and monopolar needle, melting hook, high frequency scissors or other instruments are suitable. The gentlest methods are endocoagulation at 100^{0}C and bipolar coagulation. For localized ischemia a vasopressin derivative in a dilution of 1 to 100 is injected subcapsular with an applicator. The haemostasis ischemia set shown in Fig. 13 may be used or alternatively the Veress needle can be inserted in a separate abdominal incision to inject the Vasopressin dilution.

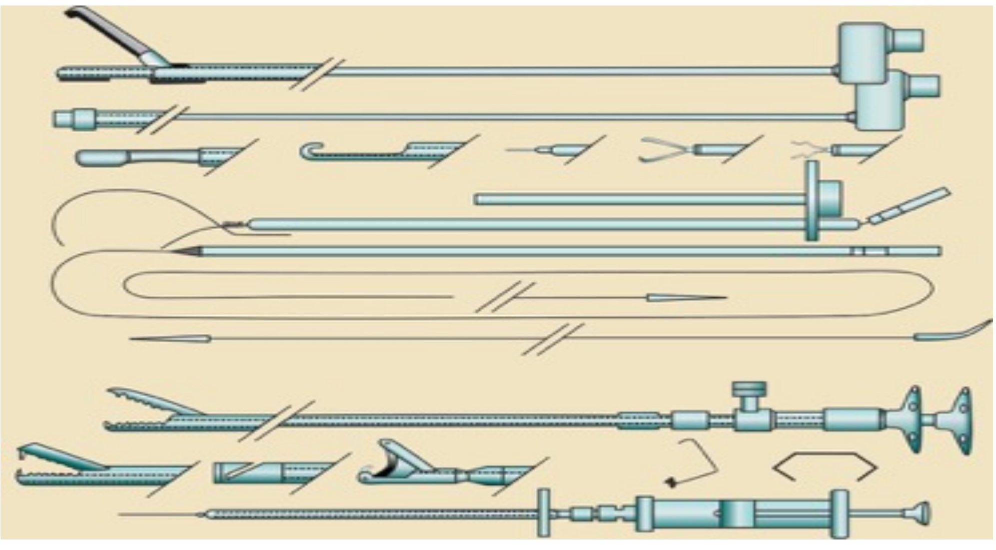


Figure 13: Instruments for hemostasis

Gynaecologists prefer suturing and coagulation devices. However, clips and stapling devices, which are more frequently used by general surgeons, are also used for fixing meshes, for pelvic floor surgery, lymphadenectomy and hysterectomy in our field. Both Ethicon, a Johnson & Johnson company (New Bunswick, NJ, USA), and Covidien have fascinating devices on the market. Let me just mention here Covidien's new Endo Clip Applicator III (5mm) with easily placed clips and a digital clip counter (Fig. 14)

Figure 14: Endo GIA™ Ultra Universal Stapler (Covidien)

and the Endo GIA™ Stapler (Fig. 15 & 16).

Figure 15: Endo GIA™ Reloads with Tri-Staple™ Technology (Covidien)

Figure 16: Endo GIA™ Ultra Universal Stapler (Covidien)

Instruments for Clamping Large Vessels, Emergency Needle

Emergency instruments and the usual clamps used in routine gynaecological operations should not be used for clamping the vessels. Vascular clamps must be readily available (Fig. 17).

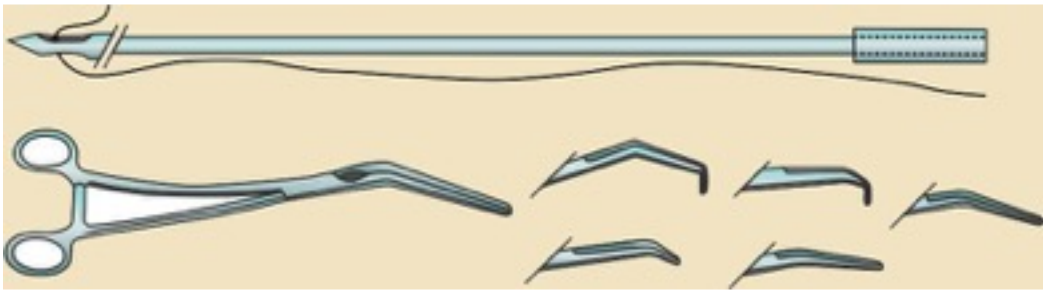


Figure 17: Vascular clamps:
a) Emergency needle
b) Vascular clamps with different tips

Large vessel injury must be immediately explored by laparotomy and the bleeding vessel clamped. If a vessel in the anterior abdominal wall is injured (epigastric artery), it is advisable to ligate it at an appropriate place with a large emergency needle.

Instruments for Drainage

The Robinson drainage is suitable (Fig. 18). for abdominal drainage.

Figure 18: Robinson drainage. The perforated end of the cannula is introduced with a 5 mm trocar and placed in the deepest part of the abdominal cavity. The drainage bottle is fixed to the patient's thigh and collects the drained fluids.

It works on a gravity basis and as a rule can be left in situ over 24 hours. The blind insertion of the secondary trocar is obsolete. Nowadays, the insertion is carried out under vision after making a subumbilical longitudinal skin incision with the knife held parallel to the abdominal wall.

CAVE: ***Fatalities have been reported by accidental slitting of the aorta. Before insertion of the Veress needle, which is always blind, it is advisable to follow the safety measures described in the chapter on Abdominal Access in this book.***

Instruments for Uterine Manipulation

Vacuum intracervical probes in the standard three sizes allow only partial movement of the uterus and facilitate tubal chrompertubation.

Various instruments for intra uterine manipulation make it possible to mobilize the uterus. The uterus can be anteflexed, retroflexed, laterally mobilized and rotated. Some uterine manipulators allow the possibility of chromopertubation. Uterine manipulation is required in endometriosis of the pouch of Douglas, for hysterectomies, in bladder dome endometriosis and for enucleation of myoma. The ACE (Abdominal Cavity Expander) serves to elevate the anterior abdominal wall in cases with adhesions. Further versions of this principle are used in the gasless laparoscopy, e.g. as Laparolift^{R}.

The Hohl, the Mangeshikar and the Donnez intra–uterine manipulators or mobilizers as well as the Konincxk uterine twister are all produced by Karl Storz and have a cup with a well palpable and visible border to visualize the resection level between vagina and cervix for all cases of TLH (Total Laparoscopic Hysterectomy) (Fig. 19).

Figure 19: Intrauterine manipulators produced by Karl Storz according to Koninckx, Clermont-Ferrand, Mangeshikar, Hohl, Donnez and Tintara

This facilitates the intracervical approach of TLH; however, they are not to be used for the extracervical approach and in oncologic cases of hysterectomy. Many companies have disposable manipulators.

Subtotal hysterectomy, as CISH (Classic Intrafascial Supracervical Hysterectomy) or LASH (Laparoscopic Assisted Supracervical Hysterectomy), is facilitated by the use of an electric loop produced by LiNA Medical ApS, Glostrup, Denmark (Fig. 20 & 21) as the LiNA Loop, by Karl Storz as the Storz Loop and by BOWA as the BOWA loop.

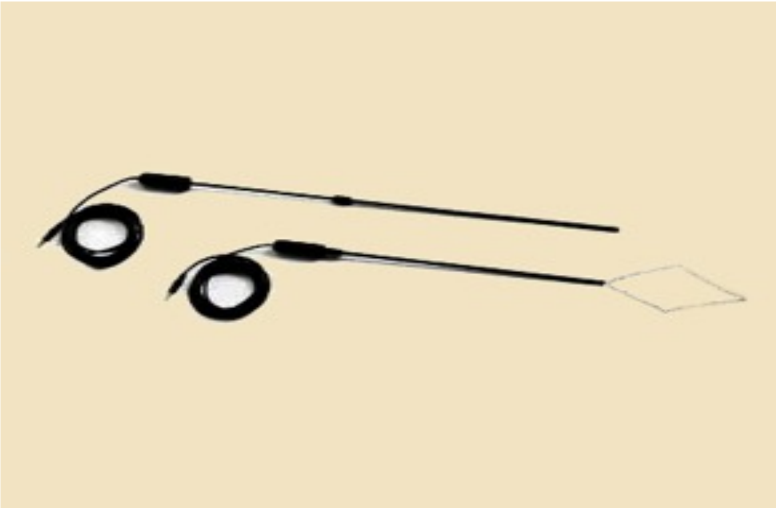


Figure 20: LiNA Loop (LiNA Medical)

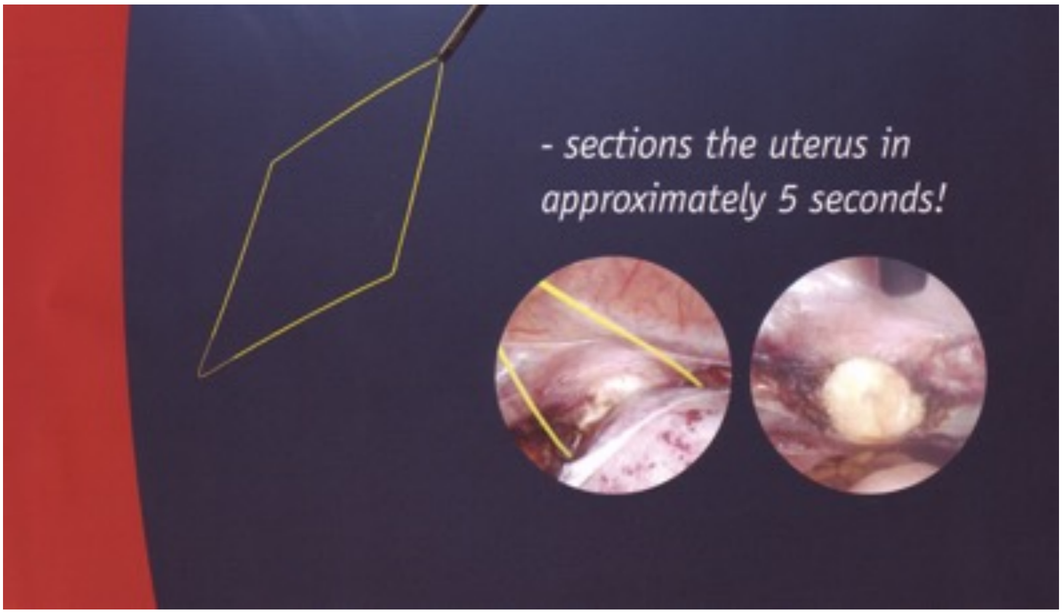
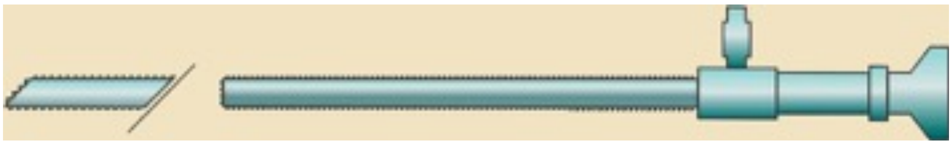


Figure 21: LiNA Loop at subtotal hysterectomy

Lenses and Endoscopes

Scopes are available in rigid and flexible systems (Fig. 22).

A)



B)

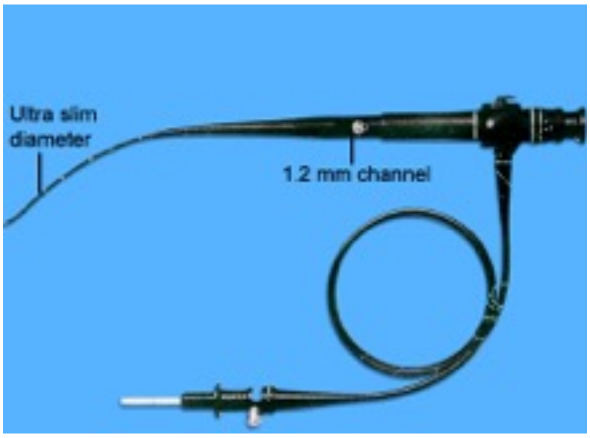


Figure 22: Endoscopes:

A: Rigid standard laparoscope (10 mm) with 30° optic (a) and with 0° optic (b)

B: Flexible endoscope

The rigid system is based on Hopkins's experience with a rod lens system, which results in good resolution and depth of focus ratio [5]. Flexible endoscopes are based on the use of optical fibre bundles. The rigid laparoscopes are in 3mm to 11mm sizes, e.g. the arthroscope with a 14^0 angle. Most of the rigid endoscopes are directly connected to the telescope through the camera coupling system. The picture is enlarged so that it looks even bigger on the monitor. In flexible endoscopes, the bundle of fibres is also enlarged. The standard laparoscopes are rigid instruments with a 0^0 lens. The 30^0 lens has the advantage of a wide panoramic view. With the Endo-Cameleon (Karl Storz) a 120 degree panoramic view is possible (Fig. 3).

Each camera has two components: head and control. A 35mm coupling system yields a much more enlarged picture than a 28mm coupler. A direct coupling transmits the picture directly to the camera.
Olympus Surgical (Hamburg, Germany) offers different flexible endoscopes as well as rigid endoscopes with flexible tips, a four-way angulation system and a miniaturized CCD chip at the instrument's tip (Fig. 23).

Figure 23: EndoEYE video laparoscope (Olympus)

With the chip on the tip of the optic the observation light passes through fewer lenses than on a rigid scope. This allows brighter and sharper images than when the camera is attached to the head of the optic.

Energy Systems for Operative Laparoscopy (Electrosurgery and Thermofusion)

Electrosurgery

Ohm's law, V=I x R. (Voltage=Current x Resistance) is described in terms of current, voltage and resistance. Electrosection, i.e. cutting of tissue between the active electrode and the tissue where an electrical arc is generated, takes place above 200^0C. During coagulation and desiccation the tissue is heated slowly. It results in denaturation, evaporation of water and secondary hemostasis. The argon beam coagulator is a monopolar electrosurgical instrument. In principle, non-combustible argon gas (4L/min) across an electrode cannula acts as a bridge for electrical current to burn the tissue superficially (up to 5mm depth) [6]. As the gas is easier to ionize than air, electrical arcs develop up to 1cm above the tissue surface. In monopolar electrosurgery, high-density current is used at the active electrode that is conducted to the patient on touching. In bipolar electrosurgery, two small electrodes of same size are used which lie close to each other and function as active passive electrodes.

Thermal techniques, such as ultrasound coagulation, laser as well as clips and suturing techniques can achieve endoscopic hemostasis. While the use of thermal hemostasis goes back to the glowing iron, according to Paquelin, the development of safe high frequency current techniques took 40 years. The application of the laser technique, ultrasonic cutting and coagulation techniques and the local thermal effects, such as thermocoagulation, take place in the range of 80 to 120^{0}C. Suturing and clip techniques are handled in next chapter.
We differentiate between fulguration and coagulation in high frequency hemostasis. In fulguration, electromagnetic oscillations across an air bridge produce radio frequency between the tip of the electrode and the surface of the organ, i.e. they come in direct contact. The generated heat is limited to tissue surface, i.e. the area visible through the scope. By coagulation we mean the heating of the tissues until intracellular water boils under the influence of high frequency current.

In addition to the technique used for fulguration and for coagulation, the most important technique in medicine and endoscopic surgery is the **electrotomy,** the cutting of tissue with the so-called electrical knife or the electrical loop. The sustained intermittent or unidirectional high frequency current, which can be produced with tubes or transistor generator, produces smooth-edged cuts. In bipolar high frequency current there is tissue destruction between the poles or their contact points. In monopolar current, the current surge arising at the tip of the instrument is used for cutting and generating heat for coagulation.

Semm developed various systems to control the energy output during controlled endocoagulation. The control unit of the Endocoagulator^{R} (WISAP company) is switched on or off by a pneumatic foot switch, i.e. without electricity. The desired temperature for coagulation can be preset between 90^0 and 120^0C just like the acoustically signalled coagulation time. The heated metal mass is reduced to a minimum in the three instruments, point coagulator, crocodile forceps and myoma enucleator, so that the instruments cool off immediately after heating. Deep burns are not caused if the intestines are touched accidently because the thermal energy is too low to emit much heat. The coagulation effects in endocoagulation produce extensive cauterization. They are not selectively controllable.

At present even with high frequency instruments there is no blind and uncontrolled burning because of the electrical system control. Therefore, we use monopolar current for cutting and bipolar instruments when coagulation is required before cutting big vessels in endoscopic surgery. Most of the systems have an autostop, so that only the required tissue is denatured. It is not set for a very big coagulation zone.

Bi-Clamp for vaginal and open surgery and BiCision (Fig. 24) for laparoscopic surgery are the thermofusion devices of Erbe Elektromedizin GmbH (Tübingen, Germany).

Figure 24: BiCision coagulation and cutting forceps (Erbe)

Their effect is electronically controlled thermofusion and the mechanical separation of tissue.

The electrocoagulation system of Erbe (Fig. 25) uses an additional argon beamer, controlled by a foot switch, which facilitates linear coagulation by switching on the argon gas. This gynaecological workstation with the high frequency module VIO 300 D can be connected to any monopolar or bipolar coagulation device. It contains several modules, such as the argon plasma coagulation (APC 2) and the smoke plume evacuator (IES 2).

Figure 25: Erbe Gynaecological Workstation VIO 300 D

The Erbe electro surgical unit (ESU) has a colour monitor display that provides the user with an on-screen tutorial as well as settings and operational information. The unit has various cutting and coagulation modes with defined effect levels to provide the physician flexibility in interventional applications (i.e. its ability to generate HF current). The system has automatic start and stop features. The equipment is programmable and various accessories (e.g. footswitches, hand instruments, etc.) as well as modes may be assigned to perform specific functions. Upon activation, the energy delivered (in watts) from the ESU to the tissue is displayed on the display screen.

The use of heat in microsurgery can be traced back to Hippocrates who used heat to burn a carcinomatous growth in the neck. Heating the tissue above 45^0C causes irreparable cellular damage. Tissue denaturation sets in at 45^0C and heating above 100^0C leads to typical desiccation with haemostasis. Temperatures above 200^0C produce carbonization and disintegration.

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 such as LigaSure (Covidien) (Fig. 26 & 27).

Figure 26: LigaSure (Covidien), bipolar vessel sealing system, 10 mm (Atlas) and 5 mm

Figure 27: LigaSure (Covidien) jaw providing a combination of pressure and energy to create vessel fusion

The Nightknife (BOWA-electronic GmbH, Gomaringen, Germany) (Fig. 28) is a bipolar vessel sealing device. The instrument incorporates atraumatic tips for secure dissecting and sealing. The integrated cutting system saves changing instruments for tissue separation.

Figure 28: Nightknife (BOWA-electronic)

The Gyrus PK (Olympus) technology delivers a proprietary, pulsing ultra-low (110 V) and high-current RF energy waveform to create a broad range of tissue effects, and allows the tissue and device tip to cool during the “energy off” phase, minimising sticking and charring (Fig. 29a,b).

Figure 29a: Gyrus PK integrated vessel sealing and cutting system (Olympus)

Figure 29b: Gyrus PK control unit (Olympus)

By means of the smart electrode technology, the ENSEAL sealing instrument (Ethicon Endo-Surgery,) permits simultaneous sealing and the possibility of tissue separation, including vessels up to 7mm (Fig. 30). The tip of the instrument has either a 5mm round tip or a 3 mm slightly curved tip enabling tissue preparation and sealing.

Figure 30: ENSEAL sealing instrument (Ethicon Endo-Surgery)

Laser

Laser beam is often described as "light that heals." Laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Fox established the first surgical laser in 1960. Bruhat and his colleagues in 1979 and Tadir and colleagues in 1996 introduced CO_2 laser in laparoscopy. Today, there are enthusiasts of laser surgery [7, 8] and enthusiasts of electrosurgery. Light energy is amplified to generate increased coherent electromagnetic radiation. Here we mention the three forms of laser used in endoscopic surgery:

- CO_2-laser
- Nd: YAG-laser
- KTP-lasers

The Neodymium: Yttrium-Aluminium-Garnet (Nd: YAG-) laser, the Argon laser and KTP- (Potassium-Titanium-phosphate-) laser are used for cutting and coagulation. All the tissue effects are produced because of the continuous or pulsing thermodynamic conversion of light in thermal energy. Because of the 15^0 refraction of the laser beam after arising from the fibre bundle, the effect can be achieved only up to 2cm from the tip of the fibres. In 1996 Wallwiener et al. introduced laser treatment into reproductive surgery [8].

Endocoagulation

Like the hot plate, endocoagulation takes place as contact coagulation, a heat denaturation by low voltage. A wider coagulation can be more easily employed as compared to point coagulation. The control unit heats three types of probes:

- Point coagulator for specific, focal hemostasis
- Crocodile forceps for coagulation of tubes
- Myoma screw for dissection and enucleation of myomata.

These devices are produced by Wisap but in the practical application are already historic. We used them from 1970-2000 in the Kiel School of Gynaecological Endoscopy. Various similar devices using the idea of local heat production are appearing on the market today.

Harmonic Scalpel - Ultrasonic Energy

The harmonic scalpel is an ultrasonically activated laparoscopic instrument that uses mechanical energy to cut and coagulate tissues. Today, the harmonic scalpel can be used as 5 to 10mm cutting blades and scissors. Activation of the titanium blade takes place by a piezoelectric crystal with a frequency of 55500 cycles per second in the hand set. The cutting and coagulation effects are comparable to that of the CO_2-laser [9]. The lateral thermal damage is less than by high frequency coagulation. Burning and carbonization of tissues are not observed.

The advantages of ultrasound energy in surgical endoscopic instruments produced by Ethicon Endo-Surgery and Olympus are well known today and highly appreciated. As an example let us focus on the harmonic ace of Ethicon (Fig. 31) which with its specific control unit (Fig. 32) allows a shorter and a longer effect of sealing. The mechanical energy works with low temperatures, small lateral damage and minimal desiccation of the tissue. The energy is applied parallel to pressure thus minimizing tissue trauma. The simultaneous cutting and coagulation gives a good balance between hemostasis and cutting. A definite coagulation of vessels up to 2mm is guaranteed. Precise dissection, cutting and coagulation are secured without the patient coming into contact with electricity.

Figure 31: Harmonic Ace forceps (Ethicon)

Figure 32: Harmonic Ace control unit (Ethicon)

A new 5mm coagulation and cutting device, "Thunderbeat" from Olympus, combines thermofusion and ultrasound technology and increases surgical speed and precision (Fig. 33).

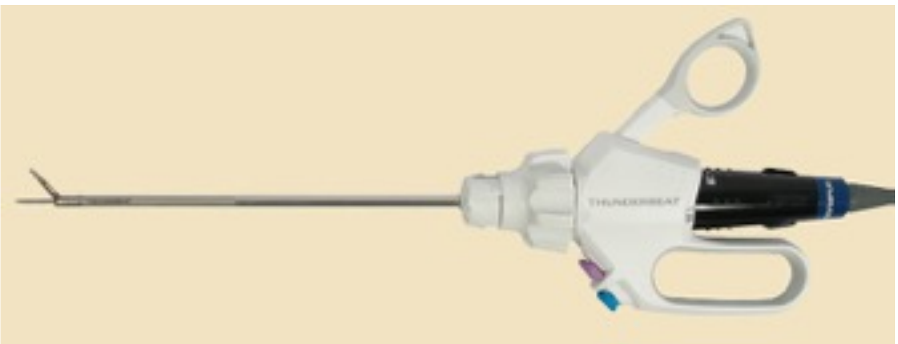


Figure 33: "Thunderbeat" forceps (Olympus)

The different harmonic instruments on the market today, such as harmonic shears, forceps and cutting rings, are applied for adhesiolysis as well as any type of adenexectomy, ovarectomy and hysterectomy. It remains up to the surgeon whether he uses them in combination with other sealing instruments or bipolar coagulation.

Microendoscopy

By rigorously following the concept of minimally invasive access for hysteroscopy and laparoscopy, advances in instrument designing have led to optic systems measuring only about 1.8 to 2mm including the trocar surrounding them. Phase optic and lens optic system with diameter between 1.2mm and 2mm are offered by instrument manufacturers. In all systems the laparoscope can be passed through the Veress needle or the sleeve. Additional trocar insertion after gas insufflation is therefore superfluous. However, compared to the standard 5mm and 10mm optics, even the most satisfactory of the mini-systems shows deficient lighting efficiency. The instrument trocars are also available in correspondingly small diameters.

The merits of minimal operative trauma and the avoidance of umbilical trocar insertion achieved by inserting the laparoscope through the Veress cannula in minilaparoscopies used to have disadvantages, such as the mechanical fragility of the minilaparoscopes and difficult operative sites with a restricted view.
Today new optics and stabile instruments have virtually eliminated these disadvantages. Therefore, a set of minilaparoscopic instruments must always be available for use in certain surgical interventions. The small diameter of the mini-instruments contributes towards reducing trauma and pain in children and in smaller surgical procedures.

Robotic Endoscopic Surgery

Among the current available robotic systems and instruments, the da Vinci robot has proved 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.

The da Vinci has been very successfully applied in oncologic surgery and facilitates a faster learning curve for laparoscopists.

A literature survey on robotic-assisted gynecological oncology clearly supports the use of the da Vinci surgical system in laparoscopic oncological surgery. Robotic precision in tumor excision, easier intracorporal suturing and favourable ergonomics for the surgeon make the da Vinci robot particularly suitable for performing complex laparoscopic, microinvasive surgical operations in gynecological oncology.

Robotic surgery combines the advantages of open surgery and endoscopic surgery. The development of the da Vinci in the treatment of patients encompasses nearly 10 years and shows continuous improvements in application for urologists, general surgeons, cardiac surgeons and gynaecological surgeons (10-12).
Fig . 34 shows the latest da Vinci surgical console and docking station and Fig. 35 the EndoWrist® instruments.

Figure 34: da Vinci Surgical System Si, integrated robotic system with working console, side cart and control unit (Intuitive Surgical)

Figure 35: EndoWrist® instruments of da Vinci Surgical System

Today, a dual console is available which allows two surgeons to collaborate during a procedure. The advantages of the system include 3D HD visualization, an integrated surgeon touch pad which offers comprehensive control of recordings and an extensive array of wristed EndoWrist® instruments with fingertip controls and foot switch performance of various tasks, such as application of energy instruments, etc. A motorized patient cart facilitates quick and controlled docking of the system to the patient.

The Italian robotic system called Telelap ALF-X (Fig. 36-38) 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 (4) which can be easily moved around the table. As a safety function, the system stops when the surgeons ceases to look at the operation site on the computer screen. Activation of any given instrument is performed by gazing at the respective icon on the screen. Each point the surgeon looks at moves to the screen's centre. 3D stereo vision simulates the vision of open surgery.

Figure 36: Telelap ALF-X at the operation table (Sofar)

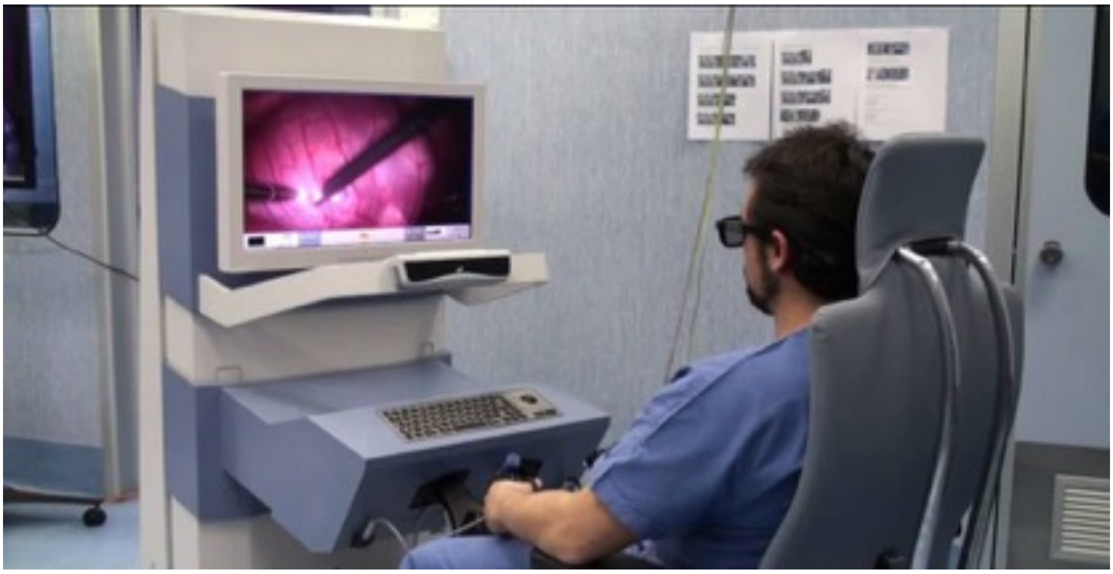


Figure 37: Telelap ALF-X control unit (Sofar)

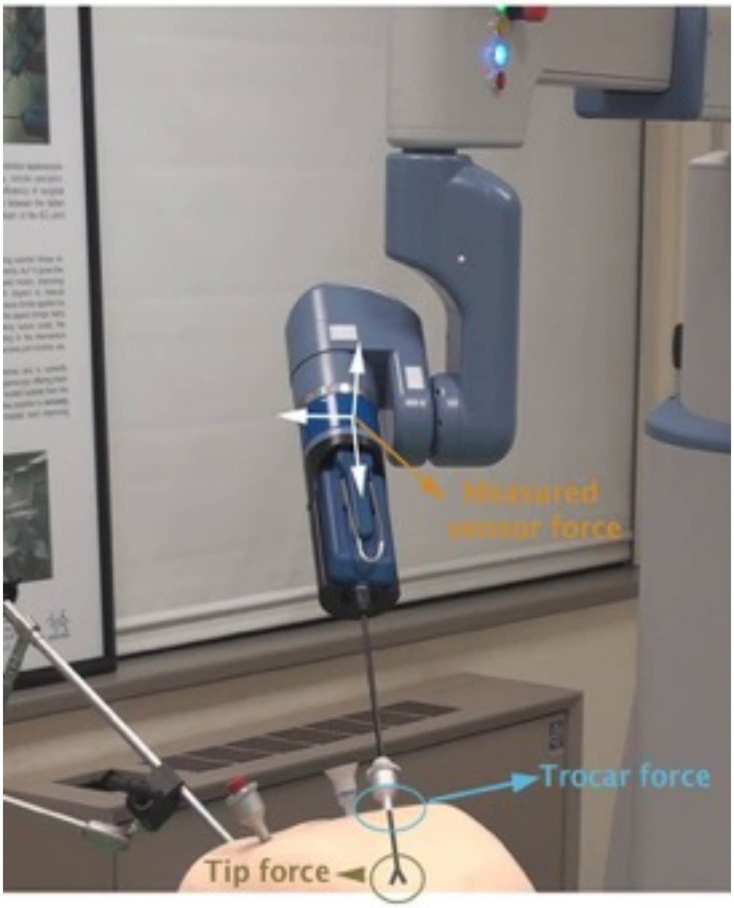


Figure 38: Telelap ALF-X unit for measuring trocar force (Sofar)

Articulated Instruments

The Terumo Kymerax System or Terumo "Precision-Drive Articulating Instrument"

A new motor-driven, handheld system that offers precision-driven articulating instruments, called the Terumo Kymerax System (Terumo, Tokyo, Japan), has recently been introduced onto the medical market in Europe (Fig. 39).

Figure 39: Terumo Kymerax System with control unit and bilateral articulated instruments

The System: The three components include a console, a handle and interchangeable instruments. Up to two handles can be connected to the console, which provides power to the motors located within the handle component of the system. The instrument is used under direct surgeon control at the OR table, is hand held, and can be used in conjunction with conventional laparoscopic instruments.

Instruments: The instruments available include a needle driver, monopolar L-hook cautery, monopolar scissors and Maryland grasper and dissector. The instruments' functions are suited for performing general surgical tasks such as manipulating tissue, ligating, suturing, knot tying, cutting, coagulating and dissecting (Fig. 40).

Figure 40: :Possibilities of instrument rotation within the Terumo Kymerax S System

Features & Benefits: 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 precision-drive articulating instrument provides an additional 2 degrees of freedom (yaw and roll of the instrument tip, independent of the shaft) to the 4 degrees of freedom allowed by standard laparoscopic instruments (pitch, yaw, roll and surge). The articulation allows the instruments to efficiently adjust the instrument tip angles to the desired tissue planes for fine dissection and cauterization of tissue while maintaining ergonomic hand positioning. The articulation also facilitates suturing by providing the operator with the ability to adjust the angles for suture placement in the ideal tissue position at the optimal angle. The opening and closing of the jaws or blades are manually controlled through a trigger on the handle. This manual function provides the operator with beneficial haptic feedback:

1) Roll: 160 degrees each way (total of 320 degrees)
2) Yaw (movement of left and right): 70 degrees each way (total of 140 degrees).

The advantages of the articulated instruments compared to robotics are the following:

- Portability
- By the bedside
- Can be used in conjunction with regular laparoscopic instruments
- Will not cost a fortune
- Precise movement of the tip
- Easy to control tip movement by the pushing the button on the handle
- Ergonomic handle (angle of wrist and position of fingers)

2) The r2 DRIVE and r2CURVE

These instruments are disposable and articulated instruments and their use is becoming more widespread. This Tübingen set of instruments (Tuebingen Scientific Medical GmbH, Tuebingen, Germany) was developed by Gerhard Bues, a creative general endoscopic surgeon.

r2 DRIVE is a hand-held instrument that offers all the degrees of freedom of a robotic system. Due to the 90° deflectable and infinite rotatable tip, in combination with the infinite rotatable shaft, surgical manoeuvres can be confidently and precisely carried out even in difficult angles and tight spaces. The instrument is primarily controlled with the fingertips, thereby offering utmost precision and comfort for the surgeon. Extensive movements are thus rendered superfluous, which obviates fatigue and discomfort on the part of the surgeon.

The shaft diameter is 5 mm, enabling body access through small incisions. Bipolar HF-technology provides secure, reproducible and clearly defined effects in preparation and hemostasis. The instrument is available in various configurations: atraumatic forceps, needle holder, dissector and scissors. The r2 DRIVE is a disposable, one-piece instrument (Fig. 41a,b).

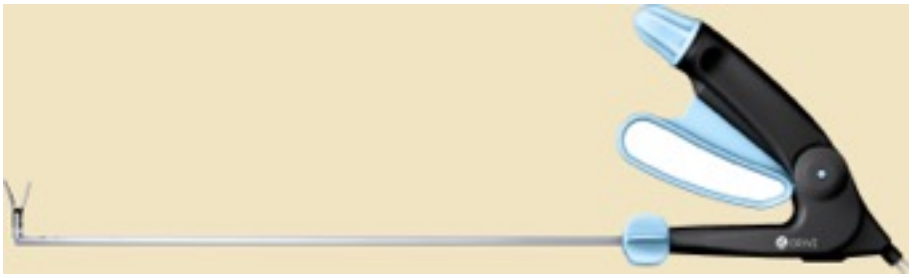


Figure 41a: r2 DRIVE hand-held instrument, left hand (Tübingen Scientific Medical)

Figure 41b: r2 DRIVE hand-held instrument, right hand (Tübingen Scientific Medical)

The r2 CURVE is a hand-held instrument to be used at single port entry that offers all degrees of freedom of a robotic system with a special design to support single port surgery (Fig. 42).

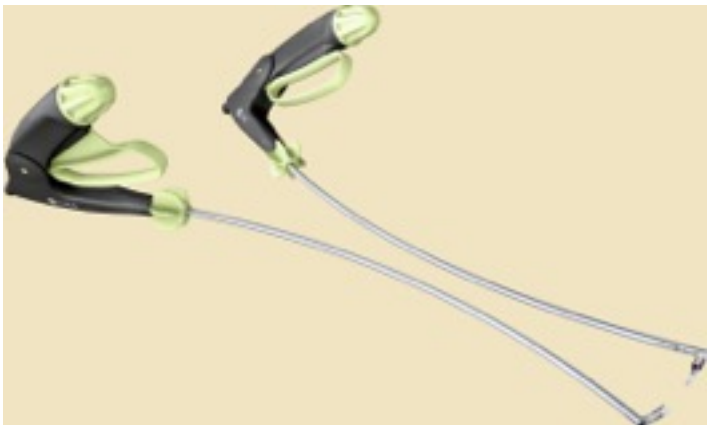


Figure 42: : r2CURVE hand-held instruments (Tübingen Scientific Medical)

The unique design of the instruments allows easy and controlled handling and precise and reliable navigation and manoeuvrability. The combination of the curved shaft with the 360° infinite tip rotation, the tip deflection and the full and infinite shaft rotation gives the freedom needed to perform single port surgery (Fig. 43). No sword fighting; no cross over; no mirrored views.

Figure 43: r2CURVE scissor tip (Tübingen Scientific Medical)

The instrument offers a shaft diameter of 5 mm and bipolar HF-technology. The instrument is available in various configurations: atraumatic forceps, needle holder, dissector and scissors. The r2 CURVE is a disposable, one-piece instrument.

Single port endoscopic entry

Laparoscopy in the 1940s started with the angled laparoscope (optic and one working channel) of Raoul Palmer in France as SEL. Laparoscopy at that time was mainly used for diagnostic purposes and for sterilizations. Kurt Semm in Germany further developed the procedure into operative laparoscopy by using multiple entries and instruments. Semm called the procedure “pelviscopy”, to differentiate the technique from the simple liver biopsies that the internists called laparoscopy, as the gynaecologist works mainly in the minor pelvis. Thus, the insurance companies started to pay for these gynaecologic laparoscopic procedures in Germany. With the improved technology of today, SEL takes the idea of the early laparoscopy to new horizons. Of the multitude of SEL ports available, let us mention two disposable and one reusable:

1) The SILS port (Covidien) (Fig. 44) is a disposable port. Here a silicone port is introduced into the abdominal cavity using a classical curved grasper with a beak of 5-6 cm. The surgeon has the choice of two ports of five mm and one allowing for a large barrel instrument of 10-12 mm or one with four 5 mm ports. The SILS, with the possibility to introduce larger instruments, is suitable for hysterectomies.

Figure 44: SILS (Covidien)

2) Another disposable port is the QuadPort (Fig. 45) of Olympus which contains duckbill valves and requires no gel for insertion. Instruments of 5, 10, 12 and 15 mm can be introduced easily for ergonomic surgery. The 5mm LESS EndoEYE video laparoscope provides excellent visualisation and helps to avoid instrument clashing.

Figure 45: QuadPort (Olympus)

Specialised curved HiQ+ LESS instruments allow internal triangulation and mimic traditional laparoscopy (Figs. 46 & 47).

Figure 46: LESS System with EndoEYE and curved instruments (Olympus)

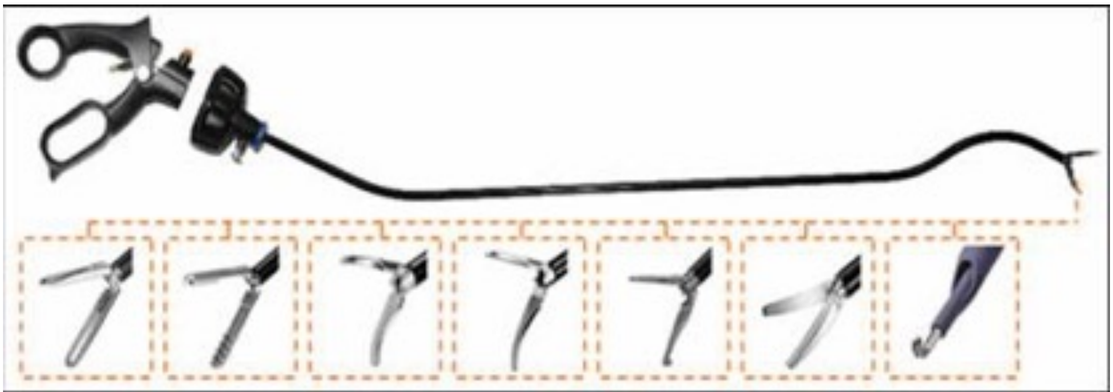


Figure 47: Seven variations of LESS curved instruments (Olympus)

3) The XCONE (Fig. 48) of Karl Storz is a reusable port. This system is operational in the abdomen with 3 – 5 entry channels, one allowing large barrel instruments. Usually the 3 or 5 mm optic is placed into the middle entry and at least one curved instrument on the left or right side.

Figure 48: XCONE (Karl Storz)

4) The ENDOCONE® (Fig. 49) is a special access system developed by the general surgeon Cuschieri in which seven instruments can be introduced simultaneously

Figure 49: ENDOCONE® (Karl Storz)

Developments are ongoing as can be seen by the ETHOS Surgical Platform™ (Ethos Surgical, Beaverton, USA), on which the surgeon is postured over the midline of the patient with optimal port triangulation options (Fig. 50).

Figure 50: ETHOS Surgical Platform™ (ETHOS Surgical)

New instruments and apparatuses are continuously being appraised. They assist the surgeon but do not replace his knowledge and have always to be critically evaluated and studied before they are applied.

Figures

Figure 1 : SMARTCART: Equipment cart for gynaecologic endoscopic surgery (laparoscopy and hysteroscopy) with electrosurgical unit, CO_2 pneuautomatic with heated gas, light source and HDTV monitor (Karl Storz 3D System)as well as control unit for hysteroscopic surgery (Karl Storz)

Figure 2: OR1™NEO (Karl Storz) with panoramic viewing possibilities, integrated commanding functions for all operative procedures and documentation

Figure 3: ENDOCAMELEON® laparoscope (Karl Storz)

Figure 4: Optics, trocars, needle holder and RoBi® instruments – rotating bipolar grasping forceps and scissors (Karl Storz)

Figure 5: Xcel, a disposable, viewing trocar for laparoscopic entry under sight (Ethicon)

Figure 6: Dilatation instruments:

a) Central introduction rod

b) Dilators

c) Mandrin, when the dilator is introduced as trocar

Figure 7: Holding, grasping and drilling instruments:

a) Atraumatic forceps

b) Various tips of forceps (left to right): 2 intestinal forceps, lymph node holding forceps, 2 biopsy forceps, spoon forceps and toothed forceps

c) Swab holder, before holding and with the swab

d) Myoma screw

Figure 8: Cutting instruments:

a) Dissection scissors with round handle, as macro and microscissors (with 2 mm span)
b) Scalpel
c) Changeable cutting blades (single use) of the scalpel

Figure 9: Suction and irrigation instruments:
a) 5 mm suction irrigation cannula with open end
b) 5 mm suction irrigation cannula with perforated end
c) Aspiration cannula for cysts
d) Manual aspiration system for Douglas exudates

Figure 10: Suction irrigation system (R. Wolf, Knittlingen, Germany)

Figure 11: ROTOCUT GI (Karl Storz), morcellation tool with protective shield, available in 2 sizes (12 and 15 mm)

Figure 12: SAWALHE II SUPERCUT Morcellator (Karl Storz)

Figure 13: Instruments for hemostasis

Figure 14: Endo GIA™ Ultra Universal Stapler (Covidien)

Figure 15: Endo GIA™ Reloads with Tri-Staple™ Technology (Covidien)

Figure 16: Endo GIA™ Ultra Universal Stapler (Covidien)

Figure 17: Vascular clamps:
a) Emergency needle
b) Vascular clamps with different tips

Figure 18: Robinson drainage. The perforated end of the cannula is introduced with a 5 mm trocar and placed in the deepest part of

Literature

1. Mettler, L., M. Ibrahim, and W. Jonat, *One year of experience working with the aid of a robotic assistant (the voice-controlled optic holder AESOP) in gynaecological endoscopic surgery.* Hum Reprod, 1998. **13**(10): p. 2748-50.
2. Semm, K., *Operationslehre für endoskopische Abdominal-Chirurgie*. 1984, Stuttgart, New York: Schattauer.
3. Veress, J., *Neues Instrument zur Ausführung von Brust oder Bauchpunktionen und Pneumothoraxbehandlung.* Dtsch Med Wschr, 1938. **41**: p. 1480.
4. Semm, K., *Die moderne Endoskopie in der Frauenheilkunde.* Frauenarzt, 1972. **13**(300-307).
5. Hopkins, H.H., *On the diffraction theory of optical images.* Proc Roy Soc A, 1953. **217**: p. 408-415.
6. Brill, A.I., *Energy systems for operative laparoscopy.* J Am Assoc Gynecol Laparosc, 1998. **5**(4): p. 333-45; quiz 347-9.
7. Daniell, J.F., *Tailoring the laser for infertility surgery.* Contemp OB/GYN Special issue, 1987(33-143).
8. Wallwiener, D., et al., *[The value of laparoscopic and laser-assisted techniques in reconstruction of distal fallopian tube pathology].* Zentralbl Gynakol, 1996. **118**(2): p. 66-72.
9. Schemmel, M., et al., *Comparison of the ultrasonic scalpel to CO2 laser and electrosurgery in terms of tissue injury and adhesion formation in a rabbit model.* Fertil Steril, 1997. **67**(2): p. 382-6.
10. Advincula AP, Wang K. *Evolving role and current state of robotics in minimally invasive gynecologic surgery*. J Minim Invasive Gynecol. 2009;16(3):291-301.
11. Mettler L, Schollmeyer T, Boggess J, et al. *Robotic assistance in gynecological oncology*. Curr Opin Oncol. 2008;20(5):581-9.

12. Nezhat C, Nezhat F and Nezhat C. *Nezhat's Video-assisted and robotic-assisted laparoscopy and hysteroscopy.* 4th Edition. Cambridge University Press, Cambridge, UK; available from March 2013