# Gynaecological Endoscopic Surgery

## Basic Concepts

Jude Okohue
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*Editors*

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# Preface

This textbook embraces most aspects of gynaecological laparoscopy and hysteroscopy, and it aims to present a comprehensive coverage of gynaecological minimal access surgeries with excellent medical illustrations.

The reader is taken on a journey that includes the history of minimal access surgery, instrumentation and ergonomics required to progress in the field, capturing practical learning steps, and navigating the reader through the diagnostic and therapeutic applications. In addition, it describes the latest technological advancement in the field, backed with high current best evidence.

The authors are practising specialists drawn from five continents who brought their wealth of experience and expertise to bear in this book.

This textbook targets a global audience of practising and trainee doctors in general gynaecology, subspecialists, and those with relevant special interests in gynaecological endoscopy surgery.


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# Part I

# General Topics

# History of Minimal Access Surgery (MAS)

Ephraim Samuels and Olanlege Olayinka Shakirat

## 1 Introduction

Right from medieval times, incisions have been used to gain access into the body cavities to carry out surgical procedures. It was thought that the larger the incision, the more successful the outcome of the procedure. However, the advent of minimal access surgery (MAS) has revolutionized the practice of surgery, as it has been shown to lead to better outcomes [1]. Presently, MAS is employed for a wide range of surgeries, originally performed using the open techniques. The type of procedure performed is dependent on the target cavity, for example, hysteroscopy for the uterine cavity, laparoscopy for the peritoneal cavity, cystoscopy for the bladder, and so on [1, 2].

The benefits of MAS include shorter hospital stay, lower postoperative morbidity, and less adhesion formation. Major surgeries in gynaecology such as hysterectomy, myomectomy, adhesiolysis for Asherman's syndrome, salpingectomy for ectopic pregnancy, and ovarian cystectomy are increasingly performed via MAS. Other gynaecological procedures where MAS is commonly employed include pelvic adhesiolysis, endometriosis treatment, tubal sterilization, etc. [3].

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## 2 Historical Perspectives

- Minimal access surgery dates back to the time of Hippocrates in 400 BC. He was documented to have used a speculum for rectal examination in a patient with intestinal obstruction [4].
- The vaginal speculum was also documented in 70 AD and 300 AD in Pompeii and Babylon, respectively [4, 5].
- Aranzi, in 1585, carried out an endoscopic procedure using sunlight focussed through a water flask which was projected into the nasal cavity. This paved the way for the use of a light source in endoscopic procedures [5, 6].
- In 1706, the term "trocar" was thought to be derived from a three-faced instrument made up of a perforator, enclosed in a metal cannula called trochartor triose-quarts [7].
- Nordentoeft in 1912 developed the contemporary trocar and this instrument has been modified severally to its present form [8].
- Philip Bozzini in 1806 designed an instrument that could be used to visualize the internal organs of the human body. He examined the genitourinary tract with an aluminium tube that


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had fitted mirrors to reflect images. Illumination was achieved with the aid of a wax candle. He called this instrument "Lichtleiter" [5]. This instrument was introduced to a patient in 1853 by Antonin Jean Desormeaux. Antoine examined the genitourinary tract with an open tube in 1867. During the procedure, alcohol and turpentine were combined with a flame to generate a more condensable and brighter beam of light. This method demystified the challenge of viewing an internal dark cavity with better illumination [5, 9].

- In 1901, Dimitri Oscarovic Ott, a Petrograd gynaecologist, reflected light to augment visualization using head mirrors on a pregnant woman during a procedure he called ventroscopy (transvaginal access using a speculum via a posterior fornix incision to examine the abdominal cavity). He may have paved the way for NOTES (natural orifice transluminal endoscopic surgery) [10, 11].
- Georg Kelling in 1901 performed the first experimental laparoscopy on account of an intra-abdominal bleed in a dog [9].
- Zollikofer of Switzerland introduced the use of carbon dioxide into laparoscopy in 1924 [12].
- H. C. Jacobaeus in 1911 used a trocar without pneumoperitoneum, to view the thorax and abdomen of a patient [9]. The possible first case of gasless entry.
- In 1918, Goetze developed an insufflation needle to make abdominal entry safer [9].
- Kurt Semm, a German gynaecologist, invented the automatic insufflator called the Semm's insufflator four decades later (Fig. 1). Its simple application, safety and clinical values endeared it to its users [9, 12].
- Veress in 1938 made the blunt-ended insufflation needle, further making abdominal entry safer. This needle, which is very important in achieving pneumoperitoneum, has an outer cannula with a bevelled needle point for cutting through tissue. Within this cannula is an inner stylet with a spring system which is a safety mechanism during entry [12].
- In 1929, Heinz Kalk, a German gastroenterologist, developed the oblique viewing scope, which was a 135-degree telescope, in addi-

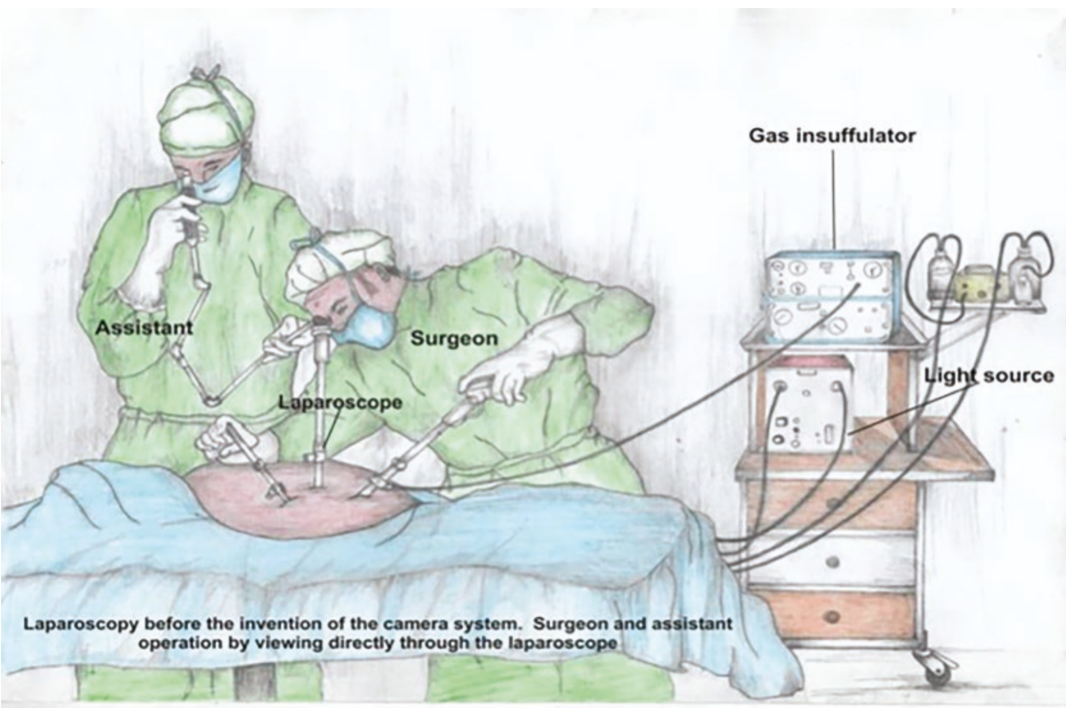


**Fig. 1** Diagnostic laparoscopy before the camera system

tion to a double trocar entry technique which he used for liver and gall bladder disease diagnosis [5, 9].

- Bovie introduced diathermy to laparoscopy in 1928, and more than four decades later, H. Courtenay Clarke demonstrated laparoscopic suturing technique for haemostasis [12, 13].
- The first therapeutic laparoscopy was performed by Fevers in 1933 for adhesiolysis. More interventions followed as Bosch carried out the first laparoscopic sterilization in 1936 [12].
- The first laparoscopic appendectomy was performed in 1983 by Semm, and he is regarded as the father of operative laparoscopy [9].
- Erich Muhe performed the first documented cholecystectomy 2 years later in 1985. More confidence in operative minimal access surgery continued as many surgeons trained in this technique carried out more procedures in both gynaecology and surgery [12].
- Bipolar desiccation for laparoscopic hysterectomy was first carried out by Harry Reich in 1989. He later demonstrated staples and finally sutures for laparoscopic hysterectomy [9, 14].
- More improvement took place with the invention of a robotic arm for holding the telescope with the purpose of reducing the need for a skilled camera operator while improving safety (Fig. 2). This achievement was in 1994 [9]. The first live telecast of laparoscopic surgery performed via the Internet remote from the patient occurred 2 years later and this gave rise to the robotic telesurgery [9].

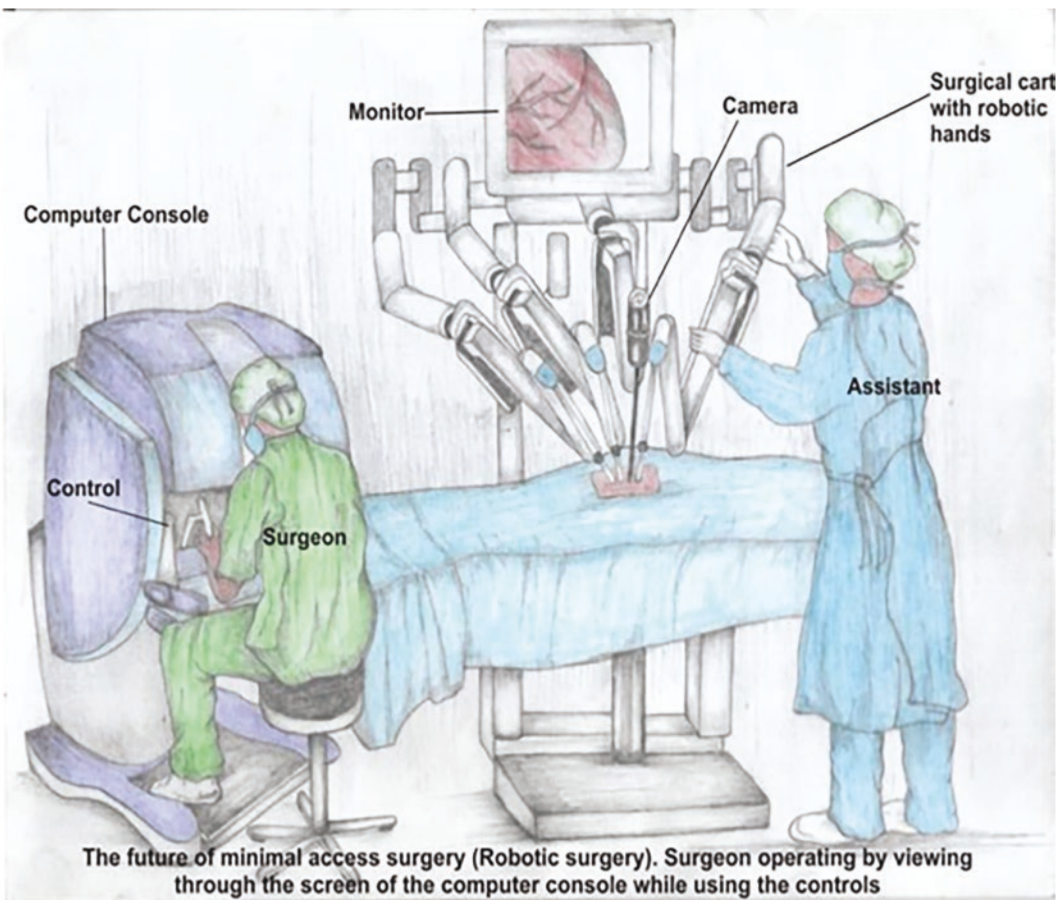


**Fig. 2** Robotic laparoscopy surgery setup

- Commander Pantaleoni in 1869 cauterized a bleeding uterine growth in a 60-year-old woman with postmenopausal bleeding using a modified cystoscope. Thus, he performed the first diagnostic and therapeutic hysteroscopy [9, 15].
- More authors described hysteroscopic procedures over the next century with improvement in the technique and procedures carried out [15, 16].
- Charles David described the diagnosis and treatment of intrauterine disease in his master's thesis for the University of Paris using a hysteroscope which was modelled after the Nitze cystoscope with a built-in lens for image magnification [15, 16]. In the following decades:
- The development of a water-rinsing system and the use of carbon dioxide for uterine distension was achieved [15].
- Illumination by candle and reflected light were replaced by the electric bulb and distal lighting which were followed by proximal lighting, halogen, xenon light system, and finally fibre optics [8].
- Eventually, a series of modifications to the hysteroscope took place making them shorter and smaller.
- Monitors were invented for external viewing and video recording (Fig. 1). Accessory instruments evolved for improved and safer endometrial procedures [8, 15].

The last century has seen significant improvements in the development and practice of MAS. It is envisaged that the later developments would see the invention of much smaller devices with complete automation, for a seamless surgical experience.

### Learning Points

- MAS has had innovations and improvements over the years.
- It is now a safer approach to gynaecological surgery compared to the past with better outcomes.
- Most diagnostic and operative gynaecological procedures can be performed with MAS.
- It is gradually moving towards robotic gynaecological surgery for seamless surgical experience and telecast procedures.
- The future holds great opportunities for more innovation and application of MAS.

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# Laparoscopy and Hysteroscopy Surgery Instruments/Equipment

Joseph Ifeanyichukwu Ikechebelu,
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and Chukwuemeka Okoro

## 1 Introduction

Like open gynaecologic procedures, gynaecologic endoscopic procedures make use of its own special instruments as a major branch of minimal access surgery (MAS). Endoscopic surgery relies not only on the skill of the surgeon but also on his mastery of the available instruments and technology [1]. The instruments and equipment for MAS are an inherent part of the surgery. Therefore, for success in MAS, the surgeon should have a good knowledge of how and when to use a particular instrument.

The gynae-endoscopy instruments are basically instruments used for laparoscopic and hysteroscopic surgeries. Some of these instruments resemble and have similar names to those used for open surgeries just that they tend to be different in configuration, longer in length and smaller in diameter so as to be suitable for a minimal access procedure. They are also more delicate and have more points of articulation. The uses of these instruments are similar to those used in open surgeries. Some other endoscopic instruments are entirely different from any known instrument used in open surgery. There are other instruments that are used in both open and endoscopic surgeries, e.g. surgical blade and holder, Sim's speculum, etc. This last group of instruments is not discussed here as it is assumed that the endoscopic surgeon should have been conversant with their names, features and uses.

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## 2 Types of MAS Equipment/Instruments

Endoscopy equipment/instruments can be categorized into four groups:

1. Optics
2. Hand instruments
3. Units, e.g. insufflators
4. Endovision system


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## 2.1 Optics

These include the telescopes which are used in MAS procedures. It is the surgeon's eye. The telescope used for laparoscopy is called a laparoscope, while the telescope used for hysteroscopy is called a hysteroscope. The telescope has four parts: the eyepiece, the light cable port, the barrel, and the objective lens. The telescope as well as its lens comes in different sizes/diameters (Fig. 1). They have varying viewing angles at their tip. Telescopes can also be autoclavable or non-autoclavable. Autoclavable telescopes offer longer life than non-autoclavable ones. It also offers the added advantage of proper asepsis. Some telescopes are disposable, while others are reuseable.

Telescopes come in various sizes depending on their external diameters. There are 10-mm, 5-mm, 4-mm and 3-mm telescopes.

The commonly available options are 0°, 30° and 45° for the 10-mm telescopes and 0° and 30° for the 5-mm telescopes, while for the 3-mm telescopes, there are 0°, 15°, 30°, and 70° (see Fig. 2).

The surgeon should choose the right telescope depending on both the type of surgery and the surgeon's level of expertise. The 0-degree deflection angle telescope is the most commonly used and provides a straightforward view [2]. However, in gynaecology and to have a good view of the pelvic organs, the 30° telescope is preferred. Newer technology from Karl Storz and Olympus has led to the production of high-definition telescopes with adjustable viewing angles and three-dimension imaging. These are EndoCAMeleon (0°–120°) from Karl Storz (Fig. 3) and EndoEYE Flex from Olympus (Fig. 4).

The telescopes used in hysteroscopy procedures are of smaller sizes and comes in various forms:

- Rigid or flexible
- Fixed or variable focus

The telescope diameter, lens offset, sheath diameter, ability to be used with a variety of distending media and ability to use either bipolar or


**Fig. 1** Different sizes/diameters of telescopes

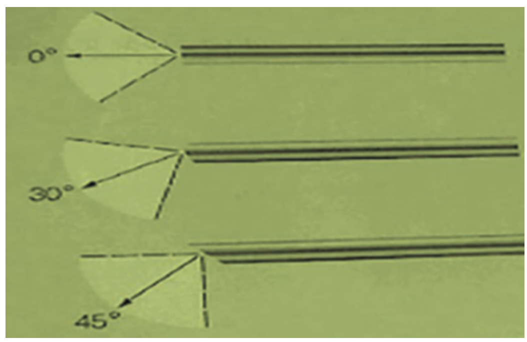


**Fig. 2** Angles of vision of the telescope

monopolar cautery are key characteristics of the hysteroscope.

The 4-mm telescope gives the sharpest, clearest image, in addition to a small outside diameter. The 2.9-mm telescopes are more contemporary with improved optics and very fragile. The available viewing angles include 0°, 12°, 15°, 30°, and 70°.

Currently, there are micro-hysteroscopes which are modern telescopes with a diameter of 2 mm. It does not require cervical dilatation. Micro-hysteroscopes, however, have low magnification, narrow field of view and are fragile and very expensive and hence not suitable for poor resource settings.


**Fig. 3** EndoCAMeleon (0°–120°) by Karl Storz

**Fig. 4** EndoEYE Flex (100° in four directions) by Olympus

## 2.2 Laparoscopic Hand Instruments

These are all the instruments used in performing laparoscopic surgery. The two varieties of hand instruments are dismountable and non-dismountable. The dismountable instruments can be separated into different parts, namely, the handle, shaft, and working element (the jaw), while the non-dismountable ones cannot be separated into different parts (Fig. 5). The hand instrument has a rotator mechanism on the handle to adjust the direction of application and a knob for attachment of the diathermy cable to energize the instrument if required.

The dismountable instruments have better asepsis, have wider options with minimum extra costs and are economical to repair. They, however, are more expensive and have weaker construction and weaker tactile feedback [2]. The non-dismountable instruments are cheaper and have a stronger design, longer life span and better tactile feedback. However, they have limited repair options and have an increased risk of sepsis due to tissue materials impacting the joints and crevices in the instrument. The commonly used hand instruments in MAS are discussed below.

### 2.2.1 Dissecting Forceps

They are commonly called "Maryland" and functions like the artery forceps in open surgery (Fig. 6). They are used for tissue dissection and can be energized for electro-dissection. The monopolar or bipolar options are available.


**Fig. 5** Laparoscopic hand instruments

**Fig. 6** Maryland forceps

### 2.2.2 Grasping Forceps

These serve as the surgeon's hands and hence are indispensable in laparoscopic surgeries. There are two types:

1. Traumatic. This is toothed (fine or coarse). It can also be called "Allis". It is used to handle thick tissue like fascia, muscle and any other tissue to be removed from the body. See Fig. 7.
2. Atraumatic. This is non-toothed and could be fenestrated or non-fenestrated for holding fragile tissues like fallopian tubes, intestines, etc. Also, there is a particular design called Babcock like the one in open surgery.

### 2.2.3 Scissors

Like in open surgery, the scissors are used for cutting. There are three commonly available types. The hook scissors is used for cutting sutures. The others are the straight scissors and curved scissors which are used for cutting and dissecting tissues. During usage, ensure that the scissors cut from "end to edge". See Fig. 8.

### 2.2.4 Biopsy Forceps

They are specially made for taking tissue specimen (Fig. 8).

### 2.2.5 Suction/Irrigation Cannula

This same instrument serves as a channel for both irrigation and suction. It has two openings, one for connection to the irrigation tube and the other for connection to the suction tube. There is a knob for switching to the irrigation channel which automatically turns off the suction channel and vice versa. It has either reusable suction tips or disposable suction tips.

The suction function can be used to aspirate fluid including blood from the pelvis, drain ovarian cysts, etc. The irrigation function can be used for peritoneal lavage, hydro-dissection, and cooling tissues that have been subjected to thermal energy. See Fig. 9.

### 2.2.6 Energy Delivery Instruments

These are instruments used to deliver energy to the tissue being operated. The energy used during MAS is usually in the cutting or coagulation

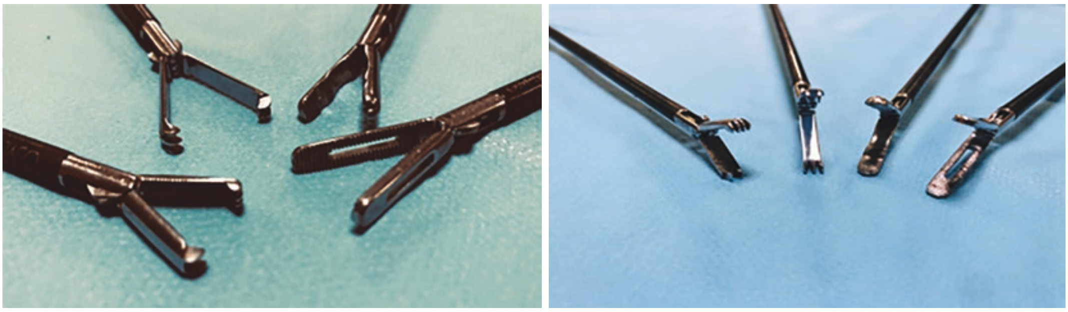

**Fig. 7** Showing Allis traumatic and fenestrated/non-fenestrated atraumatic forceps

**Fig. 8** Laparoscopic scissors—cutting, straight and curved (left) and biopsy forceps (right)

**Fig. 9** Laparoscopic suction irrigation cannula (two way)

waveform. Also, the instruments are designed to function as monopolar, bipolar or tripolar technology. As the current passes through the tissue with high resistance, heat energy is generated which cuts or coagulates the tissue. Bipolar instruments are safer than monopolar as the current only has to travel between the prongs of the electrodes and not through the patient. Many laparoscopic hand instruments can also be energized to serve as energy delivery instruments.

*Monopolar instruments* include L-hook and spatula (Fig. 10a) and any of the energized hand instruments. *Bipolar forceps* include Bissinger, U design (Fig. 10b) and bipolar Maryland.

*Tripolar devices* combine bipolar coagulation and monopolar cutting function in one instrument. It may use electrical or ultrasonic technology. Examples are Harmonics, Covidien, and Lotus brands. See Fig. 10c.

### 2.2.7 Hysteroscopic Hand Instruments and Units

Just like laparoscopy, hysteroscopy makes use of hand instruments. Because of the narrower working space in hysteroscopy, these instruments tend to be more slender and longer than those used in laparoscopy. However, the working tips are similar. Common accessory instru-

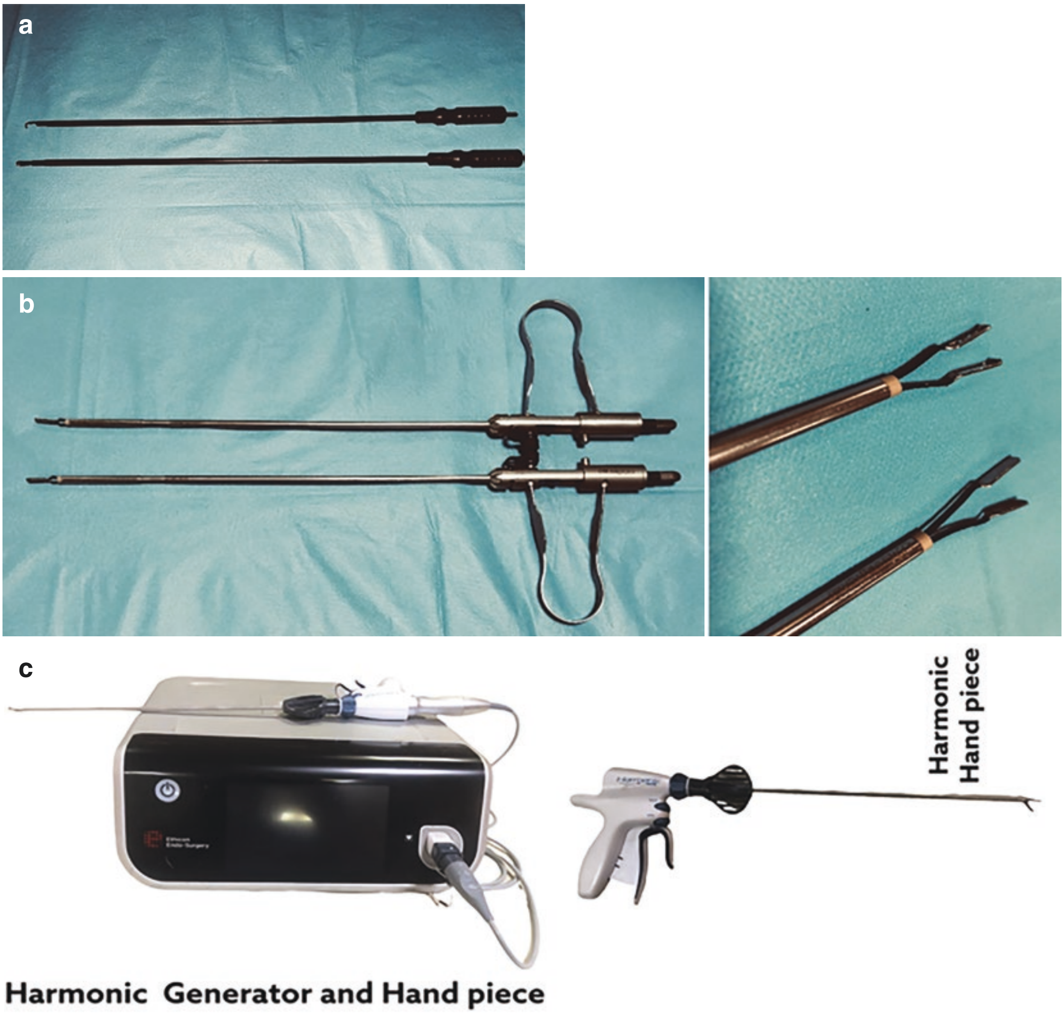


**Fig. 10** (**a**) Monopolar L-hook energy delivery instrument. (**b**) Bipolar forceps U design and the tip of the instrument. (**c**) Harmonic generator and handpiece instrument

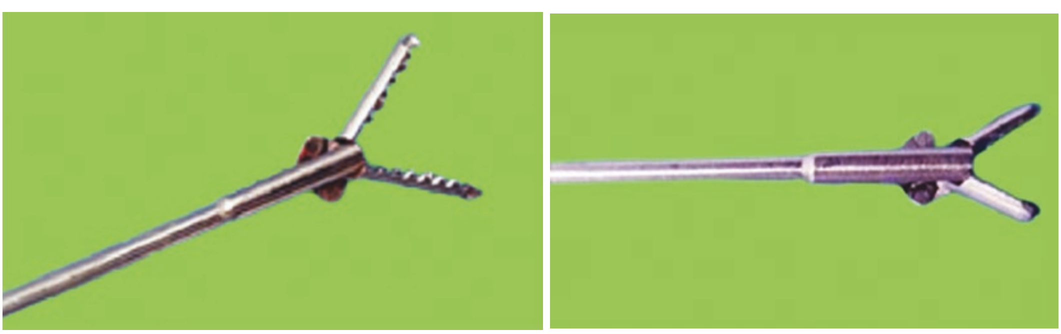

**Fig. 11** Alligator grasping (left) and biopsy forceps (right)

ments are alligator grasping forceps and biopsy forceps (Fig. 11) and scissors and tenaculum (Fig. 12).

#### 2.2.8 Hysteroscopy Sheaths

We have diagnostic and operative sheaths which can be flexible or rigid. See Fig. 13.

The hysteroscope has an inner sheath that provides the channel for the telescope and the inflow port for delivery of the distending media. It has an outer sheath with the outflow for the return of distension media. The diameter of the sheath depends on the outer diameter of the telescope and generally has a 1-mm clearance between the inner wall of the inner sheath and the telescope to create room for delivery of the distending media. This is the diagnostic sheath. The operative sheath is larger and has an extra port for the insertion of the operating instrument. This operating channel is sealed with a rubber nipple or gasket to prevent leakage of the distending medium. See Fig. 14.

**Fig. 12** Scissors (left) and tenaculum (right)

### 2.2.9 Resectoscopes

Resectoscope is a specialized electrosurgical endoscope (monopolar or bipolar) that consists of an inner sheath and outer sheath like the hysteroscopy sheaths (Fig. 15). The outer sheath is for fluid return, while the inner sheath has a common channel for the telescope, fluid medium and electrode. It has a double-armed electrode fitted to a trigger device that pushes the electrode out beyond the sheath and then pulls it back within the sheath. The operating tool consists of four basic electrodes: a cutting loop, ball, button and angulated needle (Fig. 16). Traditionally, resectoscopes are monopolar instruments, but bipolar resectoscopes are gradually replacing them for reasons of safety [1].

Most resectoscopes have a 30°telescope. The lens is angled toward the electrode to permit a clear view of the near operative field. It can be used with monopolar or bipolar circuit. When using monopolar mode, a non-electrolyte medium like glycine, sorbitol and mannitol is used and the patient return plate is applied. For bipolar mode, electrolyte medium like normal saline or non-electrolyte medium can be used. It has its special generator and a patient return plate is not required. The biggest advantage of bipolar is that the risk of hyponatraemia is obviated. Glycine causes hyponatraemia which can cause cerebral oedema and death

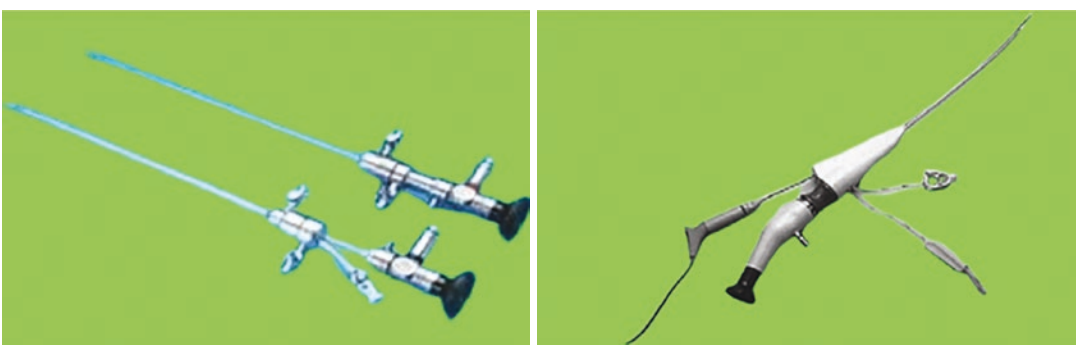

**Fig. 13** Rigid diagnostic and operative sheaths (left) and flexible hysteroscope (right)

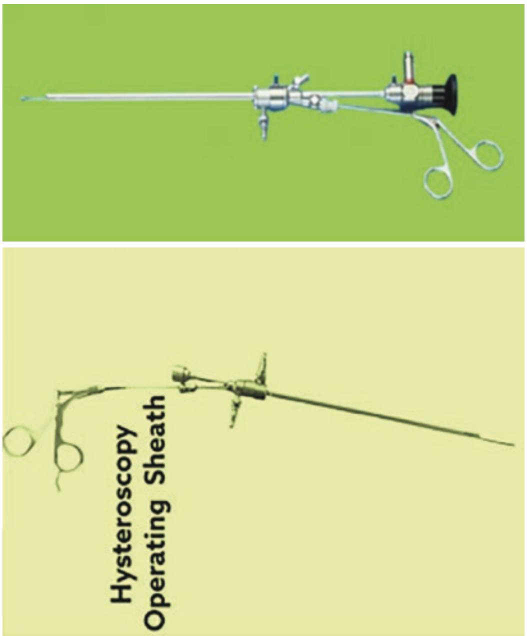


Fig. 14 Hysteroscope with operating channel

[2]. Resectoscopes are useful in a submucous myomectomy, polypectomy, intrauterine adhesiolysis, endometrial resection/ablation and metroplasty.

### 2.2.10 Media Delivery Systems

They are used to deliver the distending medium into the uterine cavity. The media delivery system can be manually operated or automated. The pressure bag is manually operated and allows for intermittent fluid delivery leading to interruptions during the procedure. This system can suffice for diagnostic purposes. Hystero-pump is automated and ensures continuous fluid delivery at controlled pressure (Fig. 17). It is recommended for all procedures (especially operative) where interruptions may be detrimental.

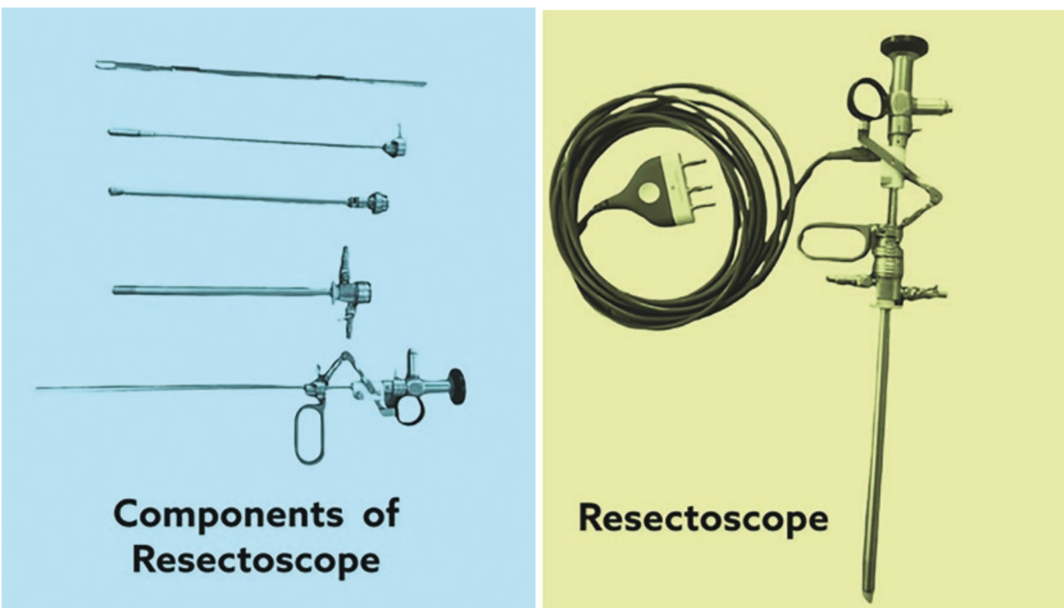


Fig. 15 Resectoscope with the different components


**Fig. 16** (**a**) Resectoscope with cutting loop (monopolar left and bipolar right). (**b**) Resectoscope electrodes (knife, ball, angle needle and cutting loop in action)


**Fig. 17** Automated fluid delivery system

## 3 Instruments for Special Applications in Gynaecology

### 3.1 Uterine Manipulator

They are used to elevate and change the position and degree of the version of the uterus during surgeries. They come in different configurations and sizes (Fig. 18).

### 3.2 Uterine Cannula

This is used to inject dye into the uterus during dye tests. They can also improvise for uterine manipulation but the degree of manipulation is limited. The Sparkman cannula (Fig. 19) is preferred because it can be anchored to the tenaculum, unlike the Leech-Wilkinson variety.

### 3.3 Tissue Morcellators

Sometimes during laparoscopic procedures, the tissue excised may be bigger than the size of the incision made and the retrieval of the tissue becomes a challenge. Rather than making a large incision for the sole aim of retrieving the tissue, the laparoscopic tissue morcellator (see Fig. 20a) is used to slice the excised tissue into strands/bits that can be retrieved through port sites.

There are also hysteroscopic morcellators. Examples are the TruClear hysteroscopic morcellator and the MyoSure tissue remover. Hysteroscopic morcellators are used for hysteroscopic polypectomy and myomectomy. See Fig. 20b.

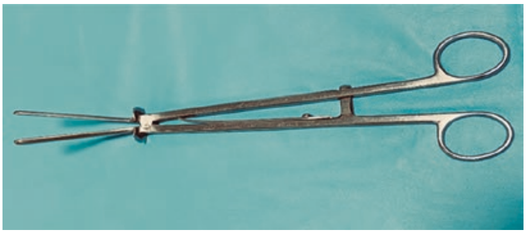

**Fig. 18** Mechanical uterine manipulator

**Fig. 19** Sparkman uterine cannula

### 3.4 Monopolar Drill

It is a monopolar instrument that is used for laparoscopic ovarian drilling in polycystic ovaries. See Fig. 21.

**Fig. 21** Monopolar drill

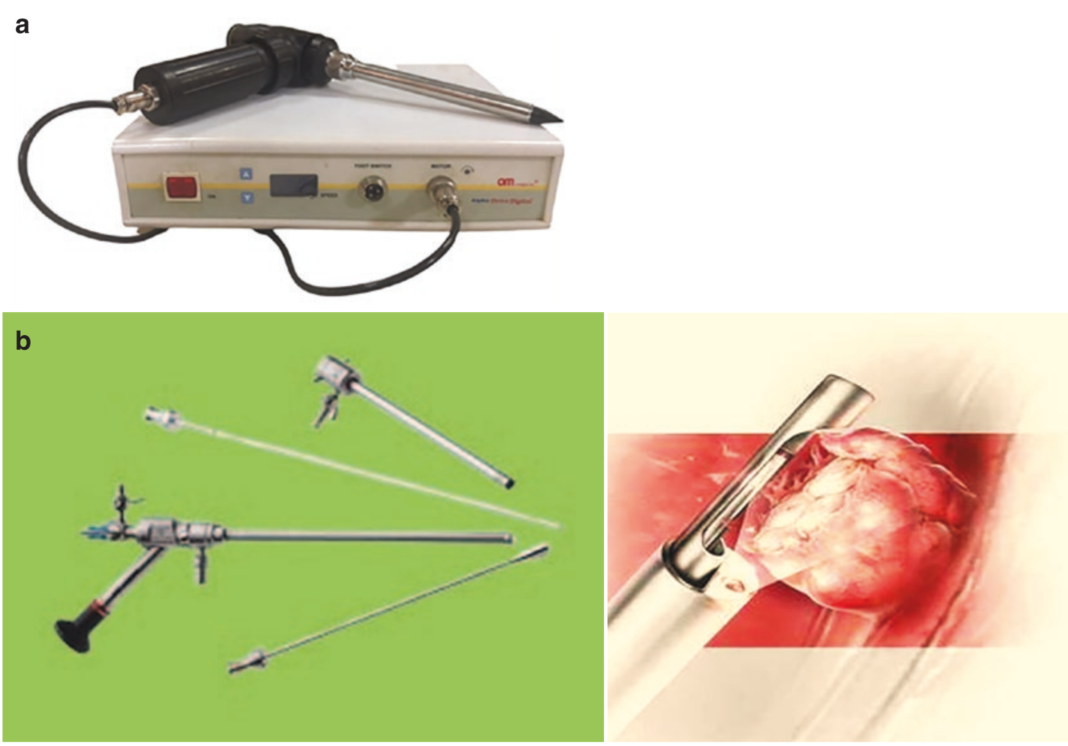

**Fig. 20** (**a**) Laparoscopic morcellator. (**b**) Hysteroscopic morcellator

**Fig. 22** Probe, myoma screw and striper

**Fig. 23** The needle driver/holder (straight, toothed and curved jaws)

### 3.5 Probes

Blunt probe is used for movement, displacement, stabilization and manipulation of mobile tissues (e.g. intestines and ovaries) during endoscopic procedure. See Fig. 22.

### 3.6 Myoma Screw and Striper

It is used in myomectomy for enucleation of uterine myomas (particularly the intramural types). See Fig. 22.

## 4 Instruments for Tissue Approximation and Haemostasis

These include instruments used for suturing and for application of clips and staples.

**A.** *The needle driver/holder* is used for suturing. The jaws could be straight, curved or toothed in some designs to include grasping function (Fig. 23). The handle may be straight or curved. The straight handle is considered to be ergonomically more suitable for suturing in varying situations.

**B.** *The clip applicator* is used to put the clips in place (Fig. 24). A sturdy clip applicator is preferred as the process of applying clips uses a lot of force. The clips come in three sizes – small, medium and large. The clip applicator similarly has detachable tips of different sizes to match the small, medium and large clip sizes.

**C.** *Laparoscopic staplers* are used for the application of surgical staples. The Endo GIA laparoscopic stapler is designed for gastrointestinal anastomosis but can be used in gynaecologic laparoscopy as a stapling device for securing haemostasis and dividing tissue (Dutta, 2013) [3]. After placing and firing the preloaded device, six staggered rows of staples, 3 cm in length and 1 cm in width, are left behind. A knife blade simultaneously divides the tissue, leaving three rows of staples on each side of the incision. See Fig. 25.

**D.** *Harmonic* makes use of ultrasound energy source, and hence, there is no risk of electrical injury. It is used in cutting or coagulation of tissues. It is effective in sealing of vessels up to 4 mm in diameter. See Fig. 10c.

**E.** *LigaSure:* It is used to cut, vaporize, coagulate and seal blood vessels. LigaSure works on bipolar technology. It is less likely to cause lateral thermal spread, sticking and charring of tissues. It seals blood vessels, up to 7 mm in size.

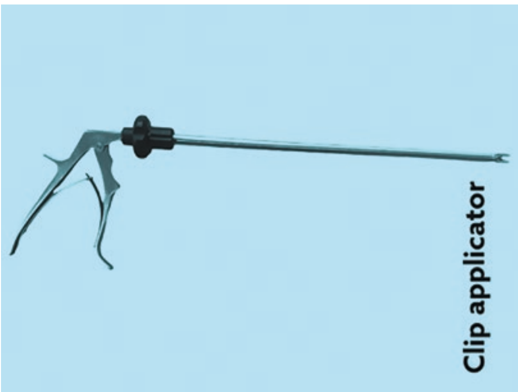


**Fig. 24** Clip applicator

## 5 Instruments for Access

### 5.1 Veress Needle

It is used to insufflate the abdomen with gas so as to create pneumoperitoneum (Fig. 26). It is available in reusable and disposable models. It contains a spring-loaded tip that retracts as it pierces the abdominal wall, allowing a blunt tip to engage on entry to the peritoneal cavity. The spring system helps to avoid injury to the bowel, intra-abdominal organs and major blood vessels [3].

### 5.2 Trocar and Cannula/Sleeve

They are used to pierce the abdominal wall and create a conduit for the placement of the laparoscope and hand instruments (Figs. 27 and 28). The cannula bears the trocar. After piercing the abdominal wall, the trocar is removed and the telescope or hand instrument is introduced through the cannula (sleeve). The trocar/cannula ranges from 3 to 15 mm in diameter so as to accommodate the various sizes of telescopes and instruments. Trocar and cannula are available as reusable, disposable and reposable systems.

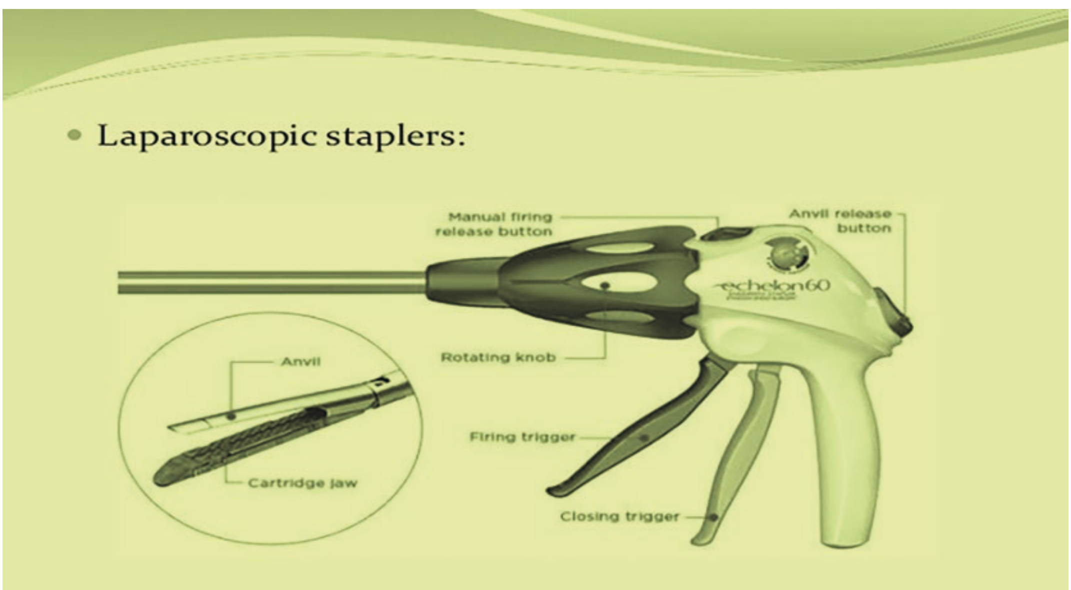


**Fig. 25** Laparoscopic stapler

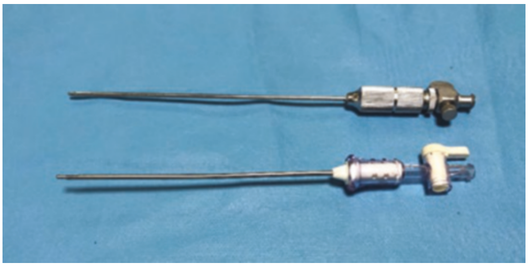

**Fig. 26** Veress needle (metallic reusable and plastic disposable)

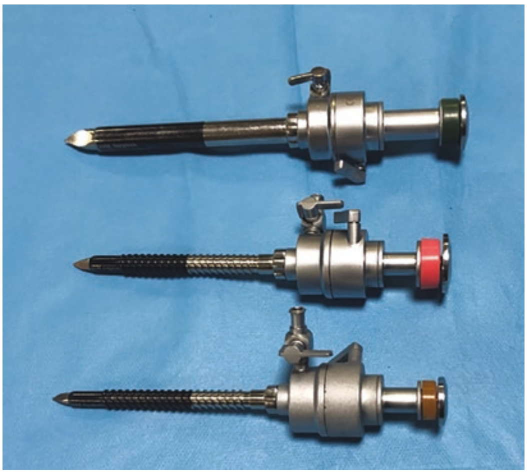

**Fig. 27** Trocar and cannula/sleeves (reusable). Different sizes 10 mm, 7 mm and 5 mm

Reusable trocars are cost-effective and sharpness must be maintained. They should be sterilized and properly prepared in between patients. In reposable systems, the sleeves are reusable, while the trocars are disposable. Most sleeves contain a Luer lock port that attaches to the insufflation tube. The tip of the trocar could be pyramidal, conical (reusable), bladed or blunt-tipped, or have optical access (disposable). Conical and blunt-tipped trocars make smaller fascial defects but require greater force to place. Optical access trocars enable the surgeon to visualize the layers of the abdominal wall during placement. Expandable trocar sheaths are available that are initially placed through the abdominal wall with a Veress needle and then expanded to accept a 5- to 12-mm port.

## 5.3 Single-Port Access Devices

Recently, there has been single-port laparoscopic surgery (Fig. 29). It involves the placement of a single large port, about 2–3 cm, which can accept up to three instruments. It is also known as single-port access (SPA) laparoscopy or single-incision laparoscopic surgery (SILS). It can be used in procedures such as salpingectomy for ectopic pregnancy and ovarian cystectomy [4, 5].

It is commonly observed that a surgeon stepping into the world of minimal access surgery would like to begin with less expensive instru-

**Fig. 28** Trocar and cannula/sleeves (plastic)

**Fig. 29** Single-port access device

ment options thereby possibly compromising on the quality aspect. It is our feeling that if anybody needs good-quality instruments, then it is the beginner. An experienced surgeon can do with any option available to him.

## 6 Endoscopy Units and Endovision System

The units assist not only in creating the right environment for surgery but also in making the surgery easier. The various units used during laparoscopic surgeries include insufflators, suction/irrigation apparatus, endovision system, diathermy/electrosurgical unit, morcellators and other emerging devices [6–9]. These are stacked on the trolley or pendant in the operating room. See Fig. 30.

**Fig. 30** Trolley containing the endoscopy unit (hybrid)

### 6.1 Insufflators

They are used to create controlled pneumoperitoneum. It controls the rate of flow of the gas and the intra-abdominal pressure. The rate of gas flow rate (L/min) and intra-abdominal pressure (mm of Hg) is usually displayed on the insufflator [3]. Depending on the demands of the application, you can choose between a standard flow or a high flow. High gas flow is usually used for LASER surgeries. Insufflators could be analogue or digital. Digital automated (microprocessor controlled) insufflator is recommended (Fig. 31). Some insufflators have provision for warming the $CO_2$ prior to insufflation. Good quality equipment is almost always a better option than a cheap one.

### 6.2 Electrosurgical Unit/ Diathermy

The electrosurgical generator is essential in minimal access surgery (MAS) for cutting and coagulation (Fig. 32). It is the commonest means of achieving haemostasis. Electrosurgical generators can be used in one of three modalities: bipolar, monopolar cutting (including pure cut and blended cut) and monopolar coagulation (including desiccation, fulguration and spray) [1]. Electrosurgical generators with both the monopolar and bipolar options are preferred to those with a single option. Generators with a tissue response option like in vessel sealer are available and preferable.

### 6.3 Endovision System

The endovision system comprises the camera, the light source, the light cable, the telescope and the monitor. They serve as the eye of the operating team.

#### 6.3.1 Light Sources

Various types of light sources are available and includes the halogen, metal halide, xenon and light emission diode (LED). The colour temperature of halogen light source is approximately 3600 K, and the metal halide is approximately


**Fig. 31** Digital automated insufflator

**Fig. 32** Electrosurgical unit (ESU)

**Fig. 33** Light source (LED) with fibre-optic cable in situ

5600 K, while xenon is approximately 6000 K. The best option is LED, which nowadays is available at a very reasonable price. Xenon has about 5000 hours of life and gives bright white daylight. However, LED has the advantage of a much longer life of 30,000 hours. See Fig. 33. During an endoscopic procedure, it is wise to have a spare light bulb should the bulb fail in the middle of a procedure [3]. This may not apply to LEDs due to the long life.

### 6.3.2 Light Cable

It is a fibre-optic cable that transmits the light from the light source to the telescope. It comes in different sizes depending on the size of the telescope. A 3.5-mm diameter light cable is used for telescopes of 4 mm and less, while a 4.8-mm light cable is used for greater telescope diameters. This is important not only for proper light transmission but also to avoid heating at the light guide end of the telescope. The appropriate light cable should be selected. Light cable should be handled with care as kinking and knotting can damage the fibres thereby reducing their ability to transmit light. See Fig. 34.

### 6.3.3 Camera Systems

The camera system consists of a camera head, cable and camera control. The camera head is attached to the eyepiece of the telescope. The basis of laparoscopic cameras is the solid-state silicon computer chip (SSSCC) or charge-coupled device (CCD). There are three types: high-definition (HD), three-chip, and single-chip camera. Select the one you can afford which also provides good vision as this is the basic requirement of the surgery.

The basic difference between a "single-chip" and a "three-chip" camera is that in the single-chip camera, all the three basic colours, i.e. red, green and blue, are processed by a single CCD chip, whereas in the triple-chip camera, all the three basic colours, i.e. red, green and blue are processed by individual CCD chips. The number of chips on the CCD determines the quality of the image. The high-definition (HD) camera ensures colour reproduction close to natural when combined with an LED light source. The image resolution is determined by the number of pixels on the chip [2, 3]. High-definition digital camera uses resolution up to 1100 lines to produce more vivid images. See Fig. 35.


**Fig. 34** Fibre-optic cable

### 6.3.4 Monitors

The monitor is the device that ultimately shows the picture. It is therefore necessary that the monitor is compatible with the camera system. For a single-chip camera, a monitor with 450-line resolution should be used. For a three-chip camera, a monitor with more than 600-line resolution should be chosen. For an HD camera, a high-definition monitor should be used. An LED television could be adapted to be used as a monitor. Today, 3D monitors are available and they provide a good appreciation of depth in pelvic laparoscopy surgery. In low-resource setting, the conventional LED flat-screen television can be


**Fig. 35** Camera with camera head (HD and 3D)


**Fig. 36** Monitors (high definition, left, and LED flat-screen TV, right)

**Fig. 37** Specimen retrieval bag

improvised and used effectively as a monitor with good imaging. See Fig. 36.

#### 6.3.5 Video Recorder

Recorded videos and images are useful for recording purposes, for evidence in medico-legal cases. Some companies have cameras with archiving systems.

### 6.4 Other Devices

#### 6.4.1 Specimen Retrieval Bag

They are specially made bags for retrieving delicate tissues (Fig. 37). It helps to preserve the tissue and prevents contamination of the port by the tissue being retrieved. Sometimes the use of retrieval bags may obviate the need for extending the incisions as larger masses when put in the bags can be removed through a posterior colpotomy via the pouch of Douglas.

### 6.5 LASER Devices

LASER is light amplification by spontaneous emission of radiation. Surgical LASER available for gynaecological use include carbon dioxide, argon, potassium titanyl phosphate (KTP), and neodymium/yttrium-aluminium-garnet (Nd:YAG). Carbon dioxide LASER is the most commonly used. They have the ability to vaporize, cut and, to varying degrees, coagulate tissue. The depth of tissue penetration depends on the type of laser used [3].

## 7 Robotics

**Robotic Systems:** The da Vinci Robotic surgical system and the Zeus Robotic Surgical system allow the surgeon to operate from a remote station with hand controls that can provide increased dexterity and minimize fatigue, tremors or incidental hand movements.

## 8 Conclusion

Laparoscopy and hysteroscopy seem to be the future of gynaecological surgery. Tremendous success has been achieved in widening their relevance and application in the diagnosis and treatment of various gynaecological conditions. Mastery of the instruments used in these minimal access procedures is important for proper utilization. Continuous practice is key to success in this field.

**Learning Points**

- The instruments for laparoscopic and hysteroscopic procedures are quite different from the ones used in open surgery though they perform similar functions.
- A good understanding of the workings of the instruments will make your surgery less stressful.
- Also, care of the instruments is important to prolong the life span.
- A regular update is necessary to meet up with the level of advancement in instrument design.
- The proper set of these instruments in the operating room is essential to a successful procedure.
- A good biomedical or instrument engineer is required at all times in the facility to assist with maintenance and set-up.

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# Sterilization of Endoscopic Instruments

John O. Imaralu, Idris Haruna, and Hyacinth Onah

## 1 Introduction

The gynaecologic endoscopic instruments are essentially the laparoscopic and hysteroscopic instruments. They, however, bear a lot of similarity to instruments used in other forms of minimal access surgery like bronchoscopy, thoracoscopy, arthroscopy and instruments used in natural orifice transluminal endoscopic surgery (NOTES) such as upper and lower gastrointestinal endoscopy. It is these shared peculiarities in structure and reprocessing needs that differentiate them from instruments used in open surgery. These features include their complexity in design, more delicate to handle, possession of more articulations and joints and possession of crotchets, ratchets and locks. They are also longer and contain more crevices and lodging spaces for tissue debris and microorganisms. These characteristics, in addition to their higher cost, create the demand for special consideration and detail in maintenance, cleaning and sterilization.

Endoscopic instruments come in two major forms: single-use instruments (SUIs) or devices and reusable instruments (RIs). Two major considerations in the evolution and advancements in these sets of instruments are based on the safety of the patients (limitation of iatrogenic cross-infection) and cost of instrument procurement and maintenance. SUIs are generally more expensive than RIs; they can be as high as nine times the cost of RIs [1]. The use of RIs is thus inevitable especially in resource-poor settings or in settings where healthcare financing is a challenge. They have been shown to be cost-effective even after maintenance and reprocessing costs have been considered [1–5]. Studies have also suggested the reprocessing of single-use laparoscopic instruments (SULIs), based on reports of similarity in the outcome of successful sterilization rates between SULIs and reusable laparoscopic instruments. The major challenges of this practice, however, are the fact that some instruments may not function properly again after a single use and legislation against reprocessing SULIs in some climes [6].

The expectations of better cosmetic outcomes and less morbidity from minimal access surgery may be frustrated when a surgical site infection complicates this procedure. As high as one-third

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of cases of laparoscopy-related infections may be missed because of early discharge from the hospital [7]. More than half of the 'Ten Commandments' for preventing laparoscopy infections propounded by Prakash et al. deal with issues relating to endoscopic instrument handling and reprocessing [8]. Properly reprocessed endoscopic instruments will not only prevent iatrogenic cross-infection but also prolong the lifespan of the instruments.

## 2 General Infection Risks and Rates in Minimal Access Surgery (MAS)

### 2.1 The Types of Infections in Endoscopic Surgery

According to the CDC, surgical site infections (SSIs) are categorized into [9]:

1. Superficial SSI: involving the skin and subcutaneous layer
2. Deep SSI: involving the fascia and muscle
3. Organ/space SSI: involving specific organs or recesses around organs, e.g. sub-hepatic abscess, peritonitis, etc.

Surgical site infections refer to infections complicating or due to incisions whether in conventional open or minimal access surgery. The term 'SSI' as related to laparoscopic surgery is referred to as 'port site infection' (PSI).

SSI is commoner in conventional surgery than in minimal access surgery [10–12]. Laparoscopic surgeries have an infection rate (PSI) of 8–9% [13]. Some of the reasons for these lower SSI rates with minimal access surgery (MAS) include less tissue trauma and the consequent lower severity of metabolic and immunologic response. There is also less exposure of tissues to exogenous contamination.

Surgical procedures done by laparoscopy belong to the CDC classes 1 and 2 of wound categories [9]. The classification system for wounds is as follows:

1. Clean wound: a surgical wound that neither is exposed to any inflamed tissue nor has breached the gastrointestinal, respiratory, genital or uninfected urinary tract.
2. Clean-contaminated wound: a surgical wound where there is controlled entry into the gastrointestinal, genital or uninfected urinary tract with minimal contamination.
3. Contaminated-fresh wounds related to trauma, surgical wounds with a major breach in sterile technique or gross contamination from the gastrointestinal tract and other incisions through nonpurulent inflamed tissues.
4. Dirty or infected wounds, old wounds, following trauma, having devitalized tissue and surgical procedure performed in the presence of active infection or visceral perforation.

## 3 Organisms Responsible for Infections in MAS

Exogenous flora from any contaminated sources present in the sterile surgical field such as instruments, room air or surgical team has been implicated in PSI [14].

The pathogenic organisms causing SSIs differ with the procedure performed. For clean wounds, *Staphylococcus aureus* from patient's skin or exogenous source is often the culprit, while in clean-contaminated, contaminated and dirty surgical wounds, organisms are often polymicrobial, and in many cases, they are endogenous flora of the target organ [14]. A study on clean laparoscopic surgeries reports that hospital-acquired pathogens were responsible for all cases of port site trocar-related infections and not umbilical commensals [13].

Laparoscopy-related infections can be divided into two based on the timing of onset of symptoms: early onset, which is commoner, with patients presenting within a week of endoscopic surgery or while still in the hospital. This type is often due to gram-positive or gram-negative bacteria contracted from patients' skin or infected surgical site. The other type (late-onset) is caused by rapidly growing atypical *Mycobacteria* species with incubation periods ranging between 3 and 4 weeks. This second type of infection is characterized by a poor response to the usual antibiotics [15].

### 3.1 Non-Mycobacterial Isolates

Superficial SSI is the most common type of infection in MAS and *Staphylococcus aureus* is the commonest isolate. Other organisms that have been implicated include *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Acinetobacter* spp., *Proteus* spp., *Escherichia coli* and *Citrobacter freundii*. In deep surgical site infection, *Klebsiella* spp. is the commonest offending organism [16].

### 3.2 Mycobacterial Isolates

Rapidly growing mycobacteria, especially *M. fortuitum* and *M. chelonae*, have been isolated from laparoscopy infection sites. These microbes have been demonstrated to cause disease in man and animals; they are saprophytes whose spores can be found in sewage, soil and tap water which they colonize [16]. They are especially capable of producing disseminated infection in immunocompromised individuals. In man, the skin and subcutaneous tissue are their target sites. The source of an outbreak of PSIs due to *M. chelonae* was found in an audit to be water used for washing instruments after chemical disinfection [17].

These exogenous sources of laparoscopic infections are totally avoidable. The most common mechanism of laparoscopic infections with atypical mycobacteria is a breach in sterilization protocol for laparoscopic instruments. The joints, crevices and locks of these instruments can hide tissues and the use of such instruments without proper reprocessing would result in contamination with atypical mycobacteria endospores, which may get deposited in the subcutaneous tissue or skin of patients and then germinate in 3–4 weeks [18].

## 4 Classification of Devices Based on their Processing Needs

Generally, instruments or devices can be classified, based on the degree of sterility required, into:

1. Critical items

   The devices in this category pose a high risk of infection if contaminated with microorganisms, including bacterial spores. Their sterility must not be in doubt, since they would come in contact with sterile tissue or enter the vascular system. Instruments in this category include cardiac pacemakers, cardiac and urinary catheters, implants and needles. Laparoscopic instruments in this category include hand instruments and energy devices like harmonics. They should either be purchased sterile or used only once (disposable) or sterilized, if reusable.
2. Semi-critical items

   These instruments come in contact with the mucus membrane of individuals or skin that is not intact. This group of instruments includes endoscopes and other endoscopic instruments, anaesthesia equipment and the transvaginal ultrasound transducer. These instruments require high-level disinfection for their processing.
3. Non-critical items

   These are items that come in contact with intact skin but not mucus membranes. The intact skin of a normal immune-competent person is an effective barrier to most microorganisms and thus sterility is not essential. Examples of endoscopic items in this group include fibre-optic and insufflation cable, suction/irrigation tubing and diathermy cables. Others include bedpans, blood pressure cuffs, crutches, bed rails, bedside table, patient furniture and some food utensils.

## 5 General Principles of Infection Control in Endoscopic Surgery

### 5.1 Definition of Terms

Instrument reprocessing refers to all the procedures involved in the handling, removal of contaminants, transport, sterilization or disinfection, storage and other maintenance of endoscopic instruments, done to make them safe or more effective for use or to prolong their lifespan.

Sterilization is the absolute elimination or destruction of all forms of microbial life. It can be achieved with steam, gas or chemicals [19].

Disinfection is the relative elimination of pathogenic organisms except for spores. Disinfection can be subdivided into:

1. High-level disinfection (HLD)—where all life forms except spores are destroyed.
2. Intermediate-level disinfection (ILD)—where some fungi, viruses and spores are spared.
3. Low-level disinfection (LLD)—where fungi, viruses, spores and some mycobacteria remain undestroyed.

For endoscopic instruments, sterilization and at least high-level disinfection is required to prevent iatrogenic infection.

Decontamination, according to the Occupational Health and Safety Agency (OSHA) of the United States Department of Labor, can be defined as the use of physical or chemical means to remove, inactivate or destroy blood-borne pathogens on a surface or item to the point where they are no longer capable of transmitting infectious particles and the surface or item is rendered safe for handling, use or disposal [20].

Cleaning refers to the removal of microorganisms or microorganism-bearing items on surfaces and instruments, by physical or chemical means. Cleaning and decontamination are often used interchangeably in clinical practice.

## 5.2 When Should Instrument Processing Begin?

The cleaning of endoscopic instruments should begin during the surgical procedure to prevent drying of blood, soil and debris on the surface and within the instrument lumen.

## 5.3 Where Should Instrument Processing Be Done?

The decontamination and cleaning room or section should be separate from where sterilization takes place and where sterile instruments are kept to avoid cross-contamination. This should preferably start in the theatre and subsequent decontamination process in sections or a room between the theatre and the CSSD, or a room in the CSSD separate from where sterile instruments are kept or where sterilization is done. High-level disinfection should preferably be done within the theatre suites and complexes. Sterilization can be done as in-hospital sterilization where facilities exist or as 'third party' where instruments are taken to larger hospitals with large-scale sterilization units or departments or centres dedicated to hospital instrument sterilization.

## 5.4 Who Should be Responsible for Instrument Care and Processing?

In many hospitals, the perioperative nursing departments handle this. Other professionals involved include the certified surgical technicians (CST) who have undergone formal training including certifications and have proficiency in equipment handling; they act as supports or interface between the surgeons, the instruments, the equipment and the perioperative nurse. Other healthcare workers involved can be surgeons and surgical assistants themselves. Endoscopic instruments and equipment handling require training because of the complexity, fragility and high cost. Their care should not be left in the hands of unskilled persons. Some manufacturers actually specify the level of skill of persons that should handle their instruments and do have guidelines that come with the instruments.

The OSHA regulations stipulate that: 'Health care workers involved in handling and reprocessing of contaminated instruments and devices should complete initial education, training and competency validation on the use of decontamination processes and procedures, the use of machines, chemicals used and the Personal Protective Equipment (PPEs)'. They should have initial training, continuing medical education (CME) programmes, and other evaluations on the job [20].

## 6 Steps in Endoscopic Instrument Reprocessing [21]

The steps in endoscopic instrument reprocessing include the following:

1. Dismantling
2. Decontamination
3. Pre-cleaning
4. Cleaning and rinsing
5. Rinsing-ultrasonic cleaner
6. Drying-packaging for sterilization
7. Sterilization/disinfection
8. Instrument storage

### 6.1 Dismantling

Most laparoscopic hand instruments exist as articulations of different parts which should be separated as the first step in processing. This exposes the grooves and crevices which may harbour tissue debris and microorganisms. The ports (trocars and cannulae) and sheaths used in hysteroscopy should all be dismantled for proper processing.

### 6.2 Decontamination

This process should start in the operating room; it reduces the load of microorganisms and renders the instruments safe for handling prior to further processing and transfer to the CSSD. The trained healthcare worker (nurse or certified surgical technician) should wipe off any visible tissue, debris, body fluid or bloodstain from the instrument with a sterile but damp sponge. The instruments are then immersed inside a receiver containing disinfectant such as 0.5% chlorine or hypochlorite solution. They are allowed to soak for 10 min. There is no benefit in soaking for longer as this predisposes them to corrosive damage (Fig. 1).

**Fig. 1** Decontamination: the instruments should be immersed in the disinfectant

### 6.3 Pre-Cleaning

This should be done in the CSSD or in the theatre, away from the operating room or any other controlled area within the theatre, but not where sterile instruments are kept. The preferred pre-cleaning method involves the use of enzymatic products such as protease, lipase and amylase. These proteases break down blood and other protein stains on the instruments; they should, however, be thoroughly removed from the instruments by cleaning. The use of detergents and soap scrubs may not be effective, because of their limited capacity to lyse protein debris especially on the surfaces of instruments with areas that are hard to reach for cleaning (Fig. 2).

### 6.4 Cleaning and Rinsing

Cleaning should be done with soft brushes so that debris can be removed from the groves of instruments. Rinsing is best done under running water


**Fig. 2** Enzymatic products are preferred for pre-cleaning

to clear all particulate matter and chemicals used for decontamination, pre-cleaning and cleaning.

High-pressure running water taps or cleaning guns, where available, can be used for rinsing. These guns give a directed jet of water to long instruments and instrument grooves. Stagnant water in containers should be avoided during manual cleaning as it may retain particles and solutions which may get on to other instruments. All instruments should be open during the cleaning process, to expose ratchets and locks and indeed all parts of the instrument to the cleaning agent. If cleaning and rinsing are done together, re-rinsing or proper rinsing must be done again after a brush or other forms of cleaning.

Ultrasonic cleaning is a method that is rapidly increasing in popularity. The ease of use, time saved and better efficiency make it a better method than manual cleaning. Ultrasonic cleaning is 16 times more efficient than hand cleaning.

The solution used for ultrasonic cleaning should have a neutral pH (to prevent corrosive damage) and instruments should be immersed in it for 10–15 min. Instruments made of similar material—metals such as aluminium—should be cleaned together separate from other instruments made from, for example, stainless steel and other materials. To allow optimum penetration and effect, the ultrasonic cleaner should not be overloaded and all instruments must be open. Rinsing must be done for all instruments that have undergone ultrasonic cleaning.

## 6.5 Drying

It is necessary to exclude water droplets from the instruments before they are packed for sterilization. This can be achieved with the use of an oven in the CSSD or an air gun.

## 6.6 Sterilization or Disinfection

It is widely recommended that rigid endoscopic instruments should be sterilized or at least high-level disinfected where sterilization is not feasible. Users of endoscopic instruments, however, should take note of manufacturer information regarding what to sterilize or high-level disinfect, the method of sterilization, the type of disinfectant to be used, their dilution instructions and the number of times or length of time a constituted high-level disinfectant solution can be used.

Sterilization is superior to HLD, for infection control; however, because of the fragile nature of some instruments, sterilization methods may not be feasible. The cost and availability of the sterilization methods are also important considerations.

### 6.6.1 Sterilization

There are three major sterilization methods:

1. Steam sterilization
2. Gas sterilization
3. Peracetic acid sterilization

- **Steam Sterilization**

  The use of the autoclave for sterilization is one of the commonest methods employed. It is cheap and non-toxic yet an effective method. Autoclaving at 121 °C for 15 min is sufficient for all reusable metal instruments. This method is effective for all rigid endoscopic instruments and some telescopes. Packaging of instruments for steam sterilization should be such that all items that can be damaged by heat conduction like silicone tubing, rubber insulations and coatings on cables and instruments are shielded by wrapping in two layers of linen to prevent contact with the metal container of the autoclave.

**Some Notes on Flash and Vacuum Sterilization**

1. Flash Sterilization

   This was defined by Underwood and Perkins as sterilization of unwrapped items at 132 °C for 3 min at 27–28 lbs of pressure in a gravity displacement sterilizer [22]. It was designed for use in the theatre for emergent and immediate use of a forgotten or unanticipated instrument or one that was accidentally dropped on the floor. It is a modification of conventional steam sterilization whereby the flashed item is placed in an open tray or is placed in a specially designed, covered, rigid container to allow for rapid penetration of steam. The term "immediate-use sterilization" currently replaced flash sterilization. It is sterilization with little or no dry time available. It is safe and efficacious when done correctly and when only used to process instruments intended for immediate use. It should not be used for reasons of convenience or to save time.

2. Vacuum Sterilization

   A sterilizer configured to run a vacuum cycle is equipped with a vacuum system. A typical vacuum cycle will begin with a series of alternating steam pressure injections and vacuum draws (also called pulses) to dramatically remove the air from the chamber. This will allow steam to be sucked into areas where it would otherwise have difficulty penetrating.

- Low-Temperature Steam and Formaldehyde Sterilization

  This method is especially suited for heat-sensitive instruments like cables, insulations, tubes and instruments with blind-ending lumina. It employs heat at temperature ranges of 55–80 °C, for about 5–6 h. It is important to note that the use of formaldehyde for sterilization is fast diminishing in popularity; some reasons for this include the potential risk for toxicity and irritation when in contact with the skin, eyes, nose and respiratory tract. Its efficacy in the sterilization process is being queried in reports from some studies.
- **Gas Sterilization**

  Gas sterilization is useful for hand instruments that are coated with insulation material, light cables and tubing for gas and suction irrigation. Disposable instruments can also be reprocessed using this method. Ethylene oxide (ETO) is the gas that is used for gas sterilization. Cold ETO sterilization is done at a temperature of 85 °C and instruments are exposed to the gas for 4 h 30 min, and they are then aerated for 12 h. Warm ETO sterilization is, however, done at a temperature of 145 °C with instrument exposure of 2 h 30 min and a shorter aeration time of 8 h. Gas sterilization has the advantage of ensuring that porous materials and deeper instrument areas are reached without corrosive damage to them. Its demerit, however, is that the set-up is expensive and the required steps of exposure and aeration consume a lot of time.
- **Newer Methods of Sterilization**

  This method uses the plasma chamber (STERRAD) developed by Johnson and Johnson. It uses hydrogen peroxide vapour and low-temperature gas plasma. The entire process with this method takes only about 25 min. The instruments should have undergone the earlier decontamination-cleaning cycle and should have been properly packaged. A vacuum is created inside the equipment chamber and 59% aqueous $H_2O_2$ is vaporized into it, enveloping all the items until when the $H_2O_2$ vapour is well diffused. The chamber pressure is then reduced to allow the generation of low-temperature gas plasma. A radiofrequency amplifier is used at this time to introduce radiofrequency energy into the chamber—thus causing the generation of reactive free radical species from the vapourized $H_2O_2$ which comes in contact with the instruments. The reactive energy species also react with each other to form water vapour, oxygen and other non-toxic by-products. The instruments are then dried by the equipment and are ready for use or storage. The advantages of this new method that make it cost-effective include the fact that it can be used in areas where there is rapid turnover and a shorter processing time is required. There are no toxic residues and there is no requirement for aeration or water hook-up within the set-up. The equipment is not big and does not take space; it requires only a reliable source of electricity supply.

### 6.6.2 Disinfection

High-level disinfection (HLD) is particularly useful for semi-critical instruments and fragile heat-sensitive instruments. Its effect on spores is, however, relative and depends on the duration of exposure of microorganisms to disinfectant, the concentration and temperature of the disinfectant, the amount and kind of microorganisms, organic material (blood, other fluids, tissues) and other matter (for example, dirt) present on the instrument or other item and the access to the microorganisms (for example, grooves can shield microorganisms). It is therefore pertinent that instruments for HLD undergo the preliminary phases for thorough decontamination.

HLD destroys all pathogenic microorganisms and some bacterial spores (e.g. *Clostridium difficile*) during short exposure. During long exposure, it is sporicidal for a higher number of bacterial endospores and has a limited sporicidal capability for mycobacteria, viruses and fungi. Mycobacteria are used as indicators of effectiveness. The agents that are popularly used for HLD include 2% glutaraldehyde, 6% stabilized hydrogen peroxide and peracetic acid (a mixture of acetic acid and hydrogen peroxide).

The ideal chemical high-level disinfectant should have the following characteristics:

1. Rapid turnover rate HLD (<10 min).
2. Effective against a wide range of organisms including blood-borne viruses and prion proteins.
3. There should not be any disinfectant residue after rinsing.
4. Excellent compatibility with endoscopes and other instrument materials.
5. Long shelf-life.
6. Non-irritant and non-toxic to users.
7. Environment-friendly, i.e. have no disposal problems.

- **Glutaraldehyde**
  This is the most recommended chemical disinfectant agent, by most laparoscopic instrument manufacturers. Some of its advantages include the following: it is safe, is relatively inexpensive, has good microbicidal activity, is non-corrosive to optics, and is effective in the presence of protein matter. It is, however, irritating to the eyes, skin (allergic contact dermatitis), and respiratory mucosa especially at higher concentrations ≥0.3 parts per million (ppm). It has a pungent and irritating odour and can coagulate and fix blood and tissues to surfaces. It thus requires thorough rinsing off from the instrument before use. Most commercially available glutaraldehyde solutions can be used (after preparation) for between 14 and 30 days. The manufacturer's preference for the duration of usage varies and it is advisable that this is followed. The effectiveness of glutaraldehyde as an HLD depends on its concentration, the instrument contact time, the physical configuration of the instrument, temperature, pH and the amount of organic matter on the instruments. The OSHA recommends that the maximum allowable concentration of glutaraldehyde is 0.2 ppm. Instrument exposure can however be varied to suit the HLD needs, for instance, fibre-optic light source cables and telescopes should be soaked for a minimum of 10 min. The endocamera (charge-couple device [CCD] only) can also be soaked in 2% glutaraldehyde for 10 min, but care must be taken to avoid soaking the plug part of the cable. Soaking of optical instruments should be for not more than 20 min. Metallic hand or accessory, trocars, reducers, ring/clip applicators and dye injectors should be soaked

in 2% glutaraldehyde for 60 min (long exposure) to achieve better destruction of mycobacterial spores. Glutaraldehyde is marketed with trade names as Cidex or MetriCide. Another form known as rapid Cidex or Rapicide exists which provides for shorter instrument exposure of 5 min.

A particular non-tubercolous mycobacterium, *M. massiliense* BRA100 strain, has been found to be resistant to high-level disinfection with glutaraldehyde, even at high concentrations (7% glutaraldehyde), thus suggesting that glutaraldehyde may not be effective for rapidly growing mycobacteria. Orthophthalaldehyde (OPA) and peracetic acid may substitute glutaraldehyde for HLD with better efficacy [23].

- **Orthophthalaldehyde (OPA)**
  This is sold as Cidex OPA and it exists in the concentration of 0.55%. This agent can provide effective high-level disinfection and can destroy all bacteria, fungi and mycobacterial spores with instrument exposures of as short as 5–12 min. Its minimum effective concentration is 0.3%, and after preparation, the solution can still be effective for 14 days. It is non-irritant to the eyes and mucus membranes and non-corrosive to instruments and has a weak odour. Its disadvantages, however, are that it is expensive and stains protein grey, and hypersensitivity reaction has been reported in some patients with a history of bladder cancer [19] (Fig. 3).


**Fig. 3** Orthophthalaldehyde (OPA)

- **Notes on Hydrogen Peroxide and Peracetic Acid for High-Level Disinfection**
  The characteristics of an ideal chemical sterilant used as a high-level disinfectant should include broad antimicrobial spectrum, rapid activity and masterial compatibility. The ideal HLD should be odourless, be safe, have prolonged shelf-life, and be generally cost-effective. Hydrogen peroxide and peracetic acid are both oxidizing agents that generate free radicals which can attack membrane lipids, DNA and other essential cell components. Cidex PA is one brand of high-level disinfectant that contains 0.08% peracetic acid and 1.0% hydrogen peroxide [24, 25]. It inactivates all microorganisms within 20 min with the exception of bacterial spores. The risk of corrosive damage to instruments is a major drawback to this disinfectant. Olympus does not endorse Cidex PA on any of their endoscopes and will not assume any liability for chemical damage. The manufacturers of Cidex PA currently are reformulating this product (altering the buffer system and changing anti-corrosive inhibitors) to improve its material compatibility.

### 6.6.3 Quality Control Measures for Sterilization and Disinfection

- *Bacteria indicator count:* Cultures swabs should be taken from the telescope and other instrument tips and surfaces routinely.
- *Strip checks on the disinfectant:* Manufacturer directions should be followed.
- *Temperature and pH monitoring:* They are also essential, for optimal effect of the sterilants and chemical disinfectants.
- *Keep a log for accountability:* This includes a log reporting entry and exit of instruments at every stage of reprocessing with timing properly recorded. A log of both instrument and sterilant usage frequency should also be kept.

## 7 Storage of Processed Endoscopic Instruments

The proper storage of processed unused instruments is very important. It is recommended that high-level disinfection be done when instruments are needed for use, because of the short processing time involved. However, because sterilization is more expensive, time-consuming and tedious and has greater potential to eradicate all forms of microbial existence, storage of sterilized instruments becomes expedient. In addition, third-party sterilized instruments would need storage when they arrive at centres where they are required before use, or before transport to centres where they are required.

Effective storage of endoscopic instruments to prevent contamination should take note of the following points: the storage shelves and cabinets (whether open or closed) should be dry or have very low humidity, the material used for wrapping the instruments should be such that would remain intact and dry, handling of sterile packs not meant for use should be limited, and the storage time should be kept as minimal as possible, to prevent moisture and contamination.

## 8 Notes on Emerging Disease Pathogens Related to Endoscopic Surgery

As minimal access surgery becomes increasingly available, it becomes more accessible to patients with chronic infectious diseases. Examples of these infections include hepatitis C virus, HIV, *Clostridium difficile*, *Cryptosporidium*, antibiotic-resistant microbes (MDR-TB, VRE, MRSA), *Helicobacter pylori*, newer strains of *E. coli*, coronaviruses (SARS-CoV and MERs-CoV) and Creutzfeldt-Jakob disease (no brain, eye, or spinal cord contact).

Standard disinfection and sterilization procedures for patient and equipment care are adequate to sterilize or disinfect instruments or devices contaminated with blood and other body fluids from persons infected with emerging pathogens. Where there is doubt, disposable or single-use endoscopic instruments should be used.

## 9 Conclusion

Endoscopic surgical equipment and instruments are peculiar for their complexity and high cost; the level of disinfection or sterilization is dependent on the intended use of the item. Critical items (devices that contact sterile tissue such as surgical hand instruments) require sterilization, while semi-critical items (devices that contact mucus membranes such as endoscopes) require a minimum of high-level disinfection, and non-critical items (objects that contact intact skin such as electrosurgical return plates, patches and cables) require low-level disinfection. Cleaning should always precede disinfection and sterilization.

**Learning Points**

- Endoscopic instruments are complex in design and contain many articulations and crevices where tissue debris and microorganisms can get lodged.
- The focus of endoscopic instrument reprocessing includes the prevention of hospital-

acquired surgical site infections and prolongation of instrument lifespan.

- Most laparoscopic instruments can be classified as semi-critical devices and high-level disinfection is considered appropriate.
- All the preliminary steps in endoscopic instrument processing should be followed to aid effective sterilization or disinfection.

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# The Electrosurgical Unit: Basic Principles for Practice

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## 1 Historical Perspective

Human beings have traditionally been dependent on fire for their very existence; unsurprisingly its use for medicinal purposes was initiated shortly after its discovery [1, 2]. Cautery is mentioned in some very early medicinal texts credited to Hippocrates [2, 3]. It was used to stop bleeding from injuries, amputations, etc.

From the late eighteenth century up until the late nineteenth century, the discovery of electricity and its application rose exponentially. Several renowned scientists including Galvani, Becquerel, Sèrè, D'Arsonval, Doyen and Nagelschmidt were pioneers in the field of electricity and its use in medicine.

The basic electrosurgical unit was produced by William Bovie. His invention was tested in 1926, while its use during surgery for a vascular myeloma was carried out by Dr. Harvey Cushing [4]. Since the first 'Bovie' unit was used, many modifications have been introduced to make this instrument a safe and important part of the surgeon's armamentarium.

It works by applying the principle that passing an alternating current through tissues generates certain effects which the surgeon can leverage to improve surgical precision and reduce bleeding during procedures. Intimate knowledge of the principles of electrosurgery is paramount for current surgical practice [5].

## 2 Biophysical Principles

The three main properties of electricity are current (I), voltage (V), and impedance (R).

**Current** is a measure of the movement of electrons within a circuit. It is measured in *amperes*.

**Voltage** expresses the force required to push electrons through a tissue; this is measured in *volts*.

**Impedance/resistance** is a measure of the difficulty the current must overcome to pass through a given substance (i.e., biological tissues); it is measured in *ohms*.

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In an electric circuit, these three properties are expressed by **Ohm's law: I = V/R**.

**Power** is the ability to do work per unit of time and is measured in *watts*. It is mathematically expressed as the product of voltage and current W = **V × I**

Since I = V/R,

Then W (power) = V × V/R = $V^2$/R

Or W = V × I = $I^2$R

Heat/energy produced = W × T (time) = $I^2$RT

## 3 Types of Current

### 3.1 Direct Current

As seen in computer and car batteries. Here the current is unidirectional and does not change polarity.

### 3.2 Alternating Current

where the current changes direction (polarity) periodically as seen in our home electrical outlets.

Application of direct current during surgery would lead to an electrolytic effect causing generation of sodium hydroxide and hydrogen chloride. These would have a seriously deleterious effect on the cells leading to necrosis. The use of low-frequency alternating currents (under 10,000 Hz), apart from causing similar problems, also predisposes to stimulation of nerves and muscles (Faraday effect) [6]. Due to these unwanted effects, the current used in electrosurgery is *high-frequency alternating current* (over 300 kHz).

From the above, it can be surmised that the human body, when inserted into an incomplete circuit, completes the circuit and conducts electricity. When voltage is applied across the human body, its electrons are forced to move. The tissues of the body resist the flow of these electrons and in doing so cause a local rise in temperature. The thermal energy occurring in these areas of the body causes local tissue damage and destruction.

The biophysical principle equations above show clearly that the voltage is directly proportional to the power produced and also the tissue destruction it produces. Also, the time the electrode is applied is directly proportional to the thermal effects generated. The surface area of the electrode used or the tissue in contact is inversely proportional to the heat produced at the site of application per unit time.

### 3.3 Thermal Effects on Tissue

Electrical currents when passed through tissues particularly those with a high fluid content cause movement of molecules and subsequent heat generation. The tissue effect of this heat varies at different temperatures.

## 4 The Electrosurgical Generator (Electrosurgical Unit [ESU])

In the earlier section on the type of current, the alternating high-frequency current was recommended as most appropriate for electrosurgery. To generate this current, special equipment called electrosurgical generators are used. They ramp up the normal current frequency seen in house/theatre outlets from 50–60 Hz to 500,000–3,000,000 Hz [7]. This very high frequency does not allow the faradic effect.

The tissue effect of this current depends on several factors, but the thermal damage on tissue is generally directly proportional to the volume of current passing through it. This thermal effect is a function of current density.

The size/cross-sectional area of the electrodes determines the density of the current at its tip. Smaller electrodes have a larger current density than larger-sized electrodes. Various tissue types have different electrical resistance, which affects the rate of heating. Adipose tissue and bones have high resistance and are poor conductors of electricity, whereas muscle and skin are good conductors of electricity and have low resistance.

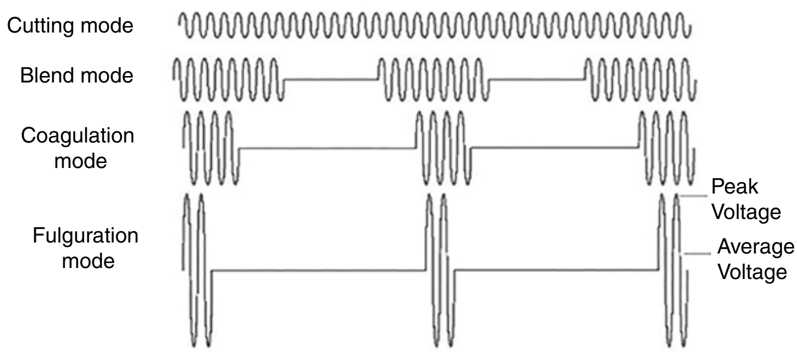


**Fig. 1** ESU output modes

The output from the generators can be modified to produce specific tissue effects. The various outputs are determined by the shape of the waveform and the duration of the specific duty cycle (the term duty cycle is used to describe the percentage of time that the ESU is producing a waveform—if it is 80% of the time, it is referred to as an 80% duty cycle).

Output modes include *cutting, coagulation, blend, and fulguration modes* (*see* Fig. 1).

### 4.1 Cutting Mode

This mode has a continuously high current and low-voltage waveform, causing a very rapid rise in temperature of up to 100 °C. As earlier noted, this causes vaporization of cell fluid and disruption of their membranes, thus resulting in cutting with no coagulation. The duty cycle in this mode is 100%. A power setting between 40 and 80 Watts is ideal for this mode [8].

### 4.2 Coagulation Mode

This is a high-voltage mode with the waves dampened and produced in bursts. The duty cycle in this mode is typically 6%. The pulsed nature of the current delivery allows for cooling of the tissues in between pulses and minimizes the cutting effect while allowing for the production of coagulum due to dehydration and denaturing of the tissue proteins. This coagulum is very effective for haemostasis. The coagulation current is operated with a power setting between 30 and 50 Watts [9]. The coagulation mode can be used for desiccation or fulguration depending on the active electrode positioning to the target tissue.

### 4.3 Desiccation

Using the coagulation mode, the surgeon can desiccate (loss of water from the tissue cells but no significant protein damage). The end result is deeper necrosis and greater thermal spread. For desiccation, direct contact of the electrode with the target tissue is necessary.

### 4.4 Fulguration

This is coagulation in a non-contact position. The electrode is held 2–4 mm away from the target tissue. An arc of current is formed which finds its way to the tissue in a spray-like effect, hence the name ‘spray coagulation’. This is due to the rapid rise in temperature and subsequent rapid cooling resulting in superficial coagulation, typically to a depth of about 0.5 mm. It covers a wider area than the surface area of the electrode alone. Its benefit is seen in small arteriolar and capillary bleeding.

### 4.5 Blended Current (Cut/Coagulation)

Blended currents are actually modulated low-voltage waveforms. It produces different tissue effects by modulating the duration of the duty cycle in the generator. It combines the cutting and coagulation modes at different percentages. Hence, we have blend 1 (duty cycle 50%), blend 2 (duty cycle 40%), and blend 3 (duty cycle 25%).

## 5 The System

The electrosurgical generator is basically a 'bipolar system' in that it contains two electrodes. The difference in instrument nomenclature is derived from the function of the second electrode. In bipolar instruments, only the portion of tissue between the electrodes has current passing through it to complete the circuit. In monopolar instruments, the patient completes the circuit between the active electrode and the passive second electrode which acts as the dispersive electrode [5] (see Fig. 2).

### 5.1 Monopolar Circuits

High-density current enters tissue from small active electrodes creating secondary thermal events. Current flows through the patient via a myriad of conductive pathways. Current is dispersed over a large surface return electrode. Current returns to isolated ground housed in the electrosurgical generator (grounding is rarely seen in contemporary ESUs); see Fig. 3.

This second electrode is needed to disperse the current which has passed through the patient. Since the passive (dispersive) electrode has a relatively large surface area, the current density at its site is very low which minimizes the potential for patient injury at its location. The active electrode is typically small and pointed to allow a high current density at its tip. This facilitates the tissue effect needed at the point of surgery, e.g. cutting, coagulation, fulguration, etc.

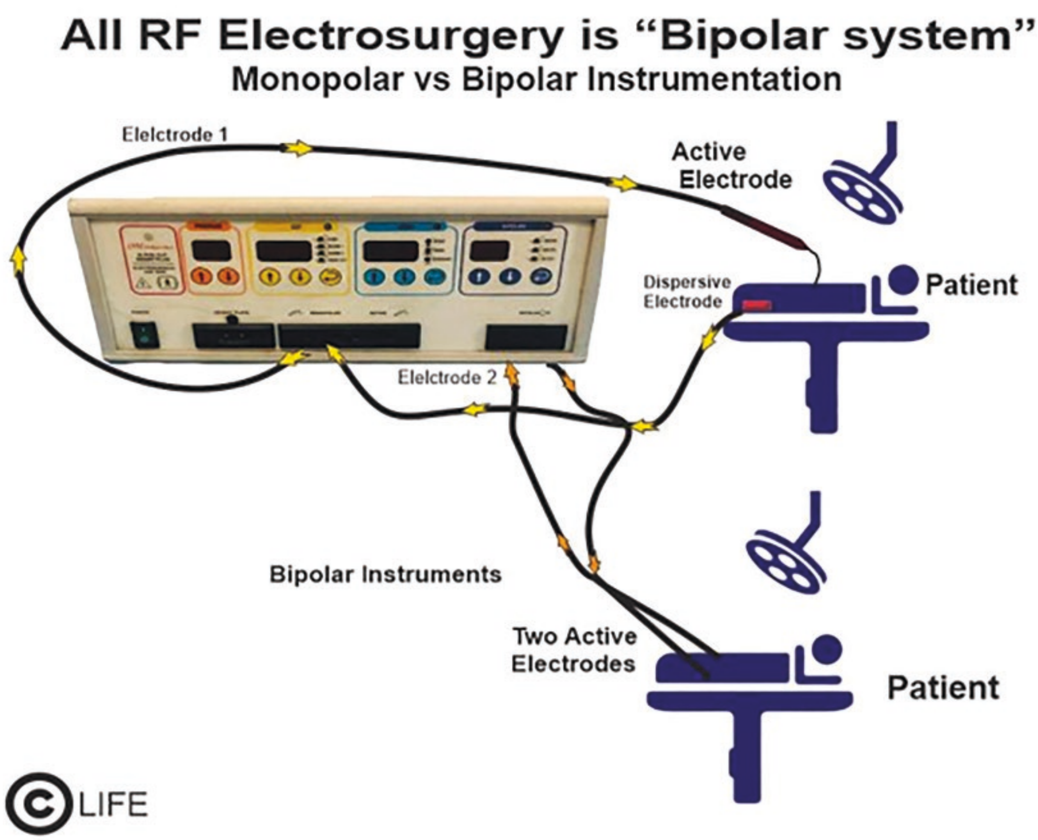


**Fig. 2** The electrosurgical systems: monopolar and bipolar circuits

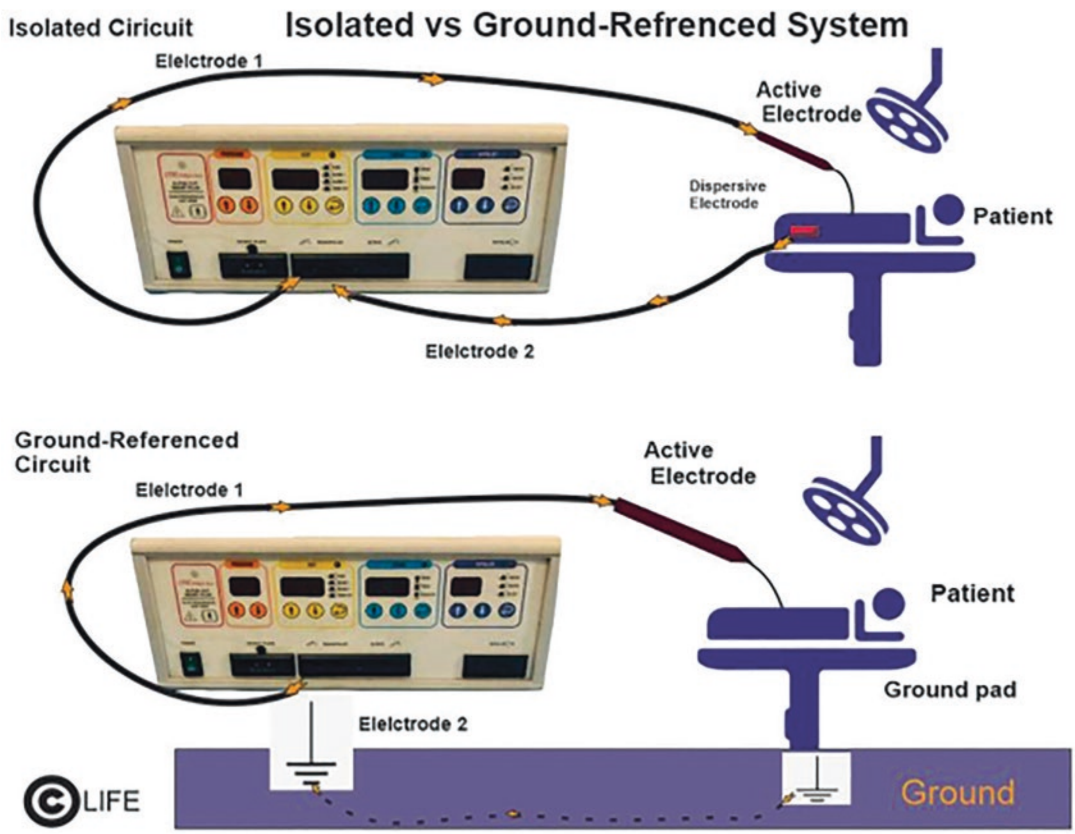


**Fig. 3** The electrosurgical systems: isolated vs. ground-reference circuit

In hysteroscopic surgery where fluid distension media are used, monopolar effects are modulated by the type of fluid medium. Electrolyte-containing distension media are effective conductors and they act to enlarge the surface area of the active electrode. This dramatically reduces the current density which attenuates the electrosurgical effect. Non-conductive distension media are effective insulators. Typical examples are glycine, sorbitol and mannitol. In such media, the current density is maintained, the electrosurgical effect is unaltered; therefore, desiccation, cutting, vaporization and fulguration are all available.

The passive electrode (return plate) is equally important during surgery with monopolar instruments. The large surface area of its dispersion pad results in low current density at the attachment site, thus minimizing the risk of skin burns. The dispersive pad is attached as close as possible to the surgical field. The pad should be applied over a large muscle and away from metallic body implants; this prevents the occurrence of burns. The modern electrosurgical generators have sensors that measure pad-to-skin contact and current density and block its function in case of any contact failure.

Monopolar surgery is very attractive because it is relatively more available; it is also cheaper to procure. It has many diverse tissue applications like cutting and fulguration as has been described above.

Its drawbacks are related to the potential for injuries remote from the operation site and also its inability to seal vessels larger than 2 mm in diameter [10].

### 5.2 Bipolar Circuits

Unlike the monopolar units, the simplest bipolar system is designed with both electrodes (passive and active) positioned on the same instrument [11, 12]. Thus, instead of current passing through the whole patient to the dispersive electrode, only the tissue within the confines of the electrodes on the instrument is affected by the current. See Fig. 2. Since the return electrode is included in the circuit at the site of surgery, the dispersive patient return electrode pad is unnecessary, and the rest of the patient's body does not form part of the electrosurgical circuit. Current is symmetrically distributed through the tissue between the two electrodes. Thermal damage is limited to a discrete volume of tissue, and power requirements are reduced leading to higher electrosurgical efficiency. The depth of thermal spread is less than 1 mm unlike in monopolar surgery where it is 3–5 mm.

Due to the relative constancy of energy delivered, it is more difficult to execute electrosurgical vaporization and almost impossible to cut efficiently. Coagulation is the major mode employed but it takes a longer period of instrument application to coagulate due to the lower power settings, which leads to charring and tissue adherence with incidental tearing of adjacent blood vessels [13].

### 5.3 Advanced Bipolar Systems (Aka Tripolar Systems)

This is the introduction of cutting components in bipolar units to overcome the challenge of cutting which is lacking in bipolar instruments. An example is the Versapoint system which can coagulate and cut with its dedicated electrosurgical generator. These devices come with a retractable blade and offer very good haemostasis with a less lateral spread of heat. Vessels of up to 7 mm in diameter can be sealed.

There are also the ultrasonic systems like harmonic which can give a bipolar cut and coagulation using mechanical vibrations. These tripolar devices can perform four functions in one—grasping, dissecting, coagulation and cutting. See Fig. 4.

**Fig. 4** Harmonic generator and hand piece

## 6 Complications of Electrosurgery

### 6.1 Direct Application

Injury by direct application of the electrosurgical probe can arise either from mistaken target or unintended activation. The speed of the procedure will result in either less or more coagulation and thermal spread. The proximity between the electrode and the tissue can determine contact (desiccation) or non-contact tissue effect (fulguration).

### 6.2 Stray Current

A stray current arising from defective insulation can injure the bowel or blood vessels. A careful preoperative inspection of equipment and after use is the best means of identifying defective insulation. The two major causes of insulation failure include the use of high-voltage currents and the frequent re-sterilization of instruments, which can weaken and break the insulation. The risk of an insulation break increases when using a 5-mm insulated instrument through a 10-mm sleeve, or by repeated use of the disposable instrument.

### 6.3 Direct Coupling

Direct coupling occurs when the active electrode is accidentally activated when it is in contact with or in close proximity to another metal instrument within the pelvic cavity, e.g. laparoscope or metal irrigation apparatus. Direct coupling can be prevented with visualization of the electrode and avoiding contact with any other conductive instrument prior to activation of the electrode.

### 6.4 Capacitive Coupling

Capacitive coupling occurs when the electric current is transferred from one conductor (the active electrode), through intact insulation, into adjacent conductive materials (e.g. metal cannula) without direct contact. A longer length of instruments, thinner insulation, higher voltages and narrow trocars increase the risk of this type of injury. Capacitor coupling can be minimized by activating the active electrode only when it is in contact with target tissues and limiting the time length of high-voltage peaks.

### 6.5 Return Electrode or Alternative Site Burns

The grounding (dispersive) pad used in the monopolar circuit offers the path of least resistance from the patient back to the generator and ensures an area of low current density. If the return electrode is not completely in contact with the patient's skin or is not able to disperse the current safely, then the exiting current can have a high enough density to produce an unintended burn. It is important to have good contact between the patient and a dispersive pad (application of a gel on the pad before application will improve on the contact with the skin). A burn at an alternative site can occur if the dispersive (ground) pad is not well attached to the patient's skin. When the dispersive pad is compromised in the quantity or quality of the pad or patient interface, the electrical circuit can be completed by some small, grounded contact points such as electrocardiogram leads, towel clip, intravenous stand, etc. and produce high current densities, causing a burn.

### 6.6 Infection Spread

There is the potential for transmission of disease from patient to physician or ancillary personnel. The discharge of an electrosurgical current over a droplet of fluid causes spattering over a distance of at least 5 cm [14]. This is because electrosurgery causes an expansion of tissue fluids resulting in the explosion of cells, and an aerosol of blood and fluid droplets is created that can potentially transmit infectious agents. It is important, regardless of the surgical procedure being performed, that all personnel observe universal precautions.

### 6.7 Carcinogenic Smoke

Smoke generated by electrosurgical procedures is mutagenic, [16] giving additional impetus to the recommendation that surgical masks be worn. Also, smoke siphoning instruments have been developed to minimize this risk. The surgical smoke can also provoke allergic reactions or responses like in asthmatic health workers involved in the operating room.

## 7 Advances in Electrosurgery

### 7.1 Advanced Bipolar Vessel Sealers

This improvement utilizes bipolar coagulation using a high current and low voltage with pressure on the tissue. The subsequent denaturation of the tissue results in a coagulum which is an excellent vascular seal. A system that calculates the energy needed to achieve this seal is built into the generator which reduces collateral damage by thermal spread [11].

### 7.2 Ultrasonic Devices

This device is not strictly an electrosurgical device. Instead of electricity generated in the tissue, it uses ultrasound technology to achieve its tissue effect. Mechanical vibrations (55.5 kHz) above the audible range generate heat, which in conjunction with compression and duration of use causes the vascular seal to occur. Cutting blades allow excision using the same instrument. There is less collateral damage than with either monopolar or bipolar usage, less smoke and less char formation. Currently, vessels of up to 5 mm can be sealed by these devices [14–16].

### 7.3 (Hybrid Technology) Thunderbeat Technology

It is a combination of advanced bipolar energy and harmonic energy. This new technology allows integrated cutting and sealing with much more efficiency. It enables a surgeon to simultaneously seal and cut vessels up to and including 7 mm in size with minimal thermal spread [17–19].

## 8 Conclusion

Advances in electrosurgical techniques have certainly had a significant impact on the practice of endoscopic surgery. To achieve desired outcomes and protect patient safety, the operator must be aware of the technology and its appropriate use.

**Learning Points**

- The electrosurgical unit generates alternating high-frequency current to produce desired thermal effects on tissue.
- Instruments used may be monopolar if the second electrode is passive or bipolar if the second electrode is active.
- Monopolar instruments need a dispersive pad to allow the exit of current from the patient, while bipolar instruments do not.
- Manipulating the delivery of current at the ESU (duty cycle) allows different thermal effects, e.g. cutting, coagulation and fulguration.
- More efficient instruments are being developed to optimize haemostasis and transection of tissues at surgery.

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# Anatomy of the Female Pelvis

Eugene M. Ikeanyi, Lateef Akinola, and Dennis O. Allagoa

## 1 Introduction

Knowledge of female pelvic anatomy is crucial for the diagnosis and surgical management of female pelvic pathologies including endometriosis and urogenital dysfunctions and in gynaecological oncology staging and treatment of pelvic tumours [1]. It is undoubtedly crucial for the understanding of the fundamental mechanisms of urogenital dysfunction and treatments. Detailed pelvic anatomy is equally very essential to understand the relationship of the pelvic anatomic structures and organs for interpretations and diagnosis in hysterosalpingogram (HSG), pelvic scans, computerized tomography (CT), magnetic resonance imaging (MRI), and dynamic MRI [1]. Furthermore, pelvic surgery requires a comprehensive knowledge of the pelvic anatomy to safely access, optimize exposure, ensure haemostasis and avoid injuries to other pelvic viscera, blood vessels and nerves.

It is important to note that the pelvis is anatomically subdivided into anterior, middle and posterior compartments with the middle compartment only in the female pelvis [1]. The contents of the posterior compartment are the rectum and anus. The anterior compartment consists of the bladder and urethra, while the middle compartment (the focus of this discussion) consists of the ovary, fallopian tubes, uterus, vagina and associated neurovascular bundles (Fig. 1).

Anatomic features that are clinically applicable to female pelvic surgery are highlighted throughout the text, together with the symbol *.

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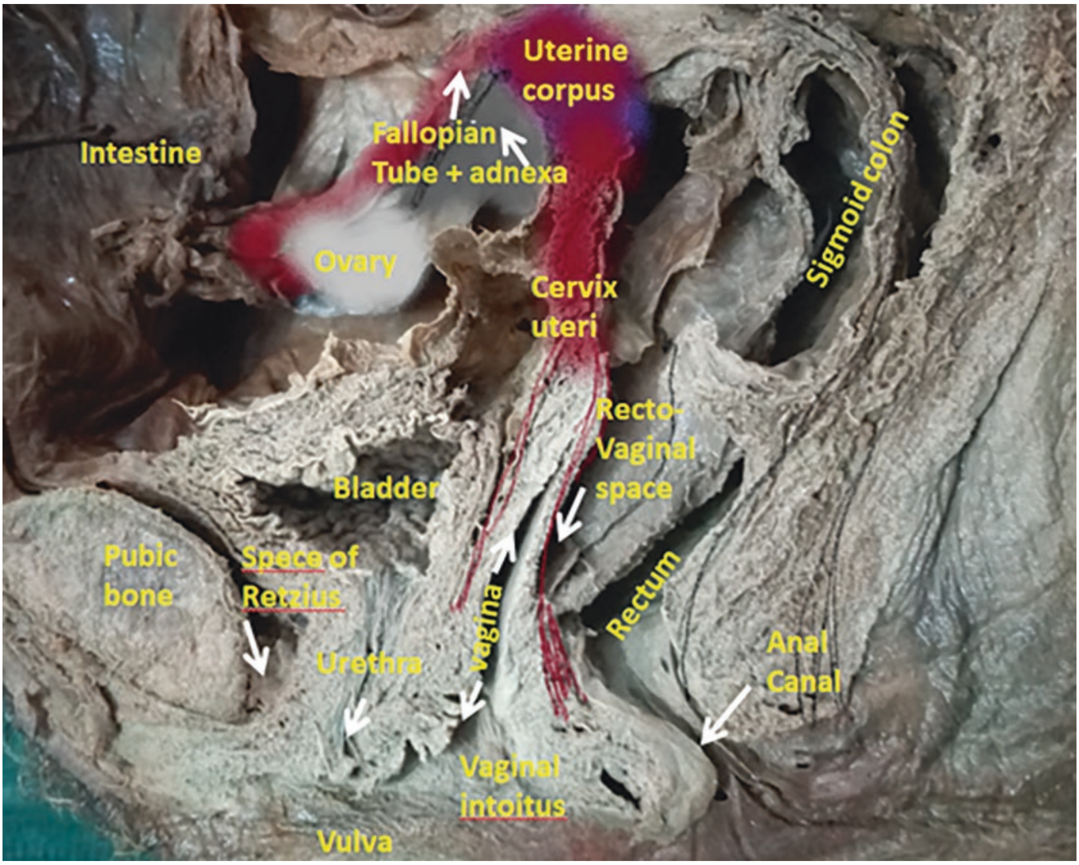



**Fig. 1** Sagittal view of female pelvic organs

## 2 Synopsis of Pelvic Anatomy

The pelvic region is the area between the trunk or main body and the lower extremities, or legs. The female pelvis is anatomically and morphologically different from that of the male. Most of the differences are not apparent until puberty. The female pelvic bones are larger and broader as they have evolved to create a larger space for childbirth. The most noticeable differences are the width of the pubic outlet, the circular hole in the middle of the pelvic bones and the width of the pubic arch, or the space under the base of the pelvis.

The bones of the pelvis are the hip bones, sacrum and coccyx. Each hip bone contains three bones, the ilium, ischium and pubis. These bones fuse as we grow older. The sacrum is made up of five fused vertebral bones, joining the pelvis at the crests of the ilium. Below the sacrum is the coccyx, or tailbone, a section of fused bone that is the end of the vertebral column. The pelvis provides the base of the spine as well as acetabular sockets of the hip joint.

The contents of the female pelvis including the small and large intestines are supported by a series of muscles known as the pelvic floor. These muscles assist in vaginal delivery and help push the baby through the pelvic outlet and vaginal opening during childbirth.

*Note: During the embryological period, failure of some developmental processes of the female genital tract results in some congenital anomalies of endoscopic surgical importance mostly from Mullerian ducts, Mullerian tubercle and urogenital sinus development.

Mullerian developmental failures can result in congenital utero-cervical and vaginal anomalies, for example, uterus didelphys, bicornuate or unicornuate, or fully septate or partially septate uterus, with varying degrees of severity. From the Mullerian tubercle and sino-vaginal bulb complex, various degrees of transverse and/or longitudinal septa can result in failed canalization of the cervix and vagina.

At birth, the bones that make up the pelvis are the ilium, ischium, pubis, sacrum and coccyx. The ilium, ischium and pubis fuse by age 16–18 years to form a single bone, referred to as the pelvic bone. Thus, in an adult, the bones of the pelvis consist of the right and left pelvic bones (hip bones), the sacrum and the coccyx. The bony pelvis is the rigid foundation to which all of the pelvic ligaments and muscles are anchored.

Each hip bone contains three bones—the ilium, ischium and pubis—which fuse as we grow older. The sacrum, consisting of five fused vertebral bones, joins the pelvis at the crests of the ilium. Below the sacrum is the coccyx, or tailbone, a section of fused bone that is the end of the vertebral column. The pelvis forms the base of the spine as well as the socket of the hip joint (Fig. 2).

The most superior component of the pelvic bone is the ilium. The upper part of the ilium expands to form a flat fan-shaped 'wing', which provides support for the lower abdomen and is also called the false pelvis. The medial surface of the ilium has two concavities forming the lateral borders of the pelvic outlet (the inferior opening of the pelvis). The superior and larger of these two concavities is the greater sciatic notch (boundaries are the sacrum, ilium and ischial spine) (Fig. 2).

The surgical landmarks of the bony pelvis are the ischial spine, pubic arch, pectineal line, obturator foramen and coccyx.

The female upper genital tract consists of the cervix, uterine corpus, fallopian tubes and ovaries. A sagittal view of the female pelvis is shown in Fig. 1. The lower genital tract consists of the vulva and vagina.

## Key Areas of Note

1. Uterus: uterine corpus, uterine cervix, uterine support structures (uterosacral and cardinal ligament complex, round ligaments, broad ligaments and the endopelvic fascia).
2. Adnexa: ovaries, fallopian tubes (Fig. 3).
3. Vasculature (common and external iliac vessels, inferior and superficial epigastric vessels, anterior division of the internal iliac artery forming the main blood supply to the uterus).

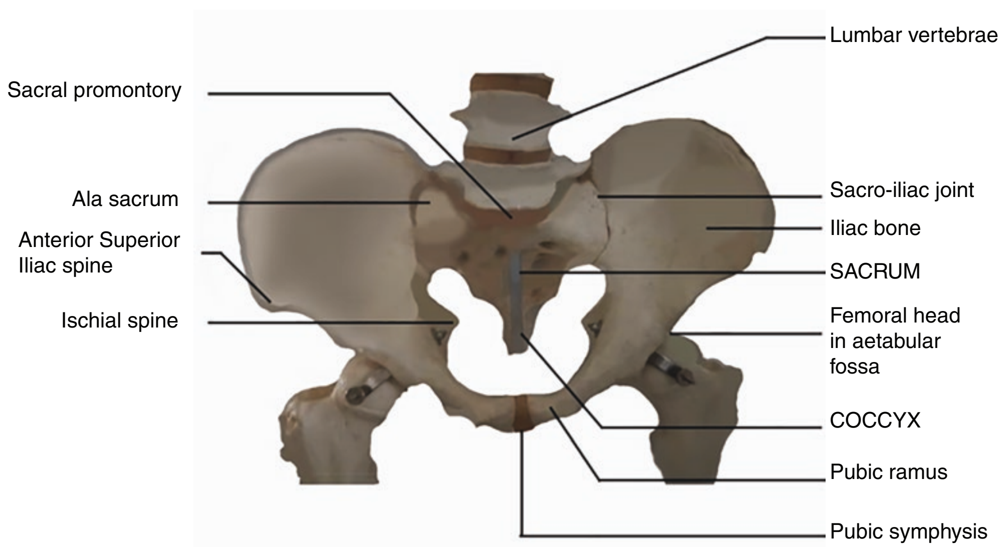
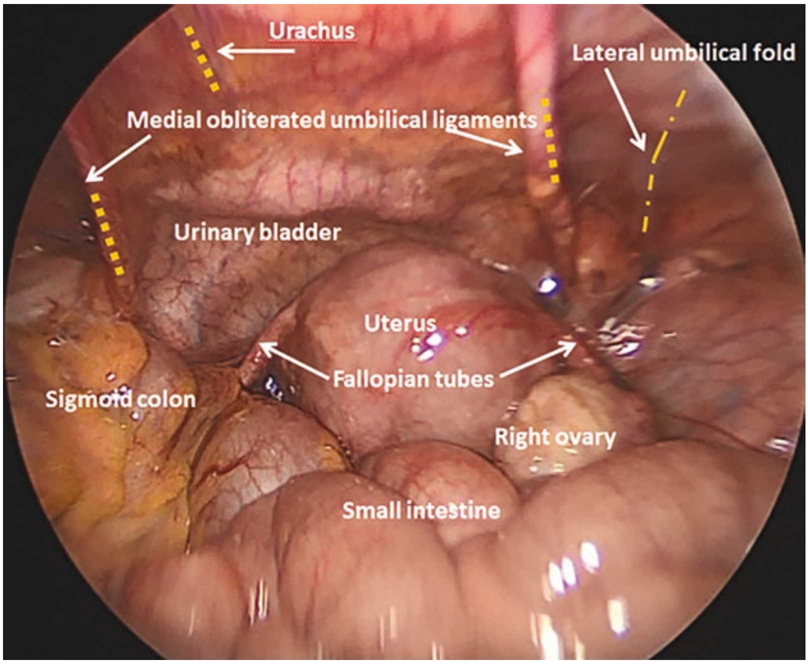



**Fig. 2** Bones of the female pelvis

**Fig. 3** The genital tract and other pelvic viscera




4. Lymphatics (obturator lymph nodes, internal iliac lymph nodes, external iliac lymph nodes, superficial inguinal lymph nodes, para-aortic lymph nodes, lymphatic drainage of the pelvic viscera, uterus and proximal vagina, ovary, distal vagina and vulva).
5. Nerves (aortic plexus, superior and inferior hypogastric plexuses, lumbosacral plexus and the nerves of the anterior abdominal wall).
6. Lower urinary tract: ureter, urinary bladder (Fig. 3) and urethra.
7. Sigmoid colon (Fig. 3), rectum and anus.

## 3 The Lower Anterolateral Abdominal Wall

The anterolateral abdominal wall layers comprise the skin, subcutaneous fat and anterior layer of fascia; medially, the rectus abdominis muscles; and laterally, the three layers of the external oblique, internal oblique and transversus abdominis muscles. Underneath the skin is the left and right rectus abdominis muscles in the midline, and laterally to the rectus abdominis are the oblique abdominis muscles—external and internal obliques—and the innermost transversus abdominis which is underlayered by the abdominal peritoneum.

The rectus abdominis is separated by the linea alba, a midline tendinous raphe. These muscles connect the pubic bone (pubic crest and symphysis) to the xiphoid process and the medial ends of the fifth and seventh costal cartilages. The rectus abdominis has tendinous intersections at the level of the umbilicus and between the umbilicus and the pubic bone below and the umbilicus and the xiphisternum above. It tilts the pelvic bone and ventrally flexes the trunk.

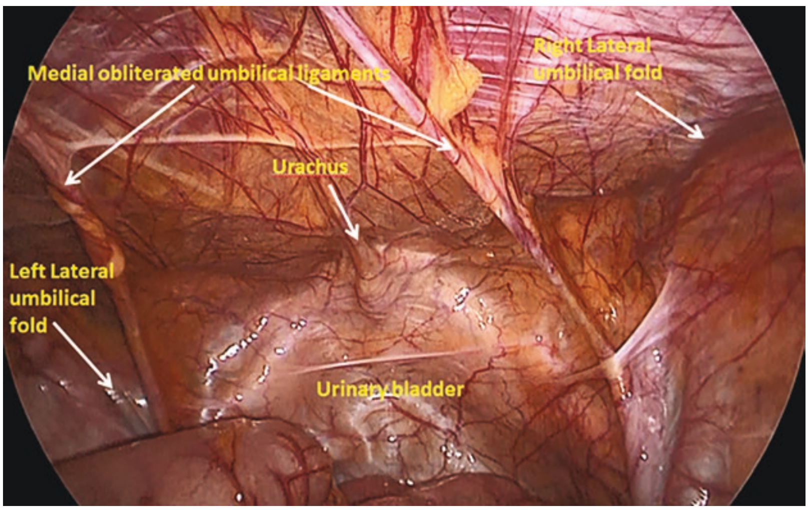
The external oblique muscle is attached between the external surfaces of the fifth to the 12th rib to the midline linea alba, iliac crest and pubic tubercle, while the internal oblique lying underneath it has its attachment from the thoracolumbar fascia, the lateral two-thirds of the iliac crest and inguinal ligament to the linea alba, borders of the tenth to 12th ribs and through the conjoint tendon to the pubic bone. The transversus abdominis is attached to the seventh to the 12th rib cartilages, the iliopsoas fascia and the middle linea alba, pubic crest and pectineal line as part of the conjoint tendon. These muscles rotate and flex the trunk and provide support for the abdominal viscera. They are innervated by the thoracic-abdominal nerves T7–T11, subcostal nerves and L1 lumbar nerve.

## 3.1 Vascular Supply to the Lower Anterolateral Abdominal Wall

The blood supplies to the lower anterolateral abdominal wall are made up of a superficial and a deep vascular supply. The superficial vascular supplies include the superior epigastric vessels, superficial circumflex iliac and superficial epigastric vessels, all from the femoral arteries. The deep vascular supplies include the inferior epigastric and deep circumflex iliac vessels from the external iliac arteries. These vessels drain via their corresponding veins to the respective origin of their arteries. To avoid injuries to the vascular supplies of the anterolateral abdominal wall, it is best to introduce the primary trocar at the level of the umbilicus slightly to its left to spare injuring the umbilical vascular plexus mostly located to the right of the umbilicus. It is also paramount to place lateral trocar insertions for laparoscopy away from the superficial and deep lower anterolateral abdominal wall vascular supplies to avoid injuries to these blood vessels (Fig. 4).

The abdominal parietal peritoneum layers the posterior surface of the transversalis fascia; this fascia in turn covers the rectus abdominis muscle, its sheath and the transversalis muscle posteriorly. Above the level of the umbilicus, the rectus abdominis muscles lie in the rectus sheath which is formed by the aponeurosis of the external oblique, internal oblique and transversalis muscles (Fig. 5). On the other hand, below the umbilicus, the aponeurosis of all three muscles passes

**Fig. 4** Laparoscopic view of the anterior abdominal wall



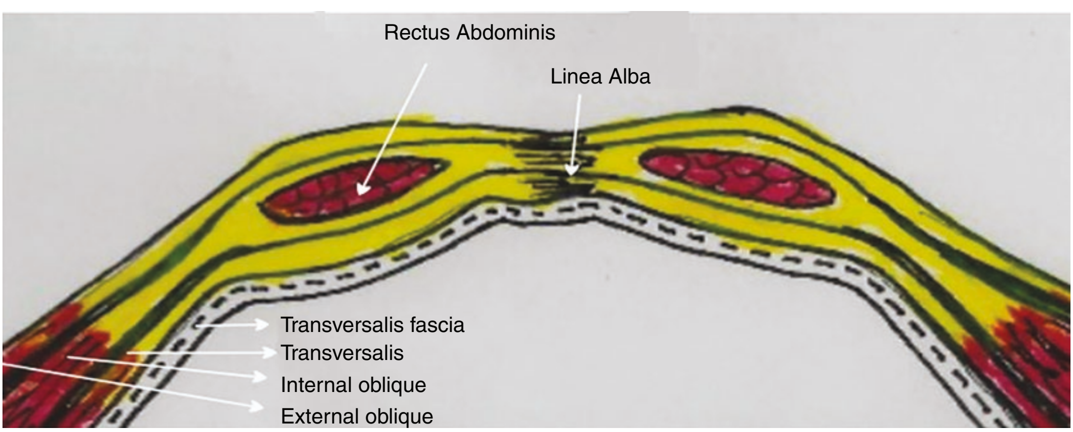




**Fig. 5** Schematic drawing of the anatomical layer of the anterolateral abdominal wall

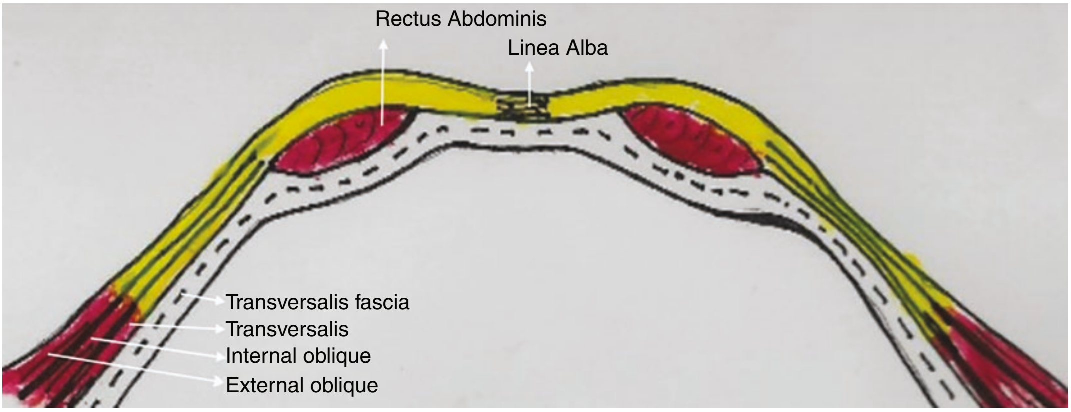



**Fig. 6** Schematic drawing of the anatomical layer of the anterolateral abdominal wall

in front of the rectus abdominis to join that of the opposite side at the midline linea alba (Fig. 6).

## 4 The Umbilicus

The umbilicus is at the level of the intervertebral discs of L3 and L4 vertebrae and T10 dermatome. The location of the umbilicus may vary with the patient's weight, the presence of abdominal panniculus and the patient's position: supine or Trendelenburg [2]. The bifurcation of the abdominal aorta into the right and left common iliac arteries is located at the level of umbilicus or L4–L5 in about 80% of patients [2, 3]. This distance varies and can be a few or more centimetres below the umbilicus depending on whether the patient is slim or obese. In slim patients (with few centimetres separating the umbilicus from the aorta and its bifurcation below), diligent caution is necessary when inserting the Veress needle and/or laparoscopic trocars into the abdomen for $CO_2$ gas instillation.

## 5 The Three Pelvic Compartments, their Borders and Contents

### 5.1 Posterior Compartment

Borders are the skeletal elements of the sacrum and coccyx dorsally, parts of the levator ani muscle laterally and the rectovaginal fascia and perineal body ventrally. The only organ is the anorectum [1]. The muscle components are all the components of levator ani muscle (pubococcygeus and iliococcygeus jointly in a triangular form attach to the coccyx and puborectalis inferiorly) [1].

*The surgical relevance of the posterior compartment is the likelihood of surgically correctable faecal incontinence in 6–30% of females at childbirth due to injury to the incompletely circular external anal sphincter that needs to be properly identified and reconstructed [1, 4].

### 5.2 Anterior Compartment

Borders are the symphysis pubis ventrally, levator ani muscle laterally, perineal membranes inferiorly and no clear border between the anterior and middle compartments in the female pelvis [1]. Content is the urinary bladder and urethra. The muscles are anterior parts of the pubococcygeus and puborectalis while other structures are connective tissues and pubovesical ligament (Fig. 1).

#### 5.2.1 The Female Urethra (Fig. 1)

The female urethra at 3–4 cm long runs from the internal urethral orifice of the urinary bladder, anterior to the vagina, to the external urethral orifice in the vulva. Two paraurethral glands open into the urethra near the external urethral orifice. It is prone to pressure injury in prolonged obstructed labour.

The urethra is innervated by the vesical plexus as well as the pudendal nerve. The urethra receives blood from the internal pudendal and vaginal arteries and returns blood through their accompanying veins. Lymph drains into the internal iliac and sacral nodes. The urethra is seldom involved in gynaecological laparoscopy injuries.

## 5.3 Middle Compartment, Only in Female

Borders are the levator ani muscle laterally, perineal body inferiorly and rectovaginal fascia and septum posteriorly. The contents are the female genital organs more or less in the coronal plane: ovaries, fallopian tubes, uterus and vagina. The pelvic fascia provides support to the uterovaginal complex especially the uterosacral ligament which is connected to the pelvic parietal fascia at the same level with the sacrospinous ligament giving upwards traction to the uterovaginal complex.

*Therefore, uterovaginal complex fixation surgeries are possible via the surgical manipulation of these fasciae and ligaments and the use of mesh in uterovaginal prolapse.

Important vessels are uterine and ovarian vessels while the nerve is the inferior hypogastric plexus.

### 5.3.1 Uterus

The uterus is a pear-shaped hollow muscular organ measuring around 7.5 × 4.0 × 2.5 cm in the longitudinal, transverse and anteroposterior diameters. It is slightly larger in the multipara than in the nullipara. The corpus uteri (body) lies above the internal os. The cornu is the area of insertion of the fallopian tubes and the fundus lies above the insertion of the fallopian tubes. Three structures attached to the cornu are the round ligament anteriorly, fallopian tube centrally and ovarian ligament posteriorly. The isthmus is an area 4–5 mm in length that lies between the anatomical internal os above and the histological internal os below. The internal os marks its junction with the uterine body. It is lined by low columnar epithelium and few glands similar to the endometrium. The isthmus expands during pregnancy forming the lower uterine segment during the last trimester.

The cervix is the elongated lower fibromuscular part of the uterus measuring 2.5–3.0 cm. It is divided by the vaginal attachment into the supravaginal portion above and the vaginal portion (portio-vaginalis) below. The cervical canal is the cavity that communicates above with the uterine cavity at the internal os and below with the vagina at the external os. The nulliparous external os is circular and transverse slit after childbirth with an anterior and posterior lip (multiparous external os). The cervical mucosa has two ridges (anterior and posterior) from which transverse ridges radiate to form the arbour: vitae uteri. The uterus is kept in an anteverted anteflexed position (with the external os lying at the level of the ischial spines), by the support of the cervical ligaments, endopelvic fascia and pelvic floor muscles (levator ani).

By anteversion, the uterus is inclined anteriorly to the axis of the vagina, and by anteflexion, the body of the uterus is bent forwards upon the cervix.

Anterior to the uterus is the bladder and uterovesical pouch, and to its posterior are the pouch of Douglas and the rectum; laterally the uterus is supported by the broad ligament on each side.

Relations of the supravaginal cervix are anteriorly the urinary bladder, posteriorly the anterior wall of Douglas pouch and laterally about 1–2 cm lateral to the internal os; the ureter is crossed by the uterine artery (i.e. ureter below the uterine artery).

The uterosacral, cardinal and pubocervical ligaments are attached to its posterior, lateral and anterior surfaces, respectively, as supporting tissues.

The uterus is histologically subdivided into the endometrium or mucosa, the myometrium or musculosa and the peritoneal covering or perimetrium. The endometrium is lined by simple cubical or columnar epithelium that contains tubular glands and undergoes cyclical changes with the menstrual cycle under the influence of the ovarian hormones.

The myometrium has three layers: the outer longitudinal muscle layer; the middle layer of interlacing crisscrossing muscle fibres, surrounding the blood vessels; and the inner circular muscle layer.

The perimetrium is anteriorly firmly attached to the fundus and body till the isthmus where it becomes loose and reflects on the superior surface of the urinary bladder forming the vesicouterine pouch. Posteriorly, the perimetrium is firmly attached to the fundus, uterine body, cervix and posterior vaginal fornix and then reflects upwards on the pelvic colon forming the pouch of Douglas. Laterally the anterior and posterior peritoneal coverings blend as the anterior and posterior layers of the broad ligaments.

Histologically the cervical endocervix is lined by simple columnar epithelium with compound racemose glands or crypts that are liable to chronic infection. It secretes alkaline cervical mucus. The muscle layer is a thick smooth muscle. The ectocervix is formed of stratified squamous epithelium covering the outer portion of the cervix. The junction between the squamous and columnar epithelium at the external os either is abrupt or may form a transitional zone of 1–3 mm known as the transformation zone.

The arterial blood supply of the uterus is from the uterine arteries (from the internal iliac artery) which arise from the anterior division of the internal iliac artery. In the base of the broad ligament, it crosses above the ureter about 1–2 cm lateral to the supravaginal cervix. It divides into two branches as it reaches the uterus at about the level of the internal os: an ascending and a descending branch. The ascending branch passes upwards in a tortuous manner parallel to the lateral border of the uterus between the two layers of the broad ligament to end by anastomosing with branches of the ovarian arteries near the uterine cornu. The descending cervical branch supplies the lower cervix and upper vagina. The venous drainage starts as a plexus between the two layers of the broad ligament (pampiniform plexus) that communicates with the vesical plexus and drains into the uterine and ovarian veins. Lymphatic drainage of the fundus drains to the para-aortic lymph nodes via ovarian vessels. The uterine cornu drains into the superficial inguinal lymph nodes via lymphatics of the round ligament. The lymphatic drainage of the uterine body goes into the internal and then external iliac lymph nodes via the uterine vessels. The uterine isthmus is as that of the cervix. The cervix has two groups of lymphatics: the primary groups are paracervical, parametrial, obturator, internal and external iliac nodes. The secondary groups are common iliac, para-aortic and lateral sacral lymph nodes.

Nerve Supply: The cervix and body are relatively insensitive to touch, cutting and burning. The cervix is sensitive to dilatation and the body is sensitive to distension. Innervations are from parasympathetic (S2, 3, 4) and sympathetic from T5 and T6 (motor), T10, T11, T12 and L1 (sensory). Both reach the uterus through branches of the inferior hypogastric plexus.

The fallopian tubes are two tortuous tubes (10 cm long) that lie in the free upper part of the broad ligament. They blend medially with the cornu of the uterus; laterally each tube's free outer end curves back towards the ovary. Their lumen communicates between the uterine and peritoneal cavities. There are four identifiable parts: the interstitial part (1 cm), piercing the uterine wall, very narrow, no peritoneal covering, no outer longitudinal muscles; isthmic part (2 cm), straight, narrow, thick-walled portion lateral to the uterus; ampulla (5 cm), the widest, tortuous and thin-walled outer part; and the infundibulum (2 cm), the trumpet-shaped outer end of the fallopian tube that opens into the peritoneal cavity at the tubal ostium. The ostium is surrounded by fimbriae, one of which is the longest and directed towards the ovary (fimbria ovarica) relevant in ovum pickup at ovulation.

Tubal Functions: Ovum pickup at the time of ovulation is achieved by their free fimbrial end. Transport of the ovum (and the zygote, if fertilization occurs) through the tubal lumen is by peristaltic and ciliary movements and the production of secretions by the tubal lining cells is necessary for capacitation of the spermatozoa and nutrition of the ova during the journey.

The fallopian tube is bounded above by loops of the intestine and below by the broad ligament and its contents; medially it blends with cornu of the uterus, while laterally they are bounded by the lateral pelvic wall. The ovaries lie posterior and inferior to the fallopian tubes at each side.

Histologically the mucosa of the endosalpinx is arranged into 4–5 main longitudinal ridges that give rise to subsidiary folds or plicae. It is lined by columnar partially ciliated epithelium. The muscle layer consists of outer longitudinal and inner circular involuntary smooth muscles. It is thick at the isthmus and thin at the ampulla. The serosa or the peritoneal covering forms the extra-uterine part which is covered by the peritoneum in the upper margin of the broad ligament.

The blood supply and lymphatic drainage of the tubes are from branches of both the uterine artery and the ovarian artery. The venous drainage is via the right ovarian vein directly into the inferior vena cava and the left ovarian vein into the left renal vein [5, 6]. The lymphatic drainage is into the para-aortic lymph nodes, directly via the ovarian lymphatics. The nerve supplies are the sympathetic and parasympathetic nerve fibres.

*Applied anatomy tubal pain is referred to the tubal points (on the lower abdominal wall 1–2 cm above the mid-inguinal points).

### 5.3.2 Ovary

The ovary is an almond-shaped organ lying in the fossa ovarica on the lateral pelvic sidewall. It measures 3 × 2 × 1 cm and it is not covered by peritoneum. The surface is pearly white and corrugated by the effect of the monthly ovulatory activity. It has three attachments: the mesovarium, a peritoneal fold that suspends the ovary to the back of the broad ligament; the infundibulo-pelvic ligament that suspends the upper pole of the ovary to the lateral pelvic sidewall and carries the ovarian vessels, nerves and lymphatics; and the ovarian ligament that attaches the lower pole to the cornu of the uterus. The ovary is bounded medially by the fallopian tube and laterally by the lateral pelvic sidewall; superiorly and anteriorly it is surrounded by the small intestine and *posteriorly by the ovarian fossa where the ureter and internal iliac vessels pass and are prone to surgical injury (Figs. 7 and 8).

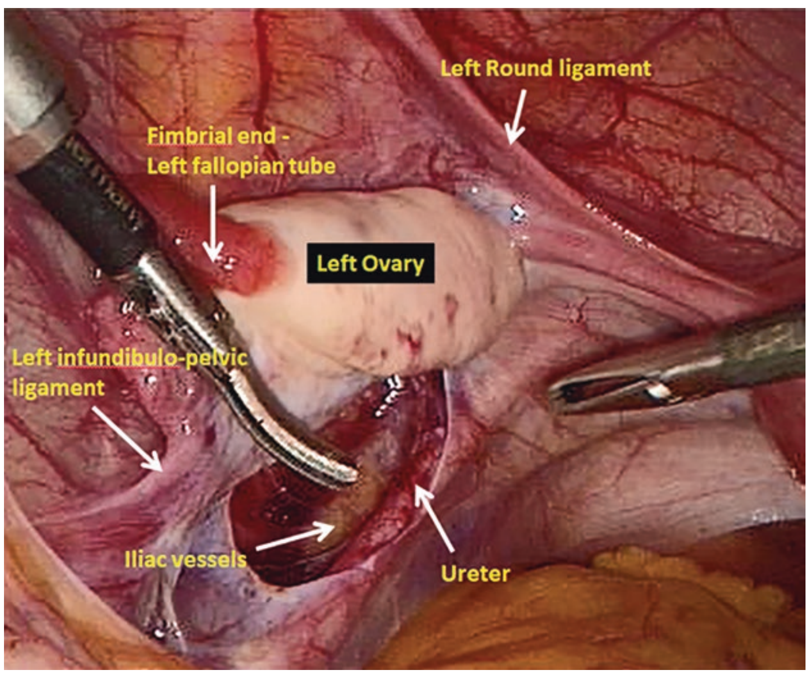



**Fig. 7** Left ovarian fossa

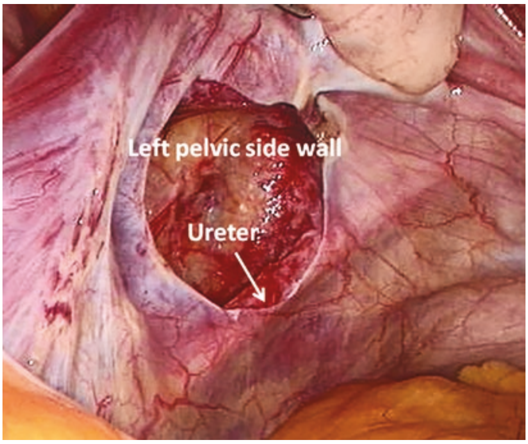



**Fig. 8** Left pelvic side wall showing the left ureter

Histologically, the ovary is subdivided into the cortex, medulla and hilum. The medulla is the central core of the ovary surrounded by the cortex and continuous with the hilum. It is formed of connective tissue.

The cortex is the outer active part of the ovary that produces hormones and oocytes. The surface epithelium is of cuboidal cells (the germinal epithelium) covering the free surface of the ovary. The stroma is composed of dense connective tissue containing the oocytes. It is condensed on the surface to form the tunica albuginea. The hilum is the site of attachment of the mesovarium that carries blood, its neurovascular supplies and lymphatics.

### 5.3.3 Ovarian Blood and Lymphatics

The ovarian artery arises from the aorta at the level of L2 and passes through the infundibulopelvic ligament. The ovarian branch from the uterine artery anastomoses with the ovarian vessels at the broad ligament. The ovarian veins accompany the arterial supply and join with the pampiniform plexus of veins and the uterine vein.

Ovarian lymphatic drainage is to the para-aortic lymph nodes via the ovarian vessels.

The nerve supply of the ovary is insensitive except for squeezing on pelvic examination. Sympathetic and parasympathetic nerves to the ovary (T10 and T11) pass through the preaortic nerve plexus that accompany the ovarian vessel.

## 6 Surgical Anatomy of the Ureter

The ureter runs retroperitoneal from the kidney to the urinary bladder. Except for congenital abnormalities and pelvic pathology, the ureter has a fairly constant and predictable anatomical course and points [7]. It enters the pelvis over the bifurcation of the common iliacs, anterior to the sacroiliac joint and medial to the infundibulopelvic ligament. At the pelvic brim, the left ureter crosses the common iliac and the right ureter crosses the bifurcation of the common iliac. The ureter is about 28 cm in length, in a normal female; half of this length traverses the abdomen above the pelvic brim while the other half passes down the pelvis en route to its entrance at the bladder trigone closely related to the lateral vaginal fornix, at the junction of the upper and middle third of the vagina, to enter the trigone of the urinary bladder. The ureter is prone to surgical injuries at dissection, ligation or cutting of the infundibulopelvic ligament at the pelvic sidewall where the ureter courses below it just as it enters the true pelvis at the sacroiliac joint. The risk of this injury is increased if the anatomy is distorted by tumours, adhesions or endometriosis indicating careful isolation of the ureter by dissecting and displaying it to avoid damage [8]. Next is as the ureter crosses under the uterine artery above the vaginal artery proximal to the cervix at dissection, ligation or cutting the uterine artery at hysterectomy. To avoid this especially in open surgery, in addition to a downwards reflection of the bladder, the uterus should be pulled cranially to the opposite side to optimize the distance between the cervix and ureter [8]. The third ureteric damage-prone site is when taking the cardinal-uterosacral ligament complex or closing the vaginal cuff during total hysterectomy as it leaves under the uterine vessels and courses very close anterolateral to the upper third of the vagina to access the bladder trigone. The ureter should be visualized during deep infiltrative pelvic endometriosis surgery to avoid injuries.

The pelvic ureter receives its blood supply from the branches from the *internal iliac artery*, *uterine artery*, *inferior vesical artery* and *vaginal artery*.

*Applied anatomy. The ureter is most prone to injuries at:

- The ovarian fossa in the lateral pelvic sidewall, the ureter and the internal iliac vessels are directly posterior and prone to surgical injury in ovarian surgery or in coagulating or cutting the infundibulopelvic ligament during hysterectomy.
- One to two centimenters lateral to the supravaginal cervix and superior to the lateral fornix, the ureter passes below the uterine artery and is at risk of surgical injury at hysterectomy, during coagulation or ligation and cutting of the uterine arteries as it passes below the uterine artery.
- During coagulation or cutting, the vaginal angles and the parametrium 1–2 cm lateral to vaginal vault.
- Note that there could be congenital alteration in the pelvic course of the ureter and acquired alteration by pelvic adhesions or tumours increasing the risk of surgical damage to the ureter.

## 7 Uterine and Cervical Ligaments of Importance in Female Pelvis

The uterine and cervical ligaments of importance in female pelvis are as follows:

- The broad ligament
- The round ligament
- The ovarian ligament

The broad ligament is a double sheet of peritoneum that extends from the lateral wall of the uterus to the lateral pelvic wall. Its outer upper part forms the infundibulopelvic ligament in which the ovarian vessels traverse their way to the ovary. Its contents are round ligament, ovarian vessels, uterine vessels, ureter, parametrial lymphatics and lymph nodes. Others include sympathetic and parasympathetic nerves, parametrial pelvic cellular tissue and fascia. Occasionally the following structures could be present, the embryological remnants of the Wolffian ducts, hydatid cyst of Morgagni, Koblet's tubules, epoophoron, paroophoron and Gartner's duct.

The round ligament is a fibromuscular ligament attached to the uterine cornu. It runs downwards and forwards in between the two leaves of the broad ligament to enter the inguinal canal via the internal inguinal ring and comes out of it at the external inguinal ring to be inserted in the upper part of the labia majora. It pulls the uterus forwards and helps to keep it in an anteverted position.

Each fibromuscular cordlike ovarian ligament attaches the inner lower pole of the ovary to the uterine cornu of the uterus posteroinferior to the attachment of the fallopian tube [6]. As a continuation of each round ligament, they are the homologues of gubernaculum testis [6]. It plays no role in the pelvic support of the uterus.

### 7.1 Cervical Ligaments

The cervical ligaments are condensed thickening of the pelvic cellular tissue, which lie between the pelvic peritoneum above and the levator ani below and radiate outwards from the cervix to reach the pelvic walls. They act as the chief support of the uterus and pelvic structures. These are the Mackenrodt's ligaments (the two cardinal ligaments of the cervix) that spread out on either side from the lateral surface of the cervix and vagina, in a fan-shaped manner, and are inserted in the lateral pelvic sidewall.

The uterosacral ligament pair runs from the posterior aspect of the supravaginal cervix and upper vagina, backwards surrounding the rectum and below the uterosacral folds of the peritoneum, to insert in the third piece of the sacrum (S3).

The pubocervical ligaments extend from the anterior surface of the cervix and vagina, forwards beneath the bladder and surrounding the urethra, to the posterior surface of the pubis. The cardinal ligament and uterosacral ligament provide level one support to the uterus and vaginal apex, while the lateral attachments of the vagina to the endopelvic fascia to the arcus tendinous fascia of the pelvis provide level two support to the bladder, vagina and rectum and the third level support from perineal membranes and perineal body to the urethrovesical junction (UVJ) and perineum [9, 10].

## 8 Vagina

This is a fibromuscular tube from the vulva to the uterus forming an angle of 60° with the horizontal plane. The anterior wall is about 8 cm and the posterior wall is about 10 cm in an adult female.

The cervix projects in the upper blind end of the vagina forming a pouch (vaginal pouch) around the cervix and is divided into four fornices, two lateral, an anterior and a posterior (deeper) fornix.

Anteriorly, the upper third relates to the trigone of the urinary bladder and the lower two-thirds to the urethra.

Posteriorly, the upper third relates to the peritoneum of the Douglas pouch, the middle third ampulla of the rectum and the lower third of the perineal body.

The lower end of the vagina relates laterally to bulbocavernosus muscle, vestibular bulb and Bartholin gland [6]. About one centimetre above the vaginal orifice is the urogenital diaphragm, 2.5cm above the orifice is the levator ani muscle with the pelvic fascia above it. The lateral fornix gives attachment to the lower part of the cardinal ligaments. The ureters pass through the cardinal ligaments 1–2 cm lateral to the vagina.

Ligamentous supports attaching to the upper vagina are the *pubocervical ligament* anteriorly, *Mackenrodt's ligament* laterally, *uterosacral ligament* posteriorly and the pubo-vaginalis part of levator ani muscles. Other supports are the triangular (sacrospinous) ligament and the perineal membrane. The vaginal fascia connective tissue is the fascia that condenses anteriorly forming the vesicovaginal fascia and posteriorly forming the recto-vaginal fascia. The cut section of the vagina appears 'H'-shaped with the approximation of the anterior to the posterior vaginal walls [11]. Histologically it has three layers: the mucosa, formed of stratified squamous epithelium without glands; the musculosa, which is fibromuscular with some fibres from the levator ani inserted into it; and the adventitia, which is connective tissue continuous with the paracolpos. As the vagina has no mucosal gland, it is only lubricated by transudate from blood vessels and secretions from Bartholin's and Skene's glands [11, 12]. Blood, lymphatics and nerve supply to the vagina are as follow. The vaginal artery (from the internal iliac artery), additional branches from the middle rectal artery (from the internal iliac artery), inferior rectal artery (from the internal pudendal artery, of the internal iliac artery). Venous drainage is via a plexus around the vagina (the vaginal plexus) and drains into the internal iliac vein by veins that accompany their corresponding arteries. Lymphatic drainage of the lower third of the vagina is to the inguinal lymph nodes, the middle third drains to both upper and lower directions, and the upper third follows lymphatic drainage of the cervix. For the nerve supply of the vagina, the pudendal nerve gives sensory fibres to the lower vagina.

*Applied anatomy: In vaginal prolapse, weakness of the vaginal supports (ligaments, fascia and muscles) may result in the descent of the anterior vaginal wall (cystocele or urethrocele), the descent of the posterior vaginal wall (rectocele or enterocele) [11] or descent of the vaginal vault after hysterectomy (vault prolapse).

The posterior fornix offers access to the pouch of Douglas for performing culdoscopy, culdocentesis and drainage of a pelvic abscess.

In the lateral fornix, the ureter lies 1–2 cm lateral to it so that it is prone to surgical injury during dissection, coagulation, ligation or cutting at the angle of the vagina in hysterectomy.

The pudendal nerve blocks: transvaginal injection of a local anaesthetic solution around the pudendal nerve as it passes around the ischial spine giving local anaesthesia sufficient for minor operations on the vulva and vagina and low forceps operations in obstetrics.

## 9 Female Avascular Pelvic Spaces (Figs. 9 and 10)

*Avascular planes/spaces of the female pelvis (anterior and posterior cul-de-sacs, vesicovaginal space, prevesical or retropubic space of the Retzius, paravesical spaces, pararectal spaces, rectovaginal space and retrorectal/presacral) to the surgeon are empty, only filled by fat and loose connective/areolar tissues and no large vessels or nerves [11].

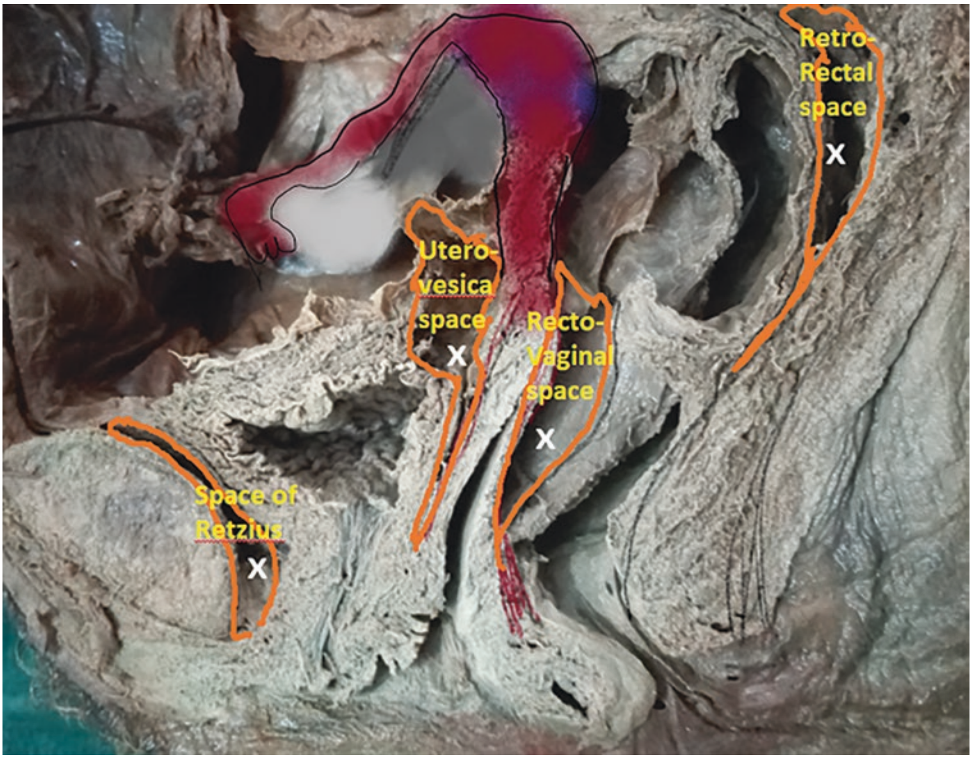
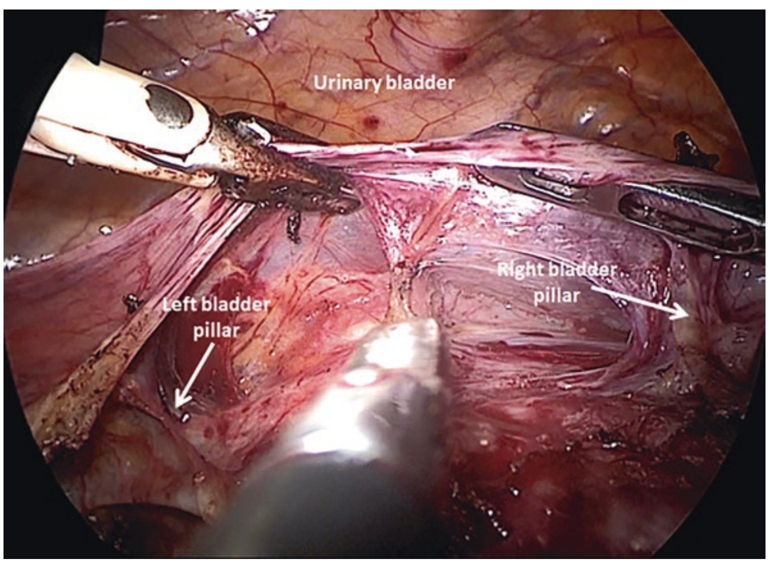



**Fig. 9** Sagittal view of female avascular pelvic spaces (*in-house use only*)

**Fig. 10** Vesicovaginal space



Three pairs of ligaments divide the pelvis into eight potential spaces filled majorly with loose connective tissues usually devoid of blood vessels and nerves [2, 13]. The ligaments include a pair of pubocervical ligament, a pair of cardinal ligaments (transverse cervical or Mackenrodt ligament) and a pair of uterosacral ligaments [13].

The eight spaces are the prevesical space (Retzius), bilateral paravesical spaces, bilateral pararectal spaces, vesicovaginal space, rectovaginal space, retrorectal space or presacral space [10].

## 10 Anatomic Surgical Areas of the Pelvis

Figure 12 shows live laparoscopic picture to depict four middle and two lateral pelvic spaces.

The pelvic spaces are virtuous spaces made of peritoneal reflections between contiguous abdominal and pelvic organs. These spaces are filled with loose areolar connective tissues, occasionally traversed by neurovascular bundles. Laparoscopic or open surgical dissections to open these spaces can be made to facilitate surgical treatments in benign conditions like deep infiltrating endometriosis and frozen pelvis and in gynaecological oncological surgeries. Surgery, especially endoscopic, remains the mainstay in the management, diagnosis and treatment of endometriosis [14].

There are four midline spaces: prevesical spaces of Retzius, vesicovaginal space, rectovaginal space and presacral space. The midline spaces are mainly used for benign gynaecological diseases like deep infiltrating endometriosis surgery and urogynaecological surgeries. Laterally there are two spaces on each side – the anteriorly located paravesical and posterior pararectal spaces. The lateral spaces are the paravesical and pararectal. The lateral spaces can be developed and very useful in gynaecological oncology, frozen pelvis and deep infiltrating pelvic endometriosis surgeries. Safe reconstructive and extirpative benign gynaecological surgery requires the identification, entry and dissection of the middle spaces, while oncologic surgery, besides, requires the penetration and dissection of the lateral spaces [11]. The floor of the pelvic spaces are formed by the pubocervical fascia and the levator ani muscles.

The prevesical space (of Retzius) is useful for Burch colposuspension and related urogynaecological surgical procedures and paravaginal prolapse repairs. It starts from the level of Cooper's (pectineal) ligament. The lateral wall is the arcus tendina (a white thick fascia formed by the fusion of the obturator fascia and puborectalis fascia) overlying the obturator internus muscle. The anteromedial border is formed by the pubic bone and the pubic symphysis. The posterior wall is the bladder, bladder neck and pubocervical fascia. Its contents are mostly areolar tissues containing vesical venous plexus.

The vesicovaginal space is the space between the posterior wall of the urinary bladder anteriorly and the anterior surface of the upper vagina and cervix posteriorly. Its lateral borders are the left and right bladder pillars (vesicouterine/vesicocervical ligaments) and the ureter. Space is opened by incision of the vesicouterine peritoneal fold during total abdominal hysterectomy to separate the urinary bladder away from the lower uterine segment, the cervix and the upper one-third of the vaginal to complete the hysterectomy. It contains mainly fibro-areolar tissues between the back of the bladder and the anterior surface of the vagina (Fig. 8).

The rectovaginal space is a safe avascular space to access the rectovaginal septum and repair the rectocele. It is bounded superiorly by the pelvic peritoneum and uterosacral ligament and laterally by the rectal pillars and the iliococcygeus muscles (part of levator ani). The rectal pillar is the crescentic fold of the peritoneum which passes backwards from the cervix, on both sides of the rectum to the posterior wall of the pelvis. Posteriorly, it lies in the rectum and anteriorly the vagina, both covered by their visceral fascial capsules. The inferior border is formed by the rectovaginal fascia and septum. To get to the rectovaginal space and dissect safely, bilateral ureterolysis is advised during corrective surgeries for rectovaginal deep infiltrating endometriosis.

These rectovaginal ligaments contain the neurovascular supplies including the autonomic pelvic splanchnic nerves that should be preserved during surgical dissection of this space in deep infiltrating endometriosis surgery.

The presacral/retrorectal space lies below the bifurcation of the aorta and laterally bounded by the internal iliac arteries.

The retrorectal space is between the rectum anteriorly and the sacrum posteriorly. This space is entered abdominally by dividing the mesentery of the sigmoid colon or through the pararectal spaces. Inferiorly this space terminates at the level of the levator muscle and laterally continues as the pararectal space and extends superiorly into the presacral space, a superior extension of it. The presacral space is bounded anteriorly by the deep parietal peritoneum and posteriorly by the anterior surface of the sacrum. The endopelvic fascia in this space envelops the visceral nerves of the superior hypogastric plexus and the lymphatic tissue. The lateral boundary of the presacral space is formed by the common iliac artery, ureter and inferior mesenteric artery. The presacral space or prelumbar space is bordered anteriorly by the rectum and posteriorly by the sacral bone hollow, from the promontory to the rectoanal junction. It begins from the bifurcation of the aorta into the common iliacs, just below the sacral promontory. On the right lateral aspect, it is bounded by the right common iliac and the right ureter and on the left lateral aspect by the left common iliac artery, the left ureter and the inferior mesenteric artery. Its floor is the ischiococcygeus muscle. The contents are the presacral nerves, fatty areolar tissues and neurovascular plexuses (hypogastric plexus of parasympathetic/sympathetic nerves and vascular plexus). At the sacral promontory, the common iliac vessels bifurcate into the external and internal iliac branches. The ureter crosses over from the lateral to the medial side. Arising from the posterior aspect of the descending aorta, a few millimetres above the bifurcation is the middle sacral artery. It enters the space and lies directly on the sacral bone. The middle sacral vein accompanies the artery. Surgical dissection into the presacral space is used mainly for sacral neurectomy to treat intractable/chronic pelvic pain and other pathologies, e.g. endometriosis or cancer of the abdominopelvic organ.

The pararectal space is bilateral, and the boundaries are rectal pillars medially, levator ani laterally and posteriorly and above the ischial spine by the sacrum. It is separated from the retrorectal space by the posterior extending rectal pillars.

The pararectal space is a triangular space posterior and inferior to the base of the broad ligament where the ureter passes underneath the uterine vessels. Its anterior border is the base of the cardinal ligament, laterally by the iliococcygeus fascia and muscles and posteriorly by the internal iliac vessels. The medial border is the ureter and the rectum. Its floor is the levator ani muscle. Posterolateral dissection into this space behind the uterine artery is oftentimes useful in the surgical management of deep infiltrating endometriosis and gynaecological oncology.

The paravesical spaces are bilateral and lie above the cardinal ligament. It is the space anterior and inferior to the base of the broad ligament. It leads to the retropubic/prevesical space of Retzius. The floor is the cervical fascia and arcuate tendinous fascia. Its posterior border is formed by the internal iliac veins, ischial spine and anterior border by the back of the pubic bone. The medial border is the bladder pillars and the anterior vagina, the lateral border is the pelvic sidewall (fascia of obturator internus and levator ani) obturator vessels and nerves, and the superior border is the lateral umbilical ligaments (Figs. 11 and 12).

Other spaces including the Okabayashi space and the fourth space are spaces between the ureter and the broad ligaments and the space between the ureter and paravaginal, respectively.

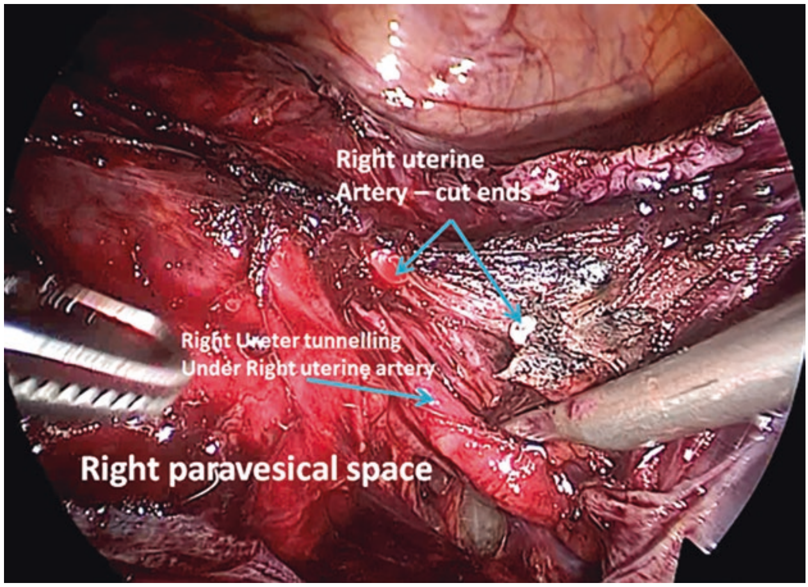



**Fig. 11** Right paravesical space

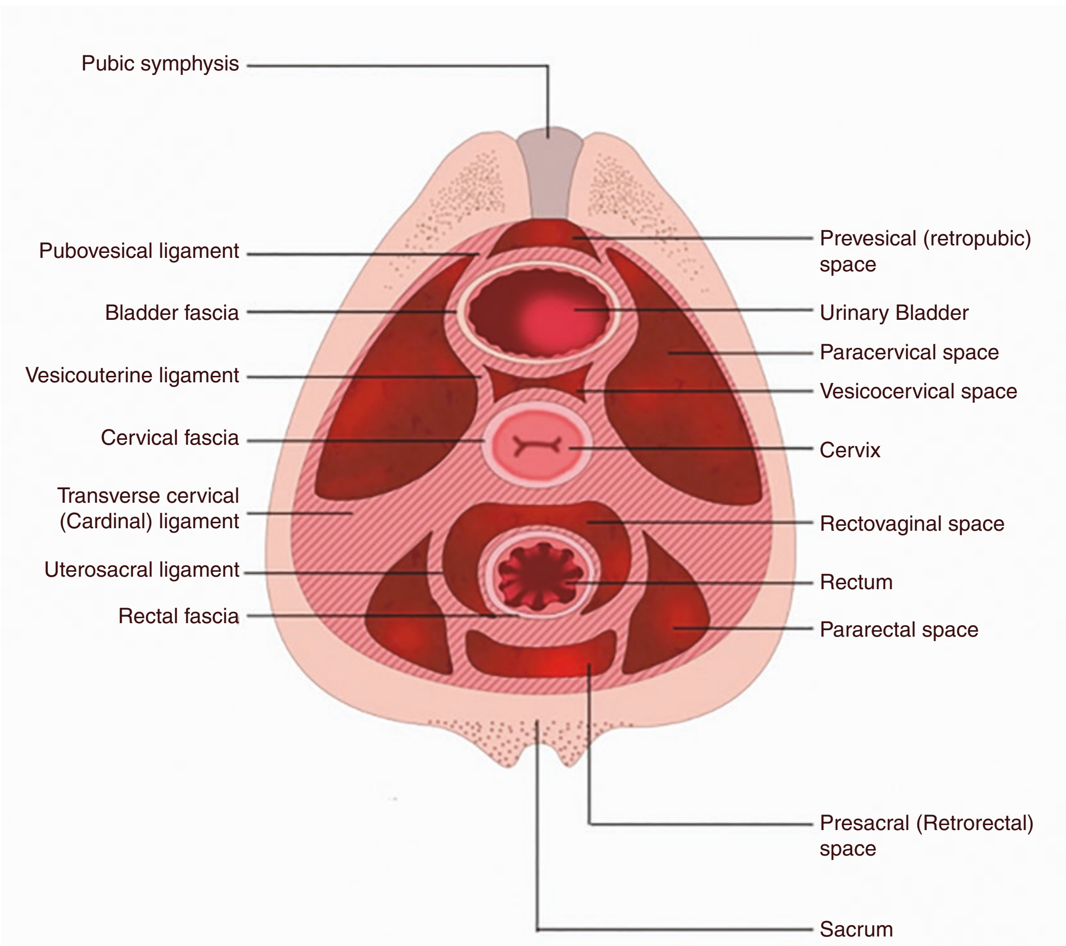



**Fig. 12** Transverse view of female avascular pelvic spaces

## 11 Conclusion

The pivotal role of good knowledge of female pelvic anatomy in the diagnosis and surgical treatment of gynaecological pathologies is not in doubt. The surgical knife in the pelvis must bear a safe course for safe surgery. The pelvic anatomy reminds us of the simple but complex environment we have to scope. The assumption usually leads to frustration; there is therefore a need to review videos of the type of procedure to be done before embarking on any.

**Learning Points**

- An overview of the surgical female pelvic anatomy as it relates to gynaecological endoscopy is discussed.
- The middle pelvic compartment is unique to the female containing the female internal genitalia.
- The knowledge of avascular pelvic spaces is key to successful gynaecological endoscopic surgical dissections in the female pelvic anatomy. To the laparoscopic surgeon, these spaces are potential anatomical spaces that can be developed to facilitate treatment of frozen pelvis, deep infiltrating endometriosis and gynaecological malignancy. Undissected and undeveloped, these spaces are filled with loose areolar connective tissues and are devoid of large vessels and nerves.
- Tears and weakness of the endopelvic fascia are the primary event in all types of vaginal prolapse [7, 15].
- The ureter and the internal iliac vessels are prone to surgical injuries during gynaecological surgical dissections, ligation, cutting or coagulation as they pass behind the ovary in the ovarian fossa.
- Similarly, the ureter can be injured at the pelvic brim as it enters the pelvis in close proximity to the infundibulopelvic ligament and in the ovarian fossa and as it passes under the uterine artery, 1–2 cm lateral to the vaginal vault. It is pertinent to note that there could be congenital alteration in the pelvic course of the ureter or acquired alteration by pelvic adhesions or tumours increasing the risk of surgical damage to the ureter.
- Gynaecological endoscopic anatomy may appear incomplete without a note on the anterolateral abdominal wall, the window to laparoscopic entry to the pelvis. To avoid injury to anterolateral abdominal vessels during laparoscopy, the primary trocar should be introduced slightly to the left at the umbilical level to avoid injury to the umbilical vascular plexus mostly located to the right of the umbilicus, while the secondary/lateral trocar insertions are away from the superficial and deep lower anterolateral abdominal wall vascular supplies to avoid injuries to these blood vessels.
- The umbilicus lies in most cases directly above the level of the bifurcation of the abdominal aorta. Therefore, all caution should be undertaken to avoid injuries to the aorta during the laparoscopic introduction of the Veress needle, trocar and cannula for carbon dioxide insufflation and introduction of laparoscopic hand instruments.

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# Ergonomics and Patient Safety in Gynaecological Endoscopic Surgery

Bolarinde Ola and Ibrahim Wada

## 1 Introduction

Ergonomics is the interaction between human factors, equipment, and the work environment (theatre set-up) needed for task completion (Fig. 1). Traditionally, the main objective of surgical ergonomics had focused predominantly on how posture, movement, convenience and comfort of the surgeon affected task completion and less on the patient or team safety [1–3]. Nowadays, however, the whole concept of surgical ergonomics has changed significantly. It is now considered a much broader subject, defined as the task-based management of the operative theatre environment, staff skills mix, equipment, information flow, team cohesion and surgeon's comfort, in order to achieve patient and team safety and optimal surgical outcomes [4]. In these contexts, the World Health Organization's safe surgery checklist [5] has been adopted widely as a robust way of ensuring patient safety through improved communication, task-based transactional leadership and surgical ergonomics in theatres.

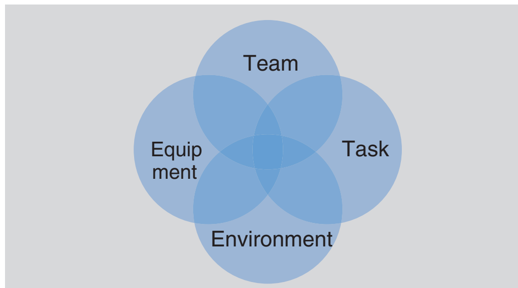


**Fig. 1** Ergonomics in the workplace

## 2 Ergonomics in Endoscopic Surgery

In endoscopic surgery, ergonomics for patient safety should ideally start with the first patient encounters, including the various aspects of patient selection. This is because patient selection will significantly inform further preparations in the areas of safer surgery checklists, theatre set-up, equipment, surgical skills, strategies, tactics, operative sequence and time management. Another important aspect is continuing professional development (CPD)—gaining new skills and acquiring new technology—which makes surgical tasks easier and safer to accomplish. These interacting factors are illustrated in Fig. 2.

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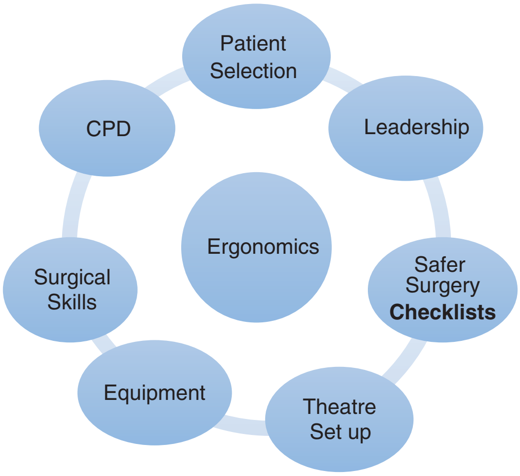


**Fig. 2** Surgical ergonomics and patient safety

## 3 Patient Selection

Three interacting factors define patient selection and can significantly influence surgical safety and optimal surgical outcomes (Fig. 3). These must therefore always be borne in mind during all encounters with the patient.

### 3.1 Patient

It is good practice for surgeons to see their patients personally at least once preoperatively and crucial to take a detailed history and perform a thorough examination. The age of the patient, body mass index (BMI) and past medical and surgical histories should be recorded clearly, as these may influence preoperative anaesthetic input, multidisciplinary team management, theatre set-up and patient positioning and whether or not a patient requires postoperative critical care. It is also very important to retrieve old records of concurrent medical conditions, previous surgery and past medical and surgical complications.

### 3.2 The Disease

One of the most important considerations for surgical ergonomics is the disease entity. A careful assessment will help determine the size, severity

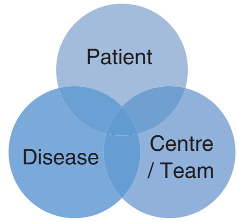


**Fig. 3** Factors influencing patient selection for surgery

and site of disease; the extent of adhesions to be anticipated, proximity to structures like the ureters, bowel or vessels; and therefore, whether to refer to another surgeon with more experience and expertise, or organise a multidisciplinary team approach. A very careful assessment of the disease will also facilitate the evaluation of anaesthetic/intubation risks, difficult access/insertion of ports, difficulty with ventilating lungs, anticipated operative haemorrhage and increased risk of high dependency unit (HDU) or intensive care unit (ICU) admissions.

### 3.3 Team and Centre

A surgeon should always observe the tenets of evidence-based practices, operate within his/her capabilities and ensure that support facilities are available in his/her centre to achieve safe and optimal surgical outcomes. Certain conditions like recto-vaginal endometriosis, gynaecological cancers and recurrent utero-vaginal prolapse are best treated in accredited specialist or subspecialist centres. Other diseases require multidisciplinary (radiology, anaesthetic, chest, colorectal, haematological or urological) team support or are best operated in hospitals with intensive or critical care support.

## 4 Communication and Leadership

Surgical ergonomics depend on forward planning, hinged on good communication and leadership. Therefore, the theatre manager should always receive a detailed theatre list in good time. This should include a column for all tactical equipment, implants and the multidisciplinary professionals needed or anticipated for each case. For example, a very obese patient may require a wide bariatric operating table, leg supports and longer instruments, trocars and cannulas. Furthermore, the provision of some specialist surgical instruments and appliances may require forewarning. It is also very important for the surgeon to make sure he/she gets the required number of trained and sufficiently experienced surgical assistants. Where a multidisciplinary team involvement has been pre-planned, each member must be copied into the theatre list circulation.

### 4.1 Safe Surgery Checklists

The World Health Organization's safe surgery checklist [5] has been adopted widely as a robust way of improved communication and task-based leadership in surgical theatres. There are four to five steps, the first three of which are essential steps of endoscopic ergonomics:

- *A team brief* is a face-to-face meeting of the whole theatre team to prepare and plan together before the operation. This starts with the introduction of each member by names and roles, a check of the environment and equipment and to ensure the theatre list, consents and requirements have not changed.
- The *sign-in* requires at least an anaesthetist and nurse to be present. It is to ensure the patient has identified him−/herself and confirmed consent for type and site of surgery, allergies, anaesthetic or bleeding risks.
- The *timeout* takes place just before knife-on-skin and requires the surgeons and anaesthetists to be present to confirm the type, site and extent of the operation and peri-operative antibiotics, review images and check the correct positioning of the equipment, patient, scrub nurse and assistants.
- The *sign-out* takes place after the completion of each operation before the patient leaves the theatre. It is to confirm that all planned procedure had been completed, instrument and swab counts are correct and all specimens are labelled correctly. The surgeon and anaesthetist also discuss any concerns for post-operative recovery.
- At the end of the list, the whole team *debriefs*. This is to evaluate the day's list, learn from incidents and identify and remedy problems and equipment failure. It is also an opportunity for the team to plan for the surgeon's next theatre list.

## 5 Theatre Set-up (Optimising the Environment)

A good theatre set-up depends on effective communication with the theatre staff about everything that is required per case before the day. A good surgeon is familiar with all his/her equipment and able to troubleshoot. It is not advisable to start until every equipment is complete, set-up and working, and competent assistants are present, with good visibility (Fig. 4).

Most theatre tables were traditionally designed for men performing open surgery. Increasingly, however, more women are becoming endoscopic surgeons, and frequently, disparities may exist in the heights of the lead and assisting surgeons. Berguer et al. [6] showed that the surgeon's comfort and task completion were much better with the handles of the instruments at about the level with the surgeon's elbow. To achieve this, the most ergonomic operating surface height should lie between 70% and 80% of the surgeon's ground-to-elbow distance as shown in Fig. 5 [7]. Studies have also shown that abnormal variations in working surface height relative to the height and upper extremity efforts of those performing tasks can cause musculoskeletal injuries [8]. As a result, modern tables can now be lowered well below 72.5 cm [7]. Abdominal insufflation with carbon dioxide as well as the Lloyd-Davis and Trendelenburg positioning will usually further raise the patient's umbilical level; therefore, the operating table usually needs to be lowered even more. Where theatre tables cannot lower enough,

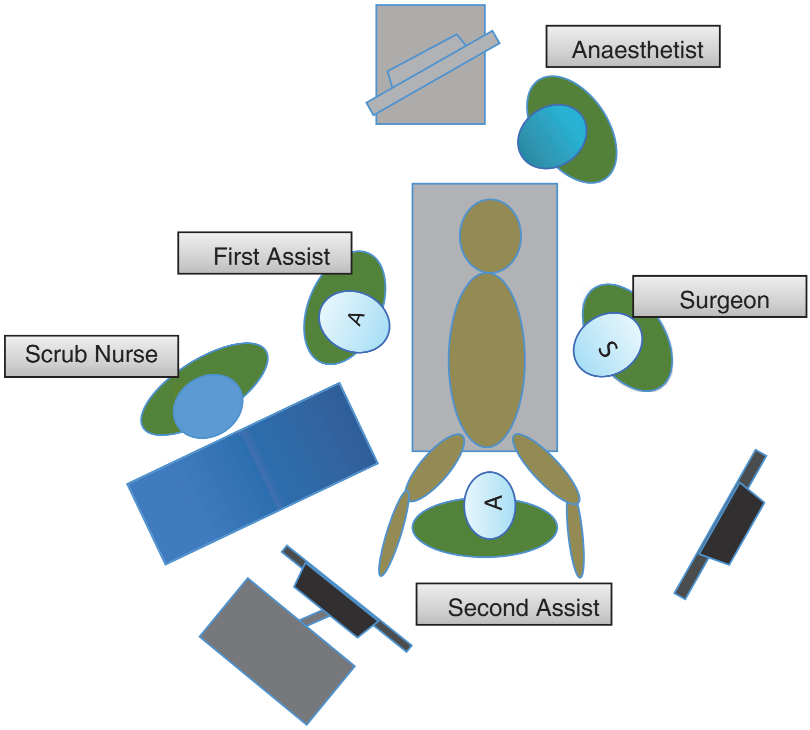


**Fig. 4** Typical gynaecology theatre arrangement. All key persons, surgeon, surgical assistant, anaesthetist scrub nurse and circulating staff should have a clear view through at least two big screens

the surgeon or assistant should elevate their elbow height as required by standing on steps.

## 5.1 Display Screen: Height and Position

In many cases, the surgeon and assistant share the same monitor, which is usually positioned at the bottom of the table. This causes prolonged axial rotation of the spine, leading to muscle ache, spasm and tiredness, particularly for the assistant. Ideally, one screen should be positioned in front of each lead and assistant surgeon, in line with the longitudinal axis of his/her dominant forearm. Studies have shown that task efficiency is best when the middle of the screen is no more than 10° below the horizontal lines from the surgeon's eyes [9–11]. The positioning and height of the monitors determine the degree of neck rotation and flexion/extension endured by the surgeon and assistants.

The ideal distance (from the surgeon/assistant to each display monitor) to avoid eye straining has been the subject of research. The maximum distance increases with the size of the display monitor. According to El Shallaly and Cuschieri [12], the mean minimum and maximum distances from a standard 34-cm cathode ray tube monitor were 136 and 221 cm, respectively. They conclude that the surgeon should never be closer than 90 cm, or a distance less than three times the diagonal distance of a 34-cm monitor screen. They also suggested that a surgeon should ideally not be farther than 300 cm (Fig. 6), or a distance of about ten times the diagonal width of a 34-cm cathode ray screen [12]. The result of this research should, however, be considered in the context of the increasing availability of bigger display thin-film transistor (TFT) screens which have much higher resolution than older cathode ray tube monitors.

## 5.2 Instrument Handles

Most gynaecological laparoscopic instruments have handles that are either in-line (rod and axial) as shown in Fig. 7, or offline (shank and pistol types) as in Fig. 8. Offline handles may require radial or ulnar deviations at the wrist to constantly align/realign the instrument with the axis

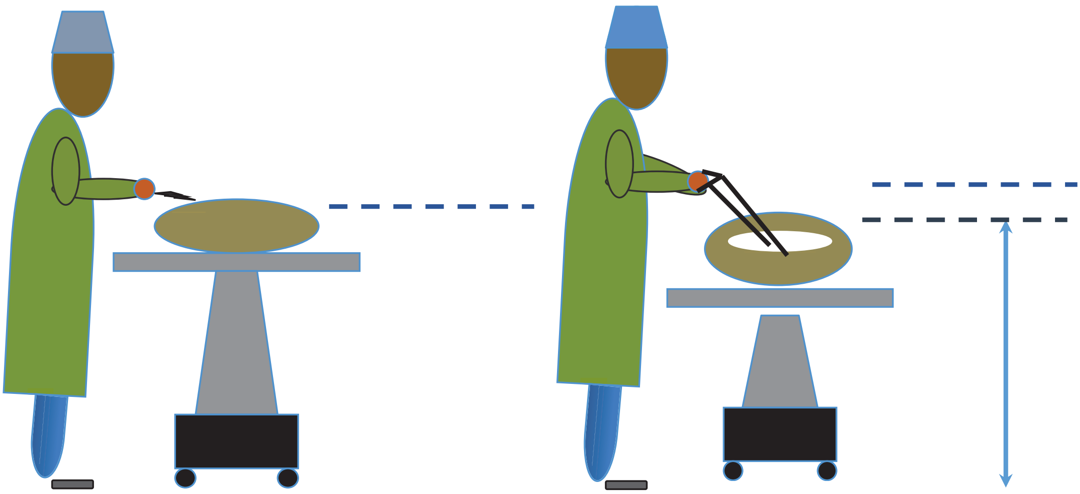

**Fig. 5** Operating table height. Ideal table heights for open and laparoscopic surgery: The patient's umbilical level is at elbow level for open surgery (left), but during laparoscopic surgery, the table should be lowered (or surgeons elevated by standing on steps) so that the patient's umbilicus is 80% of the surgeon's ground to elbow distance [7]

**Fig. 6** The ideal display distance: This should not be less than 90 cm or farther than 300 cm. The distance from the surgeon's eyes to the centre of the screen should not be lower than 10° from the horizontal

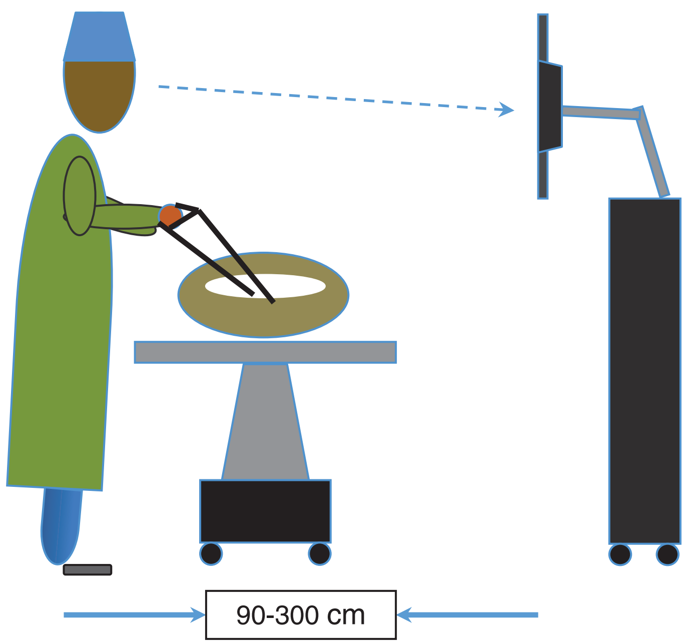


**Fig. 7** In-line (rod or axial) handles

**Fig. 8** Offline (shank or pistol) handles

of the lower arm, which can cause muscle strain. These offline instruments are also usually the same size and with fixed-size thumb and finger rings that may cause compression neuropathy after prolonged use. Axial needle holders generally used in gynaecological surgery are not best suited because of the amount of ulnar deviation and arm abduction necessary to complete suturing tasks. Increasingly, the use of armrests has been advocated for prolonged, precise and repetitive laparoscopic procedures. Experiments by Galleano and colleagues [13] found that armrests offer two advantages to laparoscopic surgeons: reducing physiological tremors and delaying the onset of fatigue and discomfort in the muscles of upper spine muscles, shoulder and arm.

### 5.3 Instrument Length

The length of surgical instruments has impacts on surgical outcomes. The shaft of a standard laparoscopic instrument is 33 cm. This is good enough for most patients, whether thin, normal or overweight. However, in very obese women, longer instruments (43 cm shaft length) and trocars are needed for good ergonomics and surgical safety.

### 5.4 Articulated Instruments

With standard instruments, the laparoscopic surgeon does not have an unlimited degree of tip movements. Most gynaecological laparoscopic instruments offer movement in only four axes, which are up and down, left or right or in and out directions; however, a laparoscopic instrument with an articulated tip (Fig. 9) can offer the operator more flexibility without exerting or straining his/her fingers, hand, wrist or upper limb.

### 5.5 The Fulcrum Effects

A fulcrum is a point, anchor or support about which a lever pivots. Laparoscopic port placements have to be carefully planned to take the fulcrum effects into consideration. The shaft of laparoscopic instruments, for the most part, functions like a lever, which pivots around a fulcrum, located underneath the entry point in the abdominal wall as shown in Figs. 10 and 11. Once the laparoscope has been sited and the decision to proceed with the proposed surgery confirmed, the secondary ports should be carefully sited, such that its fulcrum allows maximum precision and economy of movement. If the fulcrum is too low or too high (Fig. 8), task completion becomes imprecise and difficult.

### 5.6 Fulcrum Effect in Morbidly Obese Women

In women with normal BMI, the depth of the fulcrum is only a few centimetres. However, in very obese patients, difficulties of laparoscopy are further compounded by rigidity and limitation of

**Fig. 9** Articulated instruments: forceps (left) and retractor (right)

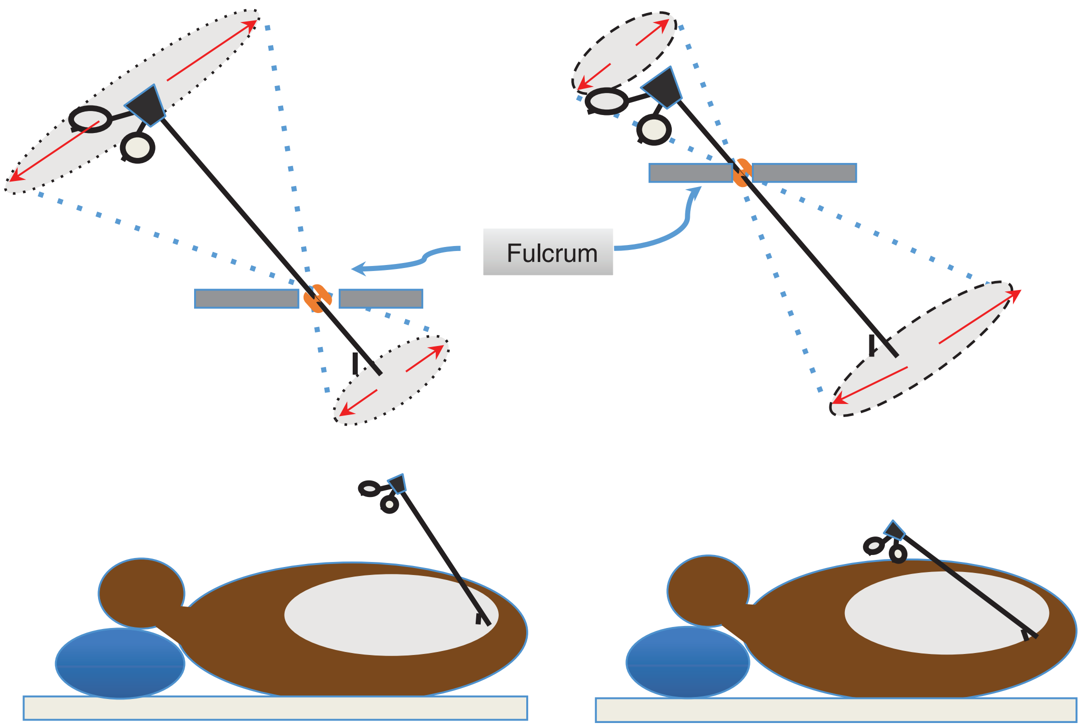


**Fig. 10** The fulcrum effect: This is too low on the left (large shaft movements cause small task movements) and too high on the right (little shaft movements cause large task movements)

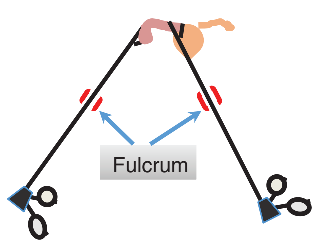


**Fig. 11** Ergonomic positioning of the secondary ports for best fulcrum effect

shaft movement caused by a very deep fulcrum, as illustrated in Fig. 12. Anticipation, forward planning and effective communication will facilitate the provision of long instruments, anti-slip mats and appropriate anaesthetic support.

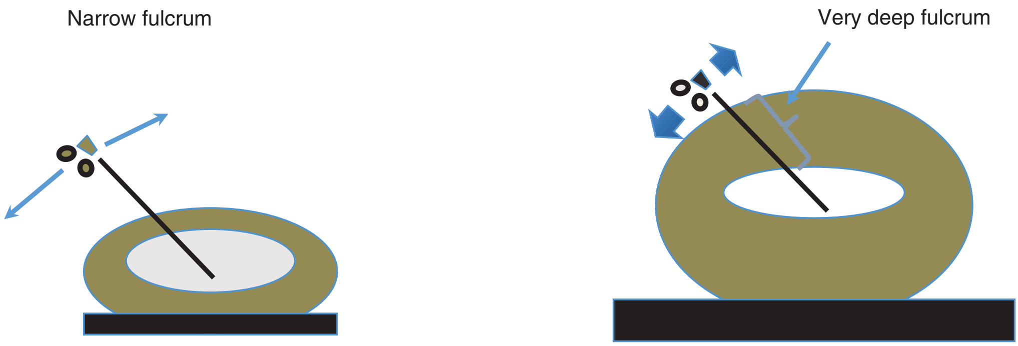


**Fig. 12** A very wide fulcrum limits shaft movement and hampers precision in very obese patients

## 6 Surgical Skills

A surgeon's skills and experience can significantly influence his/her surgical efficiency, comfort and safety. For each patient and each surgical procedure, a good surgeon should think in terms of strategy, tactics, sequence and speed.

### 6.1 Surgical Strategy

The strategy is the standard plan of action designed to achieve the overall aim. All good surgical units have routine plans, manuals or standard operating procedures (SOPs) for running each theatre list, according to speciality or subspecialty as illustrated in the fourth column of Table 1 [14]. This includes a list of standard equipment, drugs, lighting, assistants, routine patient position, team and equipment arrangement and any routinely used appliances or implants. The surgical strategy also includes routine backups, in case of commonly experienced equipment failures.

### 6.2 Surgical Tactics

Tactics, a concept also derived from the battlefield, is the reaction, plan or protocol for dealing with specific problems identified before, during or after they arise [15]. The differences between strategy and tactics are better illustrated using an example from a laparoscopic sterilisation list shown in columns four and five of Table 1. This table illustrates that if information obtained and measures taken from the first patient contact are communicated, it can bear significant influence on patient and team safety and also on surgical ergonomics. Despite good forward planning, complications can still arise during surgery; therefore, it is important not to dismiss unexpected occurrences. The surgeon must follow guidelines for dealing with complications if these exist, for example, instilling methylene blue dye to test for suspected bladder injury or performing air leak tests after bowel injury repair. A safe surgeon always assesses his/her competency to deal with the emergency/complication at hand and should tactically ask for help (surgeon, urologist or another colleague) in good time.

### 6.3 Surgical Sequence

Most surgical operations and procedures have a standard sequence from beginning to completion. It is advisable to always use standard sequence unless special or emerging circumstances dictate otherwise. It is therefore important to complete one step before proceeding to the next. For example, during a total laparoscopic hysterectomy, it is important to insert all ports before 360° inspection and ureteric identification, followed by mobilisation of adherent ovaries, bowel or bladder before sealing and ligating the uterine vessels. Not following this sequence may make a surgeon more prone to causing ureteric injuries. Also, not following standard sequence may make managing compli-

**Table 1** Laparoscopic sterilisation list to demonstrate differences between surgical strategy and tactics: the influence of forward planning on surgical ergonomics

| Patient Hospital number | Procedure | Identified problems | Routine plan (strategy) | Special requirements (tactics or problem-specific plans) |
|---|---|---|---|---|
| Miss A. G.<br>TQ 23456 | Laparoscopic sterilisation | Latex Allergy | Routine theatre set-up | (a) First on list.<br>(b) Latex-free instruments and gloves. |
| Mrs X. W.<br>TR 34567 | Laparoscopic sterilisation | Morbid obesity BMI 50 | Routine lap sterilisation pack | (a) Allow more time.<br>(b) Bariatric operating table.<br>(c) Longer instruments.<br>(d) Two anaesthetists.<br>(e) Experienced assistants.<br>(f) HDU overnight admission.<br>(g) Cross-match blood.<br>(h) Thrombo-prophylaxis. |
| Mrs T. P.<br>TX 45678 | Laparoscopic sterilisation | Nil | Routine anaesthetic set-up | Nil |
| Mrs P. Q.<br>TY 56789 | Laparoscopic sterilisation | Bleeding risk | Routine recovery set-up | (a) Cross-match blood.<br>(b) Haematologist involved. |

cations more difficult: for example, tackling brisk uterine artery bleeding before setting up the suction-irrigation system. Following standard sequence should therefore be a natural, measured and deliberate surgical habit.

## 6.4 Time Management (Surgical Speed)

Obsession with surgical speed can be dangerous. A faster surgeon is not always a better surgeon. Furthermore, hand speed does not always reflect a speedy procedure. Hurried, unsecure knots can end up delaying operating time, and in the same way, unnecessary repetitive hand movements can cause delay and fatigue. If unsure of the next step, it is better to pause, think and plan before executing your next move. It is wise to allow for enough time, to operate naturally and skilfully.

## 6.5 Robotic-Assisted Endoscopic Surgery

Robotic assistance has come a long way from the early slave-cameral holders to the current sophisticated master-slave robotic assistance which has dramatically improved endoscopic ergonomics and minimised or removed problems associated with traditional laparoscopic surgery. Berguer and Smith [16] suggested that robot assistance also reduced the surgeon's mental stress. This finding was supported by van der Schatte Olivier et al. [17], who noted a reduction in both mental and physical stress when the da Vinci robot-assisted system was compared with surgery performed with standard laparoscopic instruments.

Robotically assisted surgery offers improved ergonomics by:

- Allowing the exact movement of the surgeon's hands through articulated instruments, which have the same flexibility of movement as the human wrist.
- Robotic surgery also removes the inverted or reverse response and fulcrum effects associated with standard laparoscopic instruments.
- Three-dimensional imaging offers greater depth than the two-dimensional system of standard laparoscopy.
- The operating console allows a comfortable, ergonomic sitting position with a level or low display monitor and is well suited for long procedures.
- Furthermore, the robotic arms are power-assisted and do not fatigue.

## 7 Conclusion

Surgical ergonomics is rarely taught and, when so, has hitherto focused on patient positioning and theatre set-up arrangements aimed at maximising surgeon's comfort and precision. More current concepts of surgical ergonomics span across measures taken from patients' first encounters to actions taken in the operative theatre. Furthermore, the most important outcome measures are now recognised as task completion and safety. Most surgical ergonomic problems start days, even weeks, before the operation day. To avoid these, it is best to carefully prepare and select patients and carefully consent them personally. Specific tactics for dealing with anticipated or emerging problems should be communicated to the team. Surgeons should not delegate inappropriately and must make it a routine practice to see their patients on or before the surgery day, to clarify that nothing has changed.

**Learning Points**

A. Surgical ergonomics is closely linked to patient selection, surgical skills and safe task completion:

- Take a detailed history and examine patients preoperatively.
- Retrieve old surgical notes.
- Update all relevant investigations.
- Refer complex patients onwards or initiate multidisciplinary management.
- Do not delegate the obtaining of informed consents from patients.

B. The WHO safe surgery checklist embodies surgical ergonomics and safe task completion:

- Before the start of the day's list, do a team brief.
- Before each patient enters the theatre, complete a sign-in checklist.
- Before knife-to-skin, stop every other activity to complete a timeout checklist.
- Before each patient leaves theatre, stop all other activities to complete a sign-out checklist.
- At end of the list, debrief the team to review the day's list, learn from incidents and identify and remedy problems or equipment failure.

C. Surgical ergonomics is not just about the surgeon's comfort; it is also about safe completion of the task:

- It involves theatre set-up (theatre arrangement, instruments, lights and assistants).
- It requires effective communication and task-based transactional leadership.
- It also requires good surgical skills, which embodies concepts of strategy, tactics, sequence and time management.
- Continuing professional development should be made mandatory for all.

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# Gynaecological Endoscopy in a Low−/Middle-Income Country: Challenges and Prospects

Vincent A. Ojo, Robinson C. Onoh, and Gbolahan O. Obajimi

## 1 Introduction

Gynaecological endoscopy entails the use of specialized instruments via minimal access incisions or openings in the body to visualize the reproductive organs. It may utilize natural orifices for either diagnostic or therapeutic purposes. Gynaecological endoscopy generally comprises laparoscopy and hysteroscopy. Other endoscopic practices in gynaecology are fertiloscopy, embryoscopy and fetoscopy, though rarely practiced in developing countries. Laparoscopy provides access to the abdominopelvic cavity through pinhole incisions on the abdominal wall, while hysteroscopy, on the other hand, allows visualization of the endometrial cavity through the natural orifice (vagina and cervical canal) [1].

Gynaecological endoscopy has opened a new vista for the evaluation of the female patient. The deployment of gynaecological endoscopy, though popular in developed countries, is gradually increasing in low−/middle-income countries such as Nigeria. This is because of its advantages over orthodox surgical methods [2]. There has been a slow but continuous increase in the utilization of gynaecological endoscopy in developing countries; however, it is fraught with challenges.

Endoscopy has been regarded as a revolutionary technology available only in few centres in developing countries. Numerous challenges have been ascribed to these such as cultural factors, huge financial requirements and lack of technical support amongst others [3].

The advantages of minimal access surgery are numerous and virtually most gynaecological pathologies can be treated via endoscopy. These advantages include but not limited to rapid recovery post-operatively, minimal adhesion formation, minimal trauma with improved vision, low incidence of complications and cosmetic healing [4]. These advantages have led to increased utilization of minimal access procedures in developed countries and have practically led to a complete overhaul of open surgery with a shift in favour of endoscopy. This, however, is not the case in low−/middle-income countries where gynaecological endoscopic services are limited to few centres which are often privately driven. This is borne out of the fact that exposure to minimal access training has not been fully developed and accepted often due to lack of an enabling environment in most teaching, government and mission hospitals. Endoscopic set-up in private

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**Fig. 1** Endoscopy set-up at a private hospital in Nigeria (Ayo Specialist Hospital, Akure)

**Fig. 2** Endoscopy theatre in a developing centre at Alex Ekwueme Federal University Teaching Hospital, Abakaliki, Ebonyi State, Nigeria

(Fig. 1) and teaching hospitals (Figs. 2 and 3) in low−/middle-income country is shown below.

Furthermore, endoscopic training is not a major component of both undergraduate and postgraduate training in many developing countries, Nigeria inclusive.

**Fig. 3** Endoscopy set-up with a backup at Alex Ekwueme Federal University Teaching Hospital, Abakaliki, Ebonyi State, Nigeria

## 2 Challenges

The establishment of a functional gynaecological endoscopic unit in a developing country is not devoid of challenges. These challenges often differ from unit to unit and may also vary by country [5, 6]. These challenges vary based on the peculiarities of the practice/clinical set-up. Some challenges may be peculiar to some country's geopolitical and socio-economic situations and the extent of the endoscopic practice. In many developing countries, there exist prominent difficulties encountered in implementing policies formulated by the government. This will affect the establishment of gynaecological endoscopy especially in public institutions which are solely dependent on funding from the government. The private sector, on the other hand, is not insulated from environmental challenges which often influence the uptake and acceptability of gynaecological endoscopy. These challenges will be discussed under the following subheadings:

### 2.1 Financial Constraints

Establishing and running a gynaecological endoscopic practice is very expensive and it requires financial commitments from stakeholders especially at the initial set-up. Obtaining loans from banks often involves high interest rates, and currently, no subsidies are in place to cushion such effect, making it very expensive for the beginner. Instruments for laparoscopy are largely classified into various categories and can be purchased from different sources and coupled together. This may reduce the cost; however, it may compromise durability. These categories include hand instruments, optical instruments, light sources, insufflating instruments and energy sources. These requirements are similar for hysteroscopy except for the insufflating instrument which is replaced by a fluid pumping machine. In low-income countries, there is a strong need for synergy between cost and durability of equipment, hence the need for collaboration by gynaecologists and institutions in order to maximize output.

Another expenditure that must be considered is the cost of training. Minimal access surgery requires specialized training, oftentimes with a long learning curve [7]. This generally involves training and retraining in accredited institutions. This would include the use of simulation trainers and wet labs. Team training is preferable for effective endoscopic performance. It is then expected that the leading gynaecologist will step down the training to his contemporaries in order to develop competent assistants. Other elements of training include the development of clinical skills and competence in other ancillary staff. Endoscopic nurses must be equipped with the knowledge and skills to handle and sterilize sensitive instruments without damage. Information technology (IT) specialists who provide audiovisuals would also require appropriate training especially in the area of video recording and maintaining confidentiality.

As has often been stated, endoscopic surgery is technically demanding and requires specific psychomotor abilities and skills different from those required by conventional surgery. It is therefore imperative to invest in manpower development through training, retraining and the creation of an enabling environment [8]. The need to provide incentives to reduce the incidence of staff turnover cannot be overemphasized and has continued to pose serious challenges in low-income countries [9, 10].

## 2.2 Technical Support

Sourcing for experts with minimal access skills can be challenging. It involves detailed planning and scheduling of procedures. There is also the need for compensation for work done and payment for their passages to and from their stations. This itself can be very tasking and may discourage centres from imbibing endoscopic practices. The need to ensure that equipment is serviced as and when due is important to the smooth operation of an endoscopic unit. In developing countries, service providers are often needed urgently to ease the pains of dealing with equipment breakdown. A lot of materials and instruments are being improvised as the basic and appropriately recommended materials are usually not readily available in developing countries. In countries where the endoscopic machines and equipment are manufactured and supplied by first-party collaborators, placement and replacement can be done freely with optimal maintenance. On the contrary, second- and third-party collaborators and partners are present in most developing countries, thus introducing some bureaucracy and price hikes.

## 2.3 Energy Supply

Electricity supply can be a hindrance to setting up and running a viable endoscopic practice especially in low-income countries. Endoscopic operations are solely dependent on power for visualization both in diagnostic and operative procedures. Any disruption in power supply will affect the outcome of the surgery; hence, there is the need for a constant power supply. In developing countries with incessant power outages, there is an urgent need to have alternative sources of energy such as the generator, inverter and/or solar system. This invariably increases the cost of service provided.

### 2.4 First-Party Collaborator in Endoscopic Machine and Instrument Supply

Third-party partnership poses a real challenge to setting/running an endoscopy unit in most developing countries. There is no indigenous company producing endoscopic equipment in low-income settings like Nigeria, and so, there is a dearth of supply of the instruments on immediate demand. Consequently, the cost of procuring endoscopic equipment from third-party collaborators is very exorbitant. There is equally a limitation in the options for purchase. Technical support for instrument maintenance is still very poor and that poses a lot of challenges.

### 2.5 Institutional Policies

The current policies in most government-owned hospitals and many private facilities favour open surgery. Priority has not been placed on the development of endoscopic practices, hence the minimal attention and support for gynaecological endoscopy. A shift in this paradigm is critical in developing countries in order to achieve effective endoscopic-oriented service delivery.

### 2.6 Socio-Cultural Influences

Patients are often concerned about the safety of surgical procedures especially if unfamiliar with the modality. With the introduction of minimal access procedures in developing countries, the need often arises to distill any form of apprehension experienced by patients and their families. Acceptance of minimal access procedures influences the desire to participate. Therefore, efforts must be made to educate patients and other caregivers on the numerous advantages of gynaecological endoscopy.

## 3 Prospects

Opportunities abound in developing countries and must be harnessed by caregivers in order to ensure the delivery of qualitative health-care services. Minimal access surgery provides unique opportunities for both patients and doctors. Surmounting identifiable challenges and taking advantage of the current realities are not only imperative but expedient.

There is an urgent need in low−/middle-income countries to provide information, education and communication (IEC) materials about the safety and reliability of gynaecological endoscopy. This would help dispel fears and concerns about the safety of minimal access procedures. There is a need to partner with various stakeholders in both the public and private sector. This will improve public perception and acceptance.

The need for institutional support and policies cannot be overemphasized. This should be tailored towards the advancement of training in gynaecological endoscopy by providing the required funding and enabling environment [9, 10]. There is also a need for partnership with collaborators in the manufacturing industry in order to guaranty local content in the production and service sectors.

Training and retraining provide wide exposure and promote staff welfare and career advancement [9, 10]. A policy directed towards training would provide a wide array of qualified professionals willing and able to fill the void in developing countries, thus expanding the uptake of gynaecological endoscopy. Policies that provide affordable loans with single-digit interest rates or zero interest rates would further increase uptake by both the private and government-owned facilities.

Effective health-care financing via health insurance schemes will improve health-seeking behaviour and possibly the uptake of minimal access surgeries. Partnerships across boards will ensure seamless service delivery while minimizing costs [9, 10].

## 4 Conclusion

Gynaecological endoscopy has opened a new vista for the evaluation of the female patient. The deployment of gynaecological endoscopy, though popular in developed countries, is gradually increasing in low−/middle-income countries such as Nigeria. Numerous challenges influence the establishment and uptake of endoscopic surgery. Surmounting these challenges through a partnership by relevant stakeholders will further promote the uptake and utilization of gynaecological endoscopy.

### Learning Points

- Gynaecological endoscopy includes laparoscopy, hysteroscopy, fertiloscopy, embryoscopy and fetoscopy with laparoscopy and hysteroscopy being the commonly practiced procedures.
- Challenges in low- and middle-income countries are financial constraints, poor technical support, epileptic power supply, third-party collaboration, institutional/government bureaucracy, socio-cultural influences and out-of-pocket payment instead of the comprehensive health insurance scheme.
- Prospects in low- and middle-income countries are to surmount all the identified and future challenges in the practice of gynaecological endoscopy. Information, education and communication (IEC) is key to effective, satisfactory and successful gynaecological endoscopy.

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# Part II

# Laparoscopy

# Anaesthesia for Laparoscopic Surgery

Cyril E. Nwachukwu, Sameer Deshpande, and Joseph Ifeanyichukwu Ikechebelu

## 1 Introduction

The advancement in surgery was possible due to the development in the field of anaesthesia. One of such advances was the introduction of laparoscopy. Laparoscopic surgery has developed immensely in recent years due to the progress made in both anaesthetic and surgical techniques [1].

This surgical procedure involves the insufflation of a gas (usually carbon dioxide) into the peritoneal cavity producing pneumoperitoneum to enhance the visualization of the abdominal viscera and its manipulation.

Its use is now the standard of care for many abdominal and pelvic surgeries. It offers major benefits to the patient which includes minimized incision size with improved cosmetic results, reduced intraoperative bleeding, reduction of postoperative pain, less post-operative wound infection, reduced metabolic changes, reduced postoperative pulmonary complication, faster recovery, shorter hospital stays, lower costs and more rapid return to normal activities [2, 3].

However, laparoscopic surgery is associated with some risks. This is due to the physiological changes associated with the pneumoperitoneum, patient's positioning and clinical condition.

The perioperative management of these surgeries presents unique challenges to the anaesthetist who should be aware of inherent dangers such as gaseous embolism, hypoxemia, a potential inability to control haemorrhage, an increase in carbon dioxide arterial partial pressure, changes in arterial blood pressure, heart rate and arrhythmias. The anaesthetist must be well informed of the pathophysiological changes following the pneumoperitoneum and be prepared to prevent, detect and treat them.

Laparoscopic surgery is traditionally contraindicated in patients with severe cardiopulmonary diseases and renal dysfunction. However, the risk to the individual patient must be balanced between the risk of complications due to the position, duration, degree of carbon dioxide absorption and physiological effects of pneumoperitoneum for a particular laparoscopic procedure versus the shortened postoperative recovery time which may outweigh the increased intraoperative risk. The

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generally accepted contradictions include pre-existing raised intracranial pressure, severe uncorrected hypovolemia and patients with a known right to left cardiac shunts [4].

## 2 Physiological Changes during Laparoscopy

The physiological effects of laparoscopy are mainly due to the effects of pneumoperitoneum and patient position.

### 2.1 Physiological Effects of Pneumoperitoneum

These effects depend on the type of gas used for insufflation, the flow rate, the intra-abdominal pressure after insufflation, the volume of gas insufflated, the duration of pneumoperitoneum and the use of nitrous oxide for the maintenance of anaesthesia.

The insufflating gas should be colourless, non-toxic, non-flammable, inert, inexpensive, readily soluble in blood and easily expired through the lungs. Air, oxygen and nitrous oxide were tried in the past as insufflating gases but were abandoned due to lack of the above qualities.

Carbon dioxide is the current gas of choice used for insufflation. It is relatively inert, non-flammable and readily absorbed if there is an accidental entry into a blood vessel with a blood gas solubility coefficient of 0.48, so it produces less severe air embolism and is easily expired by the lungs [5].

Gases such as helium, argon and xenon have been studied. They are inert and provide good optical vision but have a very low blood-gas solubility coefficient (0.00018) with a very high chance of air embolism and are very expensive [6].

The effects of carbon dioxide as the gas for pneumoperitoneum are mainly due to the increase in intra-abdominal pressure and its absorption from the peritoneum. As the volume of the abdomen increases on $CO_2$ insufflation, abdominal wall compliance decreases, and intra-abdominal pressure increases. When the intra-abdominal pressure exceeds physiological thresholds, individual organ systems become compromised, potentially increasing patient morbidity and mortality.

The absorbed $CO_2$ from the peritoneum leads to hypercarbia which has both direct and indirect effects on the cardiovascular system.

#### 2.1.1 Cardiovascular Effects

There is a complex interaction between anaesthesia, intra-abdominal pressure, neuroendocrine reactions and the patient's clinical state during laparoscopy. Increased intra-abdominal pressure affects venous return, systemic vascular resistance and myocardial function. This is well tolerated in patients with normal cardiovascular function. Initially, due to auto transfusion of pooled blood from the splanchnic circulation, there is an increase in the circulating blood volume, resulting in an increase in venous return and cardiac output.

However, further increases in the intra-abdominal pressure >15 mmHg result in the compression of the inferior vena cava and abdominal aorta reducing the preload, leading to a decrease in cardiac output and subsequent decrease in arterial pressure. This is exacerbated with the elevation of the diaphragm which raises the intrathoracic pressure with further reduction in cardiac output.

The systemic vascular resistance is increased because of the direct effect of increased intra-abdominal pressure and release of circulating catecholamines especially norepinephrine and epinephrine. This change in systemic vascular resistance is generally greater than the reduction in cardiac output, maintaining or even increasing systemic blood pressure [7]. Report has shown a non-statistically significant difference in haemodynamic changes at 10 min from the time of pneumoperitoneum [8].

Hypercarbia resulting following decreased capacity of $CO_2$ elimination due to prolonged surgery or preoperative pulmonary pathology leads to alteration in haemodynamic state. Thirty percent or more increase in blood carbon dioxide level is usually associated with this change. Mild hypercapnia stimulates the sympathetic system resulting in tachycardia, increased cardiac output and systemic resistance [9].

These could lead to coronary ischaemia because of a short left ventricular ejection time and a short diastolic filling phase resulting in complications for patients suffering from ischaemic heart disease. Severe hypercapnia can lead to reduced left ventricular function and negative ionotropic action [10].

There is a vagal stimulation following peritoneal stretch, insertion of the Veress needle or the trocar, stimulation of the fallopian tube, bipolar electro cauterisation or carbon dioxide embolization. The increased concentration of $CO_2$ and catecholamine can create tachyarrhythmia. Paroxysmal tachycardia and hypertension, followed by ventricular fibrillation, have been reported [11]. The hypertensive response should be managed using β-blockers or an α-agonist [12].

### 2.1.2 Respiratory Effects

Pneumoperitoneum increases the intra-abdominal pressure leading to cephalad displacement of the diaphragm reducing its excursion. This results in the early closure of smaller airways leading to intraoperative atelectasis with a decrease in lung volume, lung compliance and functional residual capacity. This will further lead to preferential ventilation of the non-dependent part of the lung which results in ventilation–perfusion (V/Q) mismatch with a higher degree of intrapulmonary shunting.

Increasing the intra-abdominal pressure reduces the thoracic compliance and may cause pneumothorax and pneumomediastinum due to the increase in alveolar pressures [13, 14]. This mostly occurs at the intra-abdominal pressure of >15 mmHg. The respiratory changes occurring at the intra-abdominal pressure of 10–15 mmHg are well tolerated in healthy patients.

Carbon dioxide absorbed into the blood is expired through the lungs. Some accumulate in the fat tissue and muscle, which explains the high $CO_2$ expired after the end of insufflation. There is an average increase in the carbon dioxide arterial pressure ($P_aCO_2$) from 4.5 to 10 mmHg during $CO_2$ insufflation in an ASA I patient with constant minute volume mechanical ventilation. This is not the same in ASA II and ASA III patients with bigger dead space. The reliability of the $CO_2$ measurement in this group of patients is low and the increase in $P_aCO_2$ can be mis-detected by capnography necessitating the use of arterial blood sampling.

### 2.1.3 Neurologic Effects

Increased intra-abdominal pressure leads to an increase in intracranial pressure by reducing the cerebral venous drainage due to the raised intrathoracic pressure which is a direct consequence of pneumoperitoneum. Raised intracranial pressure which causes reduced cerebral perfusion may also occur due to hypercapnia and become more deleterious in a head-down position. This situation can be detrimental in patients with reduced intracranial compliance. Intraocular pressure also rises due to increase in intra-abdominal pressure. The condition worsens with Trendelenburg's position.

### 2.1.4 Renal Effects

There is a significant effect of pneumoperitoneum on the kidney. Raised intra-abdominal pressure is recognized as a major cause of acute kidney injury. Increased intra-abdominal pressure of about 20 mmHg will reduce GFR by approximately 25%. The mechanism is believed to be due to impaired renal perfusion gradient secondary to the combined effect of reduced renal afferent flow due to impaired cardiac output and reduced efferent flow due to raised renal venous pressure [4]. It is also postulated that an increase in antidiuretic hormone, aldosterone and renin leads to the reduction of renal blood flow.

### 2.1.5 Gastrointestinal Effects

Increased intra-abdominal pressure due to pneumoperitoneum markedly reduces blood flow in the portal vein, hepatic artery and superior mesenteric artery. There may be a transient elevation of liver enzymes due to a reduction in portal blood flow.

The increased intra-abdominal pressure may cause regurgitation of gastric contents with an increased risk of pulmonary aspiration. This is significant in the obese patient [7].

### 2.2 Physiological Effects of Positioning

The positioning of a patient is done to optimize the surgeon's operating view. It is normally done so that gravity causes the abdominal viscera to move away from the operating site and its extent depends on the operative procedures. Patients can be positioned head down (Trendelenburg position) for gynaecological procedures or head up (reverse Trendelenburg position) for upper abdominal surgery. This influences the cardiovascular and respiratory parameters of the patient.

Trendelenburg's position adopted for gynaecological laparoscopic procedures has an overall minimal effect on the cardiovascular system of patients with no cardiovascular condition, though it potentiates the adverse effect of pneumoperitoneum. Initially, there is an increase in venous return, which increases further when lithotomic position is associated. This leads to an increase in cardiac output in healthy patients.

This increase in venous return may not be tolerated in patients with compromised myocardial compliance. There is a further reduction in functional residual capacity, ventilation–perfusion (V/Q) mismatch with a higher degree of intrapulmonary shunting and increased risk of atelectasis. There is a further risk of endobronchial intubation. This is due to cephalad displacement of the lungs and carina. Prolonged steep Trendelenburg position increases the risk of cerebral oedema, laryngeal oedema and respiratory stridor following trachea extubation.

"Well leg compartment syndrome" is a rare but dangerous complication following prolonged surgery in a steep Trendelenburg position. This is due to a combination of impaired arterial perfusion to raised lower limbs, compression of venous vessels by lower limb supports and reduced femoral venous drainage due to the pneumoperitoneum. This presents post-operatively with disproportionate lower limb pain, rhabdomyolysis and potentially myoglobin associated acute renal failure. Risk factors include surgery >4-h duration, muscular lower limb, obesity, peripheral vascular disease, hypotension and steep Trendelenburg position [15]. Neuropathies may occur due to improper care of the pressure areas such as the elbow, knee, feet, face or cornea. Adequate padding is absolutely important.

In reverse Trendelenburg position, the diaphragm descends favouring ventilation with an increase in functional residual capacity. It causes a reduction in venous return with a compensated normal cardiac output in the young and healthy patient by increasing the heart rate and systemic vascular resistance.

However, the compensatory mechanism may not be that effective in elderly patients or patients with systemic vascular disease, thus leading to hypotension or cardiovascular collapse.

These hemodynamic alterations can be extreme in dehydrated patients when myocardial depressing drugs are used and when excessive intra-abdominal pressure compresses the caval vein [16].

## 3 Anaesthetic Management

### 3.1 Preoperative Assessment

A full preoperative anaesthetic assessment should be done with more emphasis on the cardiorespiratory system. This is due to the various effects of pneumoperitoneum and patient position. The patient with a cardiorespiratory disease will require further advanced investigation based on their disease condition. All comorbidities should be optimized. Risk assessment is done using the American Society of Anaesthesiologist (ASA) risk classification.

## 3.2 Premedication

- Short-acting anxiolytic such as midazolam is required to treat anxiety.
- $H_2$ receptor antagonist or proton pump inhibitor may be given to patients with increased risk of aspiration.
- Analgesics such as non-steroidal anti-inflammatory drugs in the form of pre-emptive analgesia [17].
- Antiemetic prophylaxis is important especially in patients with other risk factors. Multimodal regimen such as ondansetron, cyclizine and dexamethasone seems most effective in addition to general measures such as decongesting the stomach, avoiding known emetogenic drugs such as opiates and ensuring good-quality postoperative analgesia [18].
- Thromboprophylaxis is essential in morbidly obese patients. Low-molecular-weight heparin, enoxaparin 0.6 ml sc, dalteparin 5000 IU sc or fondaparinux 2.5 mg sc is given 12 h before surgery.
- Mechanical thromboprophylaxis with a sequential compression device is mandatory [19–21].

## 3.3 Monitoring

Optimal anaesthesia care during laparoscopy requires proper patient selection and monitoring to detect and manage complications.

The standard intraoperative monitoring includes:

- Non-invasive blood pressure monitor.
- Electrocardiogram.
- Pulse oximetry.
- Thermometer for temperature monitoring: This is essential to control patient's temperature because hypothermia can occur in long procedures due to irrigation fluids. This is important because of the associated complications following hypothermia.
- End tidal carbon dioxide ($ETCO_2$) monitoring: Although this is standard monitoring in regular surgery, it is essential in laparoscopy procedures in controlling the $CO_2$ absorption–elimination equilibrium with a targeted level of 35 mmHg. The $ETCO_2$ is correlated with the $PaCO_2$ from 4 to 8 mmHg but the gradient increases to become unpredictable in patients with compromised cardiopulmonary function necessitating the use of an arterial blood gas analyser [22].
- Invasive monitors such as invasive blood pressure and central venous pressure (CVP) measurement are used in monitoring patients with compromised cardiopulmonary function. CVP is misleading since the raised intra-abdominal pressure and airway pressure interfere with pressure-based indices of preload.
- Peak and plateau airway pressure which can increase with the increased intra-abdominal pressure can be measured from the anaesthesia machine.

## 3.4 Anaesthesia Technique

Various anaesthetic techniques can be performed for laparoscopic surgeries. This depends on the type of surgery and patient characteristics. These techniques must accommodate surgical requirements as well as the physiological changes following pneumoperitoneum and positioning.

They include:

- Total intravenous anaesthesia
- General anaesthesia
- Regional anaesthesia
- Local anaesthesia

**Total Intravenous Anaesthesia**: This involves the use of intravenous drugs for all the components of anaesthesia and analgesia without the use of inhalation agents. Generally, the combination of midazolam, propofol and opioid is commonly used. Neuromuscular blockers are used to facilitate endotracheal intubation if required.

**General Anaesthesia**: The use of general anaesthesia with endotracheal intubation and controlled ventilation has been traditionally considered the most acceptable and safest technique for laparoscopic procedures due to the numerous physiological changes associated with pneumoperitoneum and patient positioning. It protects the airway, provides optimal control of $CO_2$ and enhances surgical access. It is usually recommended for long surgical procedures or for patients with a history of gastro-oesophageal reflux.

Induction of anaesthesia involves the use of fast-acting and shorter-duration intravenous induction agents such as propofol and etomidate depending on the patient medical condition. Propofol has antiemetogenic effect which confers another advantage to it in preventing postoperative nausea and vomiting.

Anaesthesia is maintained with the use of rapidly acting inhalation agents such as sevoflurane and desflurane which ensures quick recovery from anaesthesia. Short-acting non-depolarizing muscle relaxants such as atracurium, vecuronium and rocuronium are commonly used to achieve muscle relaxation.

A combination of simple analgesics such as acetaminophen, non-steroidal anti-inflammatory drugs (NSAIDs) augmented with short-acting opioids such as fentanyl and alfentanil is adequate for most procedures. Multimodal analgesia with the addition of local anaesthetic infiltration of port sites can be done. The use of nitrous oxide in laparoscopic procedures is controversial. Recent literature does not convey any clinical advantage of avoiding it against a risk of intraoperative awareness [23]. It is known to cause postoperative nausea and vomiting.

The use of laryngeal mask airway (LMA) in laparoscopic procedures is controversial due to the increased risk of aspiration of gastric contents due to the increased intrathoracic pressure following pneumoperitoneum. It does not allow for control ventilation to maintain the $PaCO_2$.

ProSeal LMA has been found to be effective in pulmonary ventilation in laparoscopic surgery [24].

**Ventilation during Pneumoperitoneum**: Positive pressure ventilation with neuromuscular blocker is necessary to provide optimal surgical exposure. This is also important in ensuring $CO_2$ absorption–elimination equilibrium. This can be performed using either volume-controlled ventilation (VCV) or pressure-controlled ventilation (PCV) with the aim of adjusting minute ventilation to achieve $ETC0_2$ of 30–35 mmHg.

There is a decrease in thoracic compliance that occurs with the initiation of pneumoperitoneum which may result in a drastic decrease in tidal volume delivered for the same inspiratory pressure when PCV is used. This will lead to a decrease in minute ventilation leading to hypercapnia. Termination of the pneumoperitoneum may result in a drastic increase in tidal volume with a resultant increase in minute ventilation. These changes observed in PCV can be avoided by using VCV or altering the pressure of using PCV to achieve the ideal tidal volume.

Pneumoperitoneum and Trendelenburg position can result in increased intrathoracic pressure due to cephalad displacement of the diaphragm. This leads to the demand for a higher airway pressure to achieve adequate minute ventilation. Atelectasis can be formed due to this increase in intrathoracic pressure requiring positive end expiratory pressure on the order of 4–5 cm $H_2O$ to maintain oxygenation [25].

VCV uses constant flow to deliver a preset tidal volume to ensure adequate minute ventilation at the expense of an increased risk of barotrauma and high inflation pressures.

**Regional Anaesthesia**: The use of regional anaesthesia for laparoscopy has not gained popularity until recently due to the risk of aspiration and respiratory embarrassment caused by pneumoperitoneum.

Regional anaesthesia has several advantages over general anaesthesia in terms of quicker recovery, effective post-operative pain relief, no airway manipulation, shorter post-operative stay, cost-effectiveness and reduced post-operative nausea and vomiting [26, 27].

The various regional techniques that can be used include:

- *Epidural anaesthesia:* This is a safe technique for lower abdominal surgeries and can be used post-operatively for analgesia with only occasional complications noted [28]. Epidural anaesthesia has been used for upper abdomen laparoscopic surgeries with no adverse effect on respiratory mechanics. The effectiveness is enhanced with the addition of an adjuvant to the local anaesthetics to prolong post-operative analgesic duration [29]. It can be used for patients unfit for general anaesthesia.
- *Spinal anaesthesia:* This provides better laparoscopic surgical conditions due to profound muscle relaxation and shorter recovery. Studies have shown the safe use of spinal anaesthesia for laparoscopic upper and lower abdominal surgeries [30, 31].

  The incidence of hypotension following spinal anaesthesia for laparoscopic procedures has been found to be 20.5% and can be augmented by the Trendelenburg position and increased intra-abdominal pressure [32]. This hypotension can be prevented by liberally preloading the patient, reducing the head tilt and reducing the intra-abdominal pressure to 8–10 mmHg. The block height is aimed at T4 to ensure good relaxation for surgery and to prevent shoulder tip or neck pain following peritoneal irritation. This pain can be relieved by the instillation of local anaesthetics into the peritoneal cavity or the use of parenteral opioids.
- The changes in respiratory mechanics due to pneumoperitoneum may cause an increase in $PaCO_2$ due to absorption from the peritoneum resulting in ventilatory changes. However, reports have shown a non-significant change in either $PaO_2$ or $PaCO_2$ during laparoscopic surgery under spinal anaesthesia [33].
- *Combined spinal epidural:* This technique offers the advantages of each of the techniques. It entails the provision of effective post-operative analgesia and early ambulation of patients.

  Several studies have suggested that regional anaesthesia is comparable to general anaesthesia for laparoscopic procedure on surgical conditions, intraoperative complication and length of stay, but superior to general anaesthesia regarding post-operative analgesia, post-operative nausea and vomiting, early recovery and patient satisfaction [34–37].
- *Local anaesthesia:* This is mostly used for diagnostic and very short operative procedures. Its advantages are similar to regional anaesthesia but disadvantages include patient anxiety and pain. Sedation may be required [38].

## 3.5 Post-Operative Management

The recovery after laparoscopic surgeries is usually faster compared to open surgeries. Despite the above assertion, care of the patient at the early post-operative period should be important. This is because of delayed recovery, respiratory complications, pain, nausea and vomiting.

At the early post-operative period, the $ETCO_2$ of spontaneous breathing patients is high. There is difficulty in excreting the $CO_2$ load in patients with respiratory dysfunction. Supplemental oxygen should be given to mitigate the effect of pneumoperitoneum and the excess $CO_2$ on respiratory function.

Post-operative pain should be treated, though significantly reduced compared to open surgery. A multimodal approach to pain treatment used intraoperatively in the form of local anaesthetic infiltration of the wound site, non-steroidal anti-inflammatory drugs, acetaminophen and short-acting opioids ensures good pain management.

Post-operative shoulder tip pain following laparoscopy may be reduced by expelling as much gas from the peritoneal cavity as possible [39]. Any other pain can be managed with non-steroidal anti-inflammatory drugs and/or acetaminophen.

Post-operative nausea and vomiting (PONV) is a common and distressing symptom in laparoscopic procedures. A multimodal analgesia technique aims to reduce opioid consumption with its associated risk of post-operative nausea and vomiting.

Propofol-based anaesthesia has been associated with reduced post-operative nausea and vomiting [40]. Incidence of PONV can be managed using a 5-$HT_3$ receptor antagonist or dexamethasone.

## 4 Laparoscopy Surgery in Pregnant Women

Laparoscopic surgeries for pregnant women present several challenges. These are mainly due to the pneumoperitoneum effect and the increased intra-abdominal pressure on the utero-placental blood flow.

There are problems with space, site for trocar insertion and surgical manipulation.

The gravid uterus pushing on the diaphragm leads to a further decrease in functional residual capacity and increases in ventilation/perfusion mismatch.

$CO_2$ pneumoperitoneum may induce foetal acidosis and increase in foetal heart rate and arterial pressure.

For a good post-operative outcome, the following were recommended by the Board of Governors of the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) in May 2017 [41].

This document provides specific recommendations and guidelines to assist physicians in the diagnostic workup and treatment of surgical conditions in pregnant patients focusing on the use of laparoscopy:

- Laparoscopy can be performed during any trimester of pregnancy when the operation is indicated.
- Gravid patients beyond the first trimester should be placed in the left lateral decubitus position or partial left lateral decubitus position to minimize the compression of the vena cava.
- Initial abdominal access can be safely accomplished with open (Hasson), Veress needle, or optical trocar technique by surgeons experienced with these techniques if the location is adjusted according to the fundal height.
- $CO_2$ insufflation of 10–15 mmHg can be safely used for laparoscopy in the pregnant patient. The level of insufflation pressure should be adjusted to the patient's physiology.
- Intraoperative $CO_2$ monitoring by capnography.
- Intraoperative and post-operative pneumatic compression devices and early post-operative ambulation are recommended prophylaxis for deep venous thrombosis in the gravid patient.
- Laparoscopic cholecystectomy is the treatment of choice in the pregnant patient with symptomatic gallbladder disease regardless of trimester.
- Laparoscopic appendectomy is the treatment of choice for pregnant patients with acute appendicitis.
- Foetal heart monitoring of a foetus should occur preoperatively and post-operatively in the setting of urgent abdominal surgery during pregnancy.
- Tocolytics should not be used prophylactically in pregnant women undergoing surgery but should be considered preoperatively when signs of preterm labour are present.
- Patients should be managed as a full stomach patient. Hence, a nasogastric tube should be passed to decongest the stomach, and an acid prophylaxis should be given to prevent Mandelson syndrome and rapid sequence induction ensured.
- Due to $CO_2$ pneumoperitoneum which can lead to foetal acidosis, mechanical ventilation should be adjusted to maintain physiological maternal alkalosis.

## 5 Conclusion

Anaesthesia for laparoscopy has advanced over the years as the surgical procedure develops. Many techniques have been adopted to mitigate the associated risk and complications following the traditional technique.

Anaesthetists need to understand the various physiological changes associated with $CO_2$ pneumoperitoneum and positioning of patients to be able to mitigate them and deliver safe anaesthesia with a favourable outcome.

**Anaesthetic and Clinical Advice/Precautions for Safe Laparoscopic Surgery**

- Patient may be dehydrated due to use of Exelyte/Peglec for bowel preparation and preoperative overnight fast. Therefore, 1–2 l of Dextrose in saline solution should be administered.
- Patients with reduced renal reserve may have electrolyte abnormalities due to Peglec.
- In obese patients, DVT prophylaxis in the form of knee length anti-DVT stockings should be arranged. Alternatively, mechanical compression devices should be used. Patients should come to the operating room with the stockings on. In case stockings are not available, a 4-inch crepe bandage should be wrapped on both legs from the ankle to the thigh.
- Full monitoring of the patient should be done including $EtCO_2$ and bispectral index (BIS) (if available).
- Slow induction of anaesthesia should be done with standard IV propofol/IV etomidate for cardiac compromised cases with steroid cover.
- One ampoule of atropine should be always kept filled before starting any laparoscopy case as peritoneal $CO_2$ insufflation stretch may induce bradycardia/asystole.
- Initially, $CO_2$ insufflation should be done slowly with low pressure and low flow.
- Intra-abdominal pressure should not exceed 14 mmHg.
- Use of dexmedetomidine/nitroglycerin (NTG) intra-op to keep blood pressure between 100 and 110 mmHg.
- One should always keep a watch on airway pressure, so as not to exceed 35 mmHg even after $CO_2$ insufflation.
- Ventilator settings before $CO_2$ insufflation:
  - Calculate minute ventilation = tidal volume times respiratory rate (e.g. 500 mL × 12/min = 6 l).
- Ventilator settings after $CO_2$ insufflation:
  - Keep minute ventilation the same (i.e. 6 l) and increase respiratory rate to 15/min and decrease tidal volume to 400 mL (400 mL × 15/min = 6 l).
- One should always use the muscle relaxant atracurium, so that there is no problem of patient coming out of paralysis.
- Atracurium should be used in appropriate quantity so as to achieve the following results:
  - Complete abdominal relaxation.
  - Surgeon does not complain of intestines sliding down in the way of surgery.
  - Ensuring airway pressure remains below 35 mmHg.
- If at any point in time there is decrease in $SPO_2$ level, then one should think of:
  - Deepening plane of anaesthesia.
  - Giving one more dose of muscle relaxant.
  - Hand ventilation with bigger tidal volume and pressure.
  - If $SPO_2$ does not increase even after the above efforts, then one should consider giving a dose of Lasix and should not wait for frank pulmonary oedema to set in.
- There is often reduced urine output as $CO_2$ acts like a pneumatic tourniquet on the IVC, reducing the venous return. One should not infuse patient rapidly with IV fluids intra-op. The urine output improves once $CO_2$ desufflation takes place.
- At the end of surgery, hand ventilate with bigger tidal volume and pressure so as to open up the basal atelectasis of the lung, which occurs due to $CO_2$ pneumo-

peritoneum; otherwise the patient will have a reduced $SPO_2$ level post-op.

- In obese patients, incentive spirometry pre-op and post-op helps to reduce atelectasis of the lung and maintain good saturation levels for faster recovery.
- Post-operatively, one should consider injection of Clexane 0.6 (LMWH) because laparoscopy and Trendelenburg (head low) lithotomy position may induce DVT.
- One should ambulate patient as soon as possible post-op to avoid problems of DVT.
- Good local anaesthetic (LA) infiltration of port sites before inserting ports avoids unnecessary tachycardia and hypertension.
- Good LA infiltration of port sites at the end of surgery ensures a pain-free patient.[41]
- Any subcutaneous emphysema that may occur will recover spontaneously.
- LA instillation is done just below the diaphragm to reduce post-op shoulder pain.
- Post-op, give oxygen at 3 L/min for a couple of hours to wash out all $CO_2$. Also, put patient in propped up position.
- Full GA with endotracheal intubation and good muscle relaxation to be used instead of LMA (in times of COVID).
- The pregnant woman should be managed as a full stomach patient.

$CO_2$ pneumoperitoneum can lead to foetal acidosis during laparoscopy surgery in a pregnant woman; hence, mechanical ventilation should be adjusted to maintain physiological maternal alkalosis.

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# Laparoscopic Port Position, Placement and Closure

Fredrick Anolue and Lateef Akinola

## 1 Port Position and Placement

### 1.1 Introduction

Port is the keyhole passage in the abdominal wall through which instruments are inserted to perform laparoscopy. The choice of port position is important as it is necessary to position and place instruments at such angles to the operative site and to each other to resemble a natural relationship of the hands, eyes and target tissue during open surgery.

Wrong port placement is one of the causes of complications with increasing tendency to conversion to open surgery. It also causes stressful minimal access surgery. Good port placement is key to successful laparoscopic procedure and helps avoid the technical issue of overlap of instruments commonly referred to as swording phenomenon.

Cannulas and their accompanying trocars are used to create ports and sizes range from 3 mm, 5 mm, 10 mm, 12 mm and occasionally 15 mm. Ten-millimetre ports are usually used for passage Akinola of telescope, while 5-mm ports are used for instrument insertion. Ports of 12 mm or more are used for tissue retrieval. Bigger ports can be reduced to smaller ports intraoperatively with the aid of reducers which are readily available. Smaller ports can be dilated to bigger ones. Bigger ports of 12 mm or more has a risk of causing incisional hernia if not closed at the facial level [1, 2].

Ports are usually described as primary or secondary. The primary port, also called optic port, is first established for purposes of inserting the telescope. The secondary port, sometimes called accessory or working port, is established for purposes of inserting instruments. There is renewed interest in laparoendoscopic single-site surgery (LESS) [2]. It aims to use one port as both primary and secondary ports.

### 1.2 Primary Port

It is the port where the telescope is first inserted for view of the peritoneum and its content. The initial trochar insertion for creation of a primary port is perhaps the most dangerous aspect of trochar use and minimally invasive surgery [3]. Over 50% of trochar-related injuries to the bowel and vessels happen during the creation of a primary port [4]. Ninety-five percent of surgeons and gynaecologists use the umbilicus [1]. It has

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the advantage of being central to the abdomen as well as being the thinnest part of the anterior abdominal wall. Moreover, it can camouflage scars (Fig. 1).

The exact choice of location within the umbilicus varies. Intraumbilical is said to be the thinnest portion than infra- or supraumbilical and is therefore preferred with a vertical skin incision. Once peritoneum is entered, there should be no further advance of the sharp trocar which is removed and replaced with a telescope.

Infection rates appear higher on the umbilical port [5–7]. However, another opinion suggests that infection rate is the same as for other ports unless it is used for retrieval of infected material [1]. Similarly, rates of incisional hernia are not higher than as in other sites where a 10-mm cannula was used, but the hernia rate increases with the use of an umbilical port for *tissue retrieval* and when it is more than 10 mm [1].

Alternative primary port sites are the Palmer's and Lee-Huang's points [8, 9]. The alternate points could become necessary in the following situations: suspected periumbilical adhesions as in previous surgery, umbilical hernia, three failed attempts at insufflation and pelvic/abdominal tumours extending up to or near the umbilicus [2]. Palmer's point is in the left midclavicular line approximately 3 cm below the coastal margin [8]. Lee-Huang's point lies centrally between the xiphoid process and the umbilicus [9]. It is commonly called the mid-upper abdominal point.

Transuterine and trans-cul-de-sac routes have been described but should not be used because of the high risk of complication and infection [10].

## 1.3 Secondary Port

These are working ports for insertion of instruments and other manoeuvres in laparoscopic procedures. Proper location and placement of secondary ports ensure that there are no injuries to vessels and vestiges of the anterior abdominal wall as well as the viscera. It also ensures that target organs for surgery are approached tangentially and the angles between the working instruments and telescope are maintained at an optimum value for maximal ergonomics. Proper secondary port location also guarantees that the

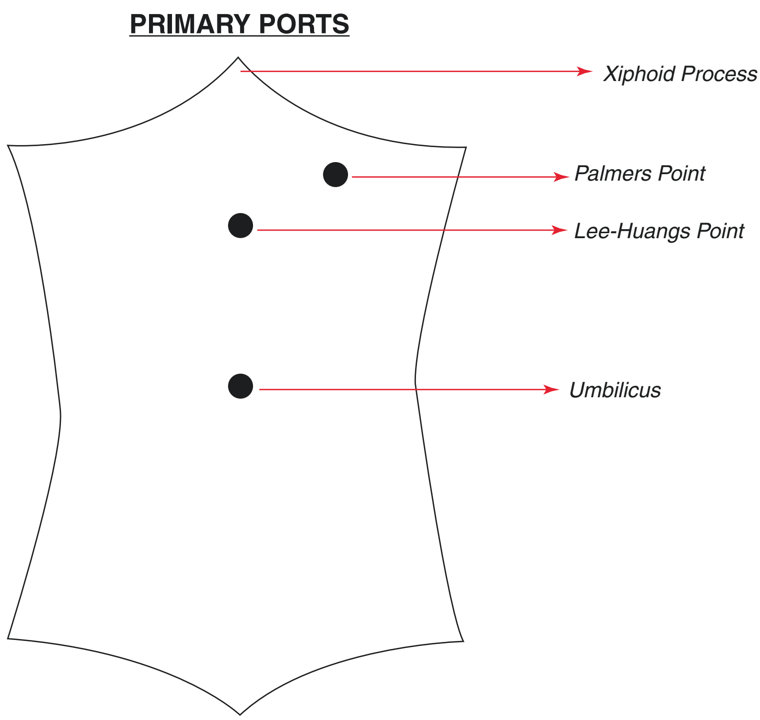


**Fig. 1** Sites for primary ports

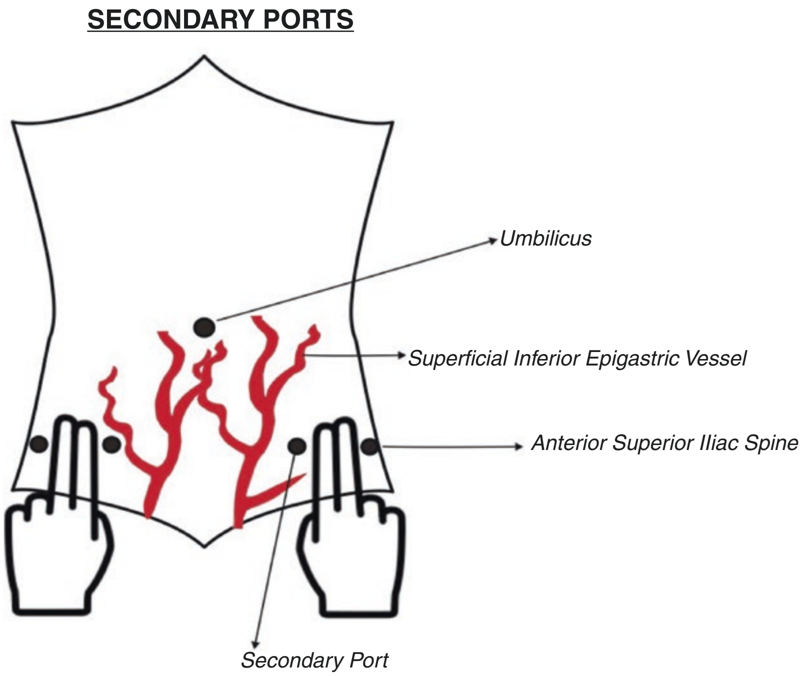


**Fig. 2** Secondary port placement

optimum length of instrument is inserted into the abdomen to enable easy up, down and lateral movements by the surgeon.

Opinions vary as to the proper location of secondary ports [1, 2]. In standard operations like diagnostic laparoscopy/dye test and laparoscopic-assisted vaginal hysterectomy, standard port sites related to surface markings may be used. The positioning of secondary ports also depends on the target organ for surgery and the organ/tissue pathology to be encountered. This may necessitate individualized port placement [1, 11].

Placement of secondary port should be under direct vision after pneumoperitoneum. Point of insertion is usually two fingerbreadths medial to the anterior superior iliac spine (Fig. 2). The insertion should be at 90 degrees to the skin and till anterior abdominal wall thickness is transversed. Insertion should be lateral to the branches of the superficial epigastric vessels which is easily picked out by transillumination especially in thin persons [2]. This move should be preceded by a mock entry by pressure from the index finger pushing at the desired point on the anterior abdominal wall. Once the tip of the trocar is sighted, it should be oriented to a near horizontal


**Fig. 3** Optimum manipulation angle of 60°

position towards a less delicate organ till passage is completely created.

Mishra [1] and Yinusa et al. [11] have described a set of guidelines for optimum port position and placement to ensure a stress-free surgery. In this guideline it is suggested that placements that achieve a 60% manipulation angle between working instruments (Fig. 3) with a half to two-thirds of the working instrument in the abdomen ensure a stress-free surgery.

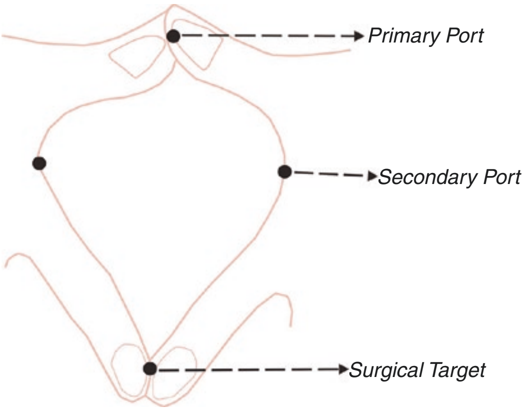


**Fig. 4** Index finger sign

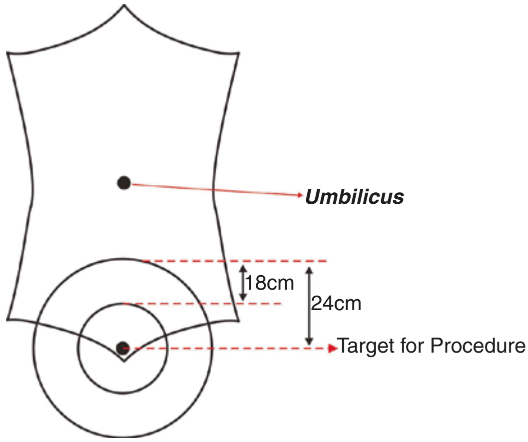


**Fig. 5** Concentric circles of 18 and 24 cm

To achieve this, identify your target in whatever procedure is being contemplated and ensure that the secondary port is at least 5 cm to 7.5 cm lateral inferiorly from the optical port. Furthermore, the following are suggested [1]:

(i) Dispose the index fingers of both hands in a manner that the tips aim for the target while the tips of the thumb unite at the primary port. The location of the junction of the skin crease of the index finger and thumb sign posts the best location for the secondary port. This makes the diagram for the ports come out like a triangle with the apex (optic port) slightly higher than the secondary ports (Fig. 4).

(ii) Draw two concentric circles of 18 cm and 24 cm diameter over the surgical target. It is advised that the secondary ports lie in between the 18- and 24-cm circle. This ensures that at least half to two-thirds of the instruments lies within the abdomen for a stress free surgery (Fig. 5).

### 1.3.1 Removal of Cannula

After surgery the cannula should be removed with caution by first deflating the abdomen and inserting a blunt obturator into the cannula to avoid sucking in bowels/omentum or having the telescope in situ while withdrawing the cannula.

Incorrect port position and placement make a surgeon struggle during his/her procedures and solutions may include additional port placement, changing the instruments to a different port or withdrawal of telescope and the use of an angled telescope.

## 1.4 Single Port

*Laparoendoscopic single-site surgery (LESS) is the name adopted for approaches aiming to do laparoscopy through a single incision usually made over the umbilicus* [12]. *It includes single-incision laparoscopic surgery (SILS).* Single-incision laparoscopic surgery was first used in the 1970s for tubal ligation using Yoon's ring and later hysterectomy [13, 14]. It was later abandoned because of the well-documented technical issues of swording. It has recently found its way back to routine gynaecological procedures and in the area of robotic gynaecological surgeries [15, 16]. This is largely because of improvements in technology specifically miniaturization of equipment as well as creation of flexible optical and coagulation systems [15].

It has the advantage of being faster, reducing morbidity especially pain, and is more cosmetically acceptable [2, 15–18]. The learning curve is however steep especially for intracorporeal suturing [15].

The devices have different numbers and sizes of ports for insertion of instruments. It is inserted through 1.5– 2.5 cm or more incisions made over the umbilicus. Some of the well-known devices are SILS Port (Covidien, Mansfield, MA, USA)


**Fig. 6** SILS Port (Covidien, MA, USA)

**Fig. 7** GelPOINT (Applied Medical Resources Corp., Rancho Santa Margarita, CA, USA)

(Fig. 6) and GelPort and GelPOINT Systems (Applied Medical, Rancho Santa Margarita, CA, USA) (Fig. 7). The integration of single-incision laparoscopic surgery and natural orifice transluminal endoscopic surgery (NOTES) has been suggested as the catalyst for wider application of this modality [16].

**Learning Points**

- Umbilicus is the preferred position for primary (optic) port. Intraumbilical site is recommended.
- Secondary (working) port position varies widely depending on surgery.
- Optimum position of secondary port will be ideally 5–7.5 cm from the optic port and between 18 and 24 cm (1/2–2/3) of the instrument should be in the abdomen.
- Entry should be guided by laparoscopic vision under pneumoperitoneum to avoid injury.
- Exit should be guided and hollow cannula blocked by a blunt instrument or telescope to avoid tissue being sucked in.
- Laparoendoscopic single-site surgery(LESS) is increasingly being practiced but the learning curve is steep.

## 2 Laparoscopic Port Closure

Laparoscopic procedures are increasingly being used for diagnostic and therapeutic purposes. Laparoscopy is cosmetically acceptable to patients and recovery is faster. Technology is driving innovations in further ensuring its safety and wide use in various pathologies. Bladeless trochars with radially expanding technology have been suggested to decrease the incidence of postoperative trochar site hernia [19]. This occurs especially when laparoscopic entry ports are improperly sutured and closed.

The entry points through which the primary instrument, telescope and working instruments are inserted into the abdomen are occasional sites for ventral abdominal wall hernias and will therefore require closure as prophylaxis against laparoscopic port-hernia formation. The incidence of port hernia ranges from 0.02% to 5% with an average of 1% [19, 20]. Hernias in all ports have been reported but the ports most at risk of causing hernias are 10–12 mm ports and above especially those in the midline [20, 21]. Ninety percent of hernias occur through 10-mm cannula or more.

## 2.1 Predisposing Factors to Port Hernia

- Large port sizes especially greater than 10 mm.
- Midline ports because of the thin fascia alba in this location.
- Ports used for tissue retrieval.
- Increased number of ports as used in complex laparoscopic surgeries.
- Pre-existing umbilical hernia.
- Comorbidities especially obesity, diabetes mellitus and wound infection.

Nacef et al. [22] noted that the most incriminated risk factors are trocar size, obesity and open laparoscopic entry. Age greater than 60 years, body mass index greater than 25 and surgery lasting more than 90 min increased the risk of hernia in laparoscopic cholecystectomy patients [23].

Clinically, port site hernias can be early or delayed. Early presentation occurs within 2 weeks of the surgery with abdominal pain of varying degrees with or without vomiting, protrusion over the site, fever and general malaise. Visible cough impulse may be obvious. The delayed variant may take months to present. A high index of suspicion needs to be maintained in a patient presenting with the above following a previous surgery. The regular workup for surgery should be done which should include blood count, serum electrolyte, urea and creatinine, abdominal X-rays and possible computerized tomography scan. Treatment involves the repair of the fascial defect. Laparoscopic or open surgical approach may be adopted. This largely depends on the surgeon's confidence to further deal with this laparoscopically and the consent by the patient.

Findings at surgery may reveal segmental bowel infarction (Richter's hernia), full bowel infarction or omental protrusion and incarceration in the fascial defect. Simple interrupted suturing or mesh placement may be adopted. Adhesions may be encountered and should be divided. The postoperative period is usually uneventful.

## 2.2 Safe Approaches to Port Closure

The most prevalent opinion is to close ports of 10 mm or more [20, 21, 24]. All approaches at port closure must be simple and safe and aim at not enlarging the skin wound for better cosmesis. An important aim is to properly approximate the fascia and the peritoneum. Reported cases of port hernia after closure is probably from poor techniques.

There are two methods:

### 2.2.1 The Standard Open Closure

This is done as for any surgical wound without laparoscopic aid. After laparoscopy, the abdomen is deflated and the cannula is removed. With the aid of a retractor, the opposite edges of the fascia are picked up for a simple suture or a figure-8 suture using Vicryl 1. Aziz [25] described a simple, cheap and safe two-step open laparoscopic port closure using two 'S'-shaped retractors on port sizes greater than 8 mm. This can be considerably easy in a thin patient and in the midline where there is minimal adiposity and fascia is merged. In some patients, efforts may be made to pick up the edges of the fascia with long Kocher's forceps for maximum retraction. Others have passed a foley catheter [20] balloon and used it to tract on the wound to facilitate suturing. Standard open closure may be difficult in obese patients necessitating enlargement of the skin incision for better access. Skin enlargement therefore becomes a necessity for optimum results.

### 2.2.2 Laparoscopic Direct Visualization

In this approach fascia and peritoneum disruption is closed under direct vision of the telescope with intact pneumoperitoneum. This helps to avoid visceral injury. The port may be in place or may be removed. Most often, the port is left in place and only removed at the point of knotting the suture. The principle is to pass a suture using a suture passer, needle or other devices. A suture passer is a needle that is notched or grooved at the tip to allow loading of the suture. There is usually an outer covering of plastic or metal for the needle that allows the suture secured and hidden for passage into the peritoneum. Passage is usually allowed through a spring-loaded mechanism or a mechanical device with a jaw handle into the peritoneum.

The tip of the needle is passed on one side of the facial defect at an angle of 30°–45° under the skin through the subcutaneous layer. Inside the peritoneum one end of the suture is dropped or picked up from the suture passer by a 5-mm grasper passing through another port. The suture passer is retrieved and again passed through the other half of the fascial defect and the suture is picked up and exteriorized for a subcutaneous knot. The end may be reloaded once or more for a figure-8 knot or continuous suturing. Cannulas are available that have two openings on opposite sides to aid easy passage of sutures. The VersaOne fascial closure system from Medtronic is a unique all-in-one solution that serves as a trochar and a fascial closure device. It is said to be safe and faster.

These devices have the additional use of controlling port site bleeding during laparoscopy.

Suture passers include Grice (Fig. 8) and Goretex (Fig. 9) devices, while needles that can

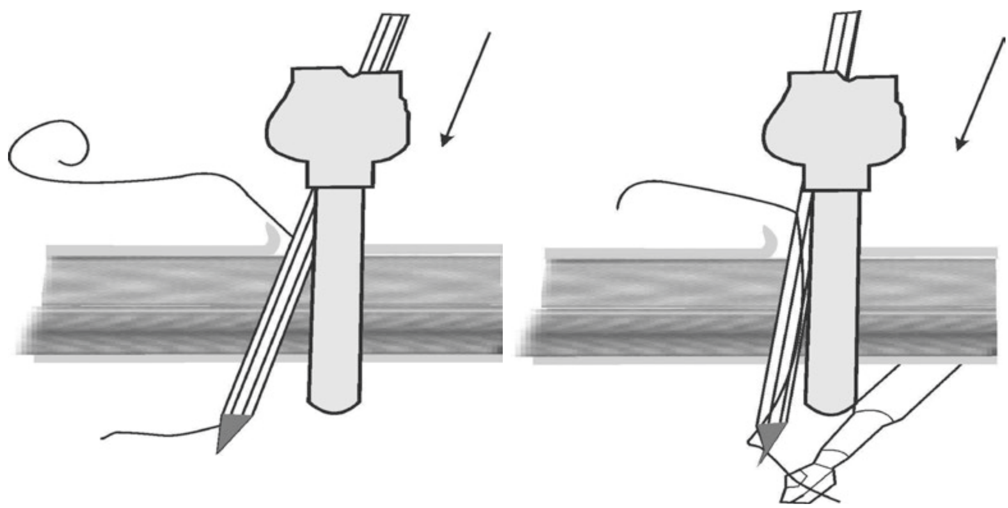

**Fig. 8** Grice suture passer

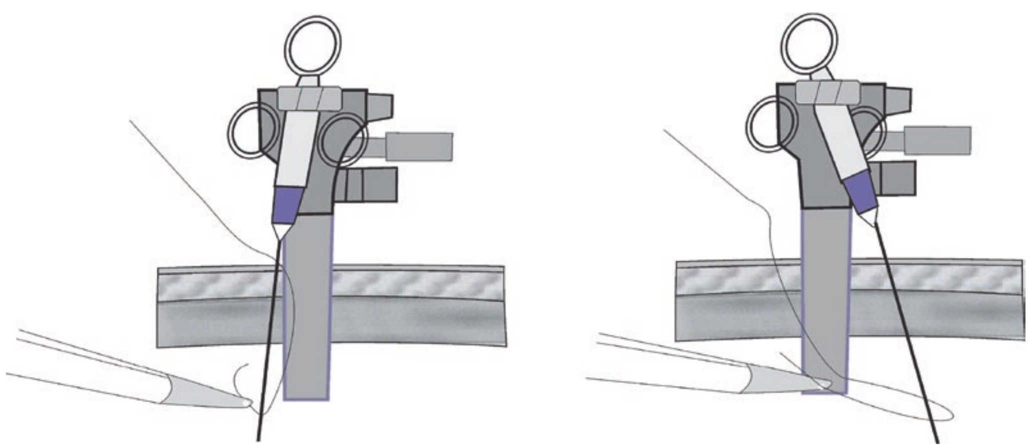

**Fig. 9** Goretex suture passer


**Fig. 10** Port closure needles (Deschamps)


**Fig. 11** Port closure needles (Reverdin)

be used to pass sutures include Deschamps (Fig. 10) and Reverdin (Fig. 11) needles.

Vein catheter, spinal cord needle and angiocath needle are cheap devices improvised for insertion of sutures and effecting fascial closure. Implantation of a bioabsorbable hernia plug Hernin has been documented on the 10-mm umbilical port [26]. Improvising with Veress needle has been practiced [27]. It is cheap as it improvises with a Vicryl 1 suture. A comprehensive list of various port closure devices can be found in a review of different port closure devices by Majid and Mishra [20].

**Learning Points**

- Port site hernias can occur in ports of any size.
- Port sizes of 10 mm or more should be closed especially if in the midline.
- A simple safe inexpensive method, with surgeon's competence in consideration, is recommended.
- Standard open visualization and closure of the facial defect and direct laparoscopic visualization of the facial defect are the two options.
- Standard open visualization and closure can be done on thin patients especially on the midline ports.
- Direct laparoscopic visualization using one of the many methods is recommended for accurate placement of suture. It also reduces visceral injury.
- Empty abdomen of pneumoperitoneum before removing ports to avoid escaping CO2 drawing omentum or bowel into the port site.
- Port closure should be accomplished before waking patient up to avoid coughing or gagging with attendant possibility of hernia.
- Increasing the size of skin suture may be a worthwhile price to pay for obese patients where adequate fascial closure is desirous.

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# Laparoscopic Entry/Access Techniques

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## 1 Introduction

Access into the abdomen is the first entry with instruments and the most important step in laparoscopy surgery. This is why the authors believe in the statement 'Access is the key to success in laparoscopy surgery'. A successful entry is already a prelude or indication of a possible successful procedure, but a turbulent entry will definitely signal danger or even truncation or conversion to open surgery. Laparoscopic entry comes with a challenge that is particular to the insertion of surgical instruments through small incisions. It is worrisome because it may be associated with injuries to the major blood vessels and abdominal/pelvic organs, with about 50% of these major complications occurring before the start of the intended surgical procedure [1–3]. The majority of the injuries are due to the primary port insertion. To reduce entry-related injuries, improved instrument design, better techniques and approaches have been introduced during the last century [2, 4]. Successful access in laparoscopy is highly dependent on the following:

- Careful patient selection.
- Good positioning of patient/equipment (coaxial arrangement).
- Surgeon's skill.
- Good knowledge and selection of equipment/instruments.

Patient selection is important as one must carefully evaluate the diagnosis in any patient. Have a clear indication for the laparoscopy procedure. Check for previous open abdominal surgeries and the type and extent of the incision used. Also check for pelvic masses and the size as measured in weeks of gestation. These will guide you in the selection of a safe entry technique for the patient. This means that an individualized approach to each patient is advocated by the authors. It is useful to assess the weight (the class of obesity) of the patient, presence of bleeding or haemoperitoneum and other medical conditions in the patient and to discuss these with the anaesthetic team as these will influence the choice of instrument, speed and method of entry.

Patient positioning at the time of introduction of the Veress needle and/or primary trocar is essen-

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tial to success. Since the entry is usually directed to the coccyx or pelvic cavity, a Trendelenburg position is desired to allow the intestines to gravitate to the upper abdomen. This is ideal but may raise concerns in regional anaesthesia and even in general anaesthesia where it accentuates cardiorespiratory changes. Recently and as applicable in our practice, it is advocated that primary entry is achieved with patient in supine position and insertion of the trocar assisted with lifting of the abdominal wall. The safe introduction of the trocar is discussed later in the chapter.

The skill of the surgeon is inversely related to the rate of injuries. It means that the higher the experience and skill of the surgeon, the lower the risk of entry complications. The general dictum is for the surgeon to use an appropriate entry technique and instrument he/she is familiar with and well trained on with safest record of its use.

The surgeon should be familiar with the different types of trocar and indication for the use of each type. This knowledge is needed to avoid the dangers of using the wrong instrument with its attendant complications. This will lead us to discuss the different types of trocar.

## 2 Types of Trocar

Laparoscopic trocars can be broadly classified into reusable trocars, disposable trocars and more recently visual/optical trocars. The reusable ones can be dismountable and non-dismountable trocar. The reusable trocars are more economical than disposable ones because they are repairable but require cleaning and sterilizing as well as regular sharpening and maintenance. Many surgeons use different trocars as the safety of the use of one type over the other is still inconclusive as there is no definitive evidence in this regard.

Refer to the chapter on laparoscopy surgery instruments for more details on the types of trocar.

## 3 Types of Laparoscopic Access/Entry Techniques

The entry techniques in laparoscopy can be broadly classified into:

- Closed/classic or conventional access technique.
- Open-access technique (Hasson, Scandinavian and Fielding techniques).

The closed-access technique can further be classified into:

- Blind non-visual access technique (Veress needle or direct trocar entry). The direct trocar entry can either be with establishment of pneumoperitoneum or without pneumoperitoneum (gasless).
- Visual access system (disposable optical trocars, Endopath Optiview optical trocar, VisiPort optical trocars, EndoTIP visual cannula).

## 4 Closed Access Techniques

### 4.1 Closed Non-Visual Access Technique with Veress Needle

It is a blind technique with pre-creation of pneumoperitoneum using Veress needle. Trocar is introduced thereafter. This is the most commonly practiced way of access in laparoscopy surgery by gynaecologists and surgeons.

### 4.2 Sites of Veress Needle Entry

The Veress needle is inserted in the umbilical area under normal circumstances to create pneumoperitoneum. This transumbilical position is chosen because of its unique characteristics: it is centrally located and the thinnest part of the anterior abdominal wall. It is relatively avascular and is cosmetically better as it is already a scar [5]. It is also preferred in obese patients because the umbilical area has the minimum thickness of fat in the whole anterior abdominal wall. The risk of infection is not increased by the use of this point and occurrence of ventral hernia is due to the use of a 10-mm port and not the location of the umbilicus. See Fig. 1.

Other sites on the midline of the abdomen could be through the inferior crease of the umbi-

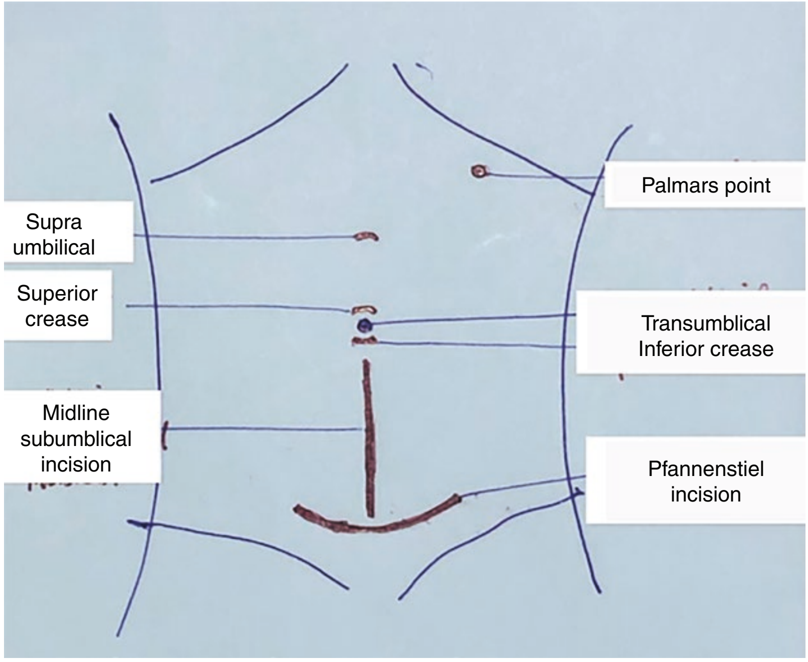


**Fig. 1** Abdominal access points

licus (smiling incision) especially in non-obese patients or the superior crease of the umbilicus (crying incision) also in non-obese patients with pelvic mass or sub-umbilical midline scar and supra-umbilical skin incision (3–5 cm above the umbilicus) where the pelvic mass is at or above the umbilicus.

In patients known or suspected to have peri-umbilical adhesions, umbilical hernia or failure to establish pneumoperitoneum after three attempts, alternative sites of Veress needle insertion outside the midline of the abdomen should be sought [2, 6–9]. Such sites of Veress needle insertion include:

Palmer's point/left upper quadrant (LUQ): It is a point 2–3 cm below the left subcostal margin in the midclavicular line [10, 11]. It is used in patients who are obese or very thin because of the relationship of the great vessels with the umbilicus in these patients [12, 13]. Palmer's point is also used in patients with previous midline scar extending above the umbilicus and in patients with a pelvic mass. It should not be used in patients with previous splenic or gastric surgery, hepatosplenomegaly, portal hypertension or gastro-pancreatic mass [14].

Trans-uterine technique: Long Veress needle is guided through the cervical canal to the uterine cavity and passed through the uterine fundus to the peritoneal cavity to create pneumoperitoneum [2]. This method is very helpful in obese patients [2, 15] but not routinely used as abdominal routes are preferred.

Transvaginal (cul-de-sac) route: Pneumoperitoneum is created by introducing the Veress needle through the posterior vaginal fornix especially in obese patients [16].

Finally, the ninth or tenth intercostal space route: Veress needle is passed through the ninth or tenth intercostal space to create pneumoperitoneum. This is because the parietal peritoneum is adherent under the surface of the rib at the costal margin. The indications and contraindications of this site are the same as Palmer's point [17, 18].

## 4.3 Steps of Veress Needle Insertion

The patient is placed in the supine position, and under anaesthesia, surgical cleaning of the abdomen is performed, and drapes are appropriately applied. It is also advisable to perform an abdominopelvic examination at this stage noting any scars and pelvic masses and deciding on the site of Veress needle entry. The Veress needle is flushed to confirm patency and it is inserted after a stab incision is made on the skin at the selected site with a pointed blade mounted on a Bard-Parker handle. The insertion of the Veress needle can also be done without a prior skin incision. The Veress needle is held like a dart and inserted into the peritoneal cavity through the stab incision directed to the coccyx, while the abdominal wall below the umbilicus is lifted up with the other hand. The direction of the Veress needle passage should vary according to the body mass index (BMI) of the patient, from the usual 45° inclination in non-obese women to 90° (perpendicular approach) in the obese [2]. This is due to the relation of the umbilicus with the aortic bifurcation at different BMIs. Once the resistance of the abdominal wall is lost, further insertion of the needle is stopped and the correct intraperitoneal placement of the Veress needle is confirmed by any of the following tests before a gas cable is connected to the needle to create pneumoperitoneum [2].

## 4.4 Veress Needle Safety Tests or Checks

Correct placement of Veress needle is vital in preventing complications that may follow wrong placement. Various techniques and tests have been described in the literature for determining the correct placement of the Veress needle in the peritoneal cavity [6, 8]. These tests include the following:

- Double-click sound of the Veress needle as it traverses the layers of the anterior abdominal wall (puncture of the rectus sheath and peritoneum) at the midline. However, it should be three-click sounds at Palmer's point because of the anterior and posterior walls of the rectus sheath.
- The needle movement test: Gentle movement of the needle should not feel any resistance. Avoid a wide range of movement as this can enlarge a small puncture injury to an injury of 1 cm or more in the viscera or blood vessel [2, 5, 19].
- Irrigation and aspiration test (syringe test): To perform the irrigation test, fill a 5-mL syringe with normal saline or sterile water and inject via the Veress needle. The injection will flow freely if the Veress needle is correctly placed inside the peritoneal cavity, if not, some resistance is felt while injecting the fluid [5].
- For the aspiration component of the test, try to aspirate the fluid back after injecting it through the Veress needle. Again, if the Veress needle is correctly placed in the peritoneal cavity, the irrigated fluid would have dispersed into the peritoneum and cannot be aspirated back. Any other material aspirated like blood, faeces or more fluid may be an indication of the wrong location of the Veress needle [5].
- Hanging drop test: Place a few drops of fluid (saline or sterile water) over the Veress needle allowing a drop to hang at the head. Then slightly lift the abdominal wall. If the Veress needle is correctly located inside the peritoneal cavity, the hanging drop will be sucked inside because of the negative pressure of the peritoneal cavity. Otherwise, it will not, indicating the wrong placement of the Veress needle [5].
- The plunger test: Attach a 2- or 5-mL syringe filled with fluid (saline or sterile water) to the Veress needle and pull out the plunger of the syringe. If the needle is correctly located in the peritoneal cavity, the fluid in the syringe will empty; otherwise, it will not. It works with the same principle as the hanging drop test [5].
- Manometric test: The five manometric parameters of the insufflator are pre-set pressure, actual abdominal pressure, pre-set gas flow rate, actual gas flow rate and gas volume. If the Veress needle is correctly placed in the peritoneal cavity, the initial abdominal pressure will be near zero before it starts rising as the gas fills the peritoneal cavity. The high initial pressure is an indication of the wrong placement of the Veress needle [5].

Evidence has shown that these tests provide a little but useful guide on the correct placement of the Veress needle [20]. However, with growing experience and practice, you will know when the Veress needle is correctly placed in the peritoneal cavity and will not have the need to perform the various safety checks [20]. Remember: the volume of $CO_2$ introduced with the Veress needle should depend on the pre-set pressure and actual intra-abdominal pressure and not on any predetermined $CO_2$ volume [2].

## 4.5 Veress Needle Modifications

Various modifications of the Veress needle have been developed, to increase the safety and the ease of inserting the needle. The pressure-sensor-equipped Veress needle and optical Veress needle (mini-laparoscopy) are the common modifications. Pressure-sensor-equipped Veress is a modification that provides the surgeon immediate feedback once the Veress needle is inside the peritoneal cavity [21]. On the other hand, the optical Veress needle assembled unit (Veress, cannula, and mini-laparoscope) shows a cascade of colour sequences that represent different abdominal wall layers that is observed on the monitor during insertion [22, 23].

## 4.6 Steps of Primary Trocar Insertion

After the creation of pneumoperitoneum, the Veress needle is withdrawn and the stab incision is extended to 11 mm, or an incision is made at the selected site. The first trocar and cannula to be inserted are usually an 11-mm trocar/cannula that will have enough space to accommodate a 10-mm telescope and leave enough space in the cannula for rapid flow of gas if required [5].

The reusable sharp-end trocar is held in the proper way with the dominant hand and the full thickness of the abdomen is lifted with the other hand or the intra-abdominal pressure is raised to 25 mmHg with the pneumoperitoneum to serve as a splint. The trocar is then inserted with care through the incision, using a blind technique with rotatory movement and aiming at the coccyx. The initial angle of insertion should be perpendicular to the abdominal wall and then tilted to a 60–70° angle once inside the abdomen. Once inside the abdominal cavity, as evidenced by the loss of resistance and hissing sound, the trocar is removed and the cannula is advanced further inside the peritoneal cavity. After proper insertion of the primary trocar, an illuminated telescope is passed through the cannula to view the abdominal cavity.

Secondary trocars are inserted under direct vision and this eliminates the risk of injury at entry. The 'baseball diamond concept' or the 'fork and knife principle' is most appropriate for selecting the site of introduction of the secondary or working ports based on the type of procedure and the anatomy of the abdomen [5]. You can use a 5- and/or 10-mm trocar/cannula at the secondary port as is appropriate for the procedure. If a smaller-size instrument is to be inserted via a larger cannula, a reducer tube or converter (gasket) is used to maintain the gas seal and prevent leakage of gas and collapse of the abdomen.

### 4.6.1 Disposable Shielded Trocar

This trocar is designed with a shield that partially retracts and exposes the sharp tip as it encounters resistance through the abdominal wall. As the shield enters the abdominal cavity, it springs forward and covers the sharp tip of the trocar [24]. Note that even when a shielded trocar functions properly and is used according to the specifications, there is a brief moment when the sharp trocar tip is exposed and unprotected as it enters the abdominal cavity [24]. See Fig. 2.

The design and use of shielded trocars are meant to decrease entry injuries. However, there is no evidence that they result in fewer visceral and vascular injuries during laparoscopic access [2].

**Fig. 2** Disposable shielded trocar

#### 4.6.2 Radially Expanding Access System

This consists of a 1.9-mm Veress needle surrounded by an expanding polymeric sleeve. The device is introduced into the peritoneal cavity and pneumoperitoneum achieved. The Veress needle is subsequently removed leaving the sleeve in situ. The sleeve acts as a tract through the abdominal wall that can be dilated up to 12 mm by inserting a blunt obturator with a twisting motion [25, 26]. More force is required to push this trocar through the abdomen than with disposable trocars [2]. See Fig. 3.

Radially expanding trocars are not recommended as being superior to the traditional trocars [2].

Though they have blunt tips that may provide some protection from injuries, the force required for entry is significantly greater than with disposable trocars [2].

## 5 Closed Access with Direct Trocar Entry (with Pneumoperitoneum or Gasless)

### 5.1 Closed Access with Direct Sharp Trocar (with Pneumoperitoneum)

This is a blind technique and similar to the steps for primary trocar insertion discussed above. It begins with a skin incision wide enough to accommodate the diameter of a sharp trocar/cannula system at the site selected for primary trocar insertion. The anterior abdominal wall is adequately lifted by the other hand, and the trocar directly inserted into the cavity by rotatory movement, aiming towards the hollow of the pelvis. See Fig. 4. Some surgeons prefer to lift the abdominal wall with two towel clips placed at

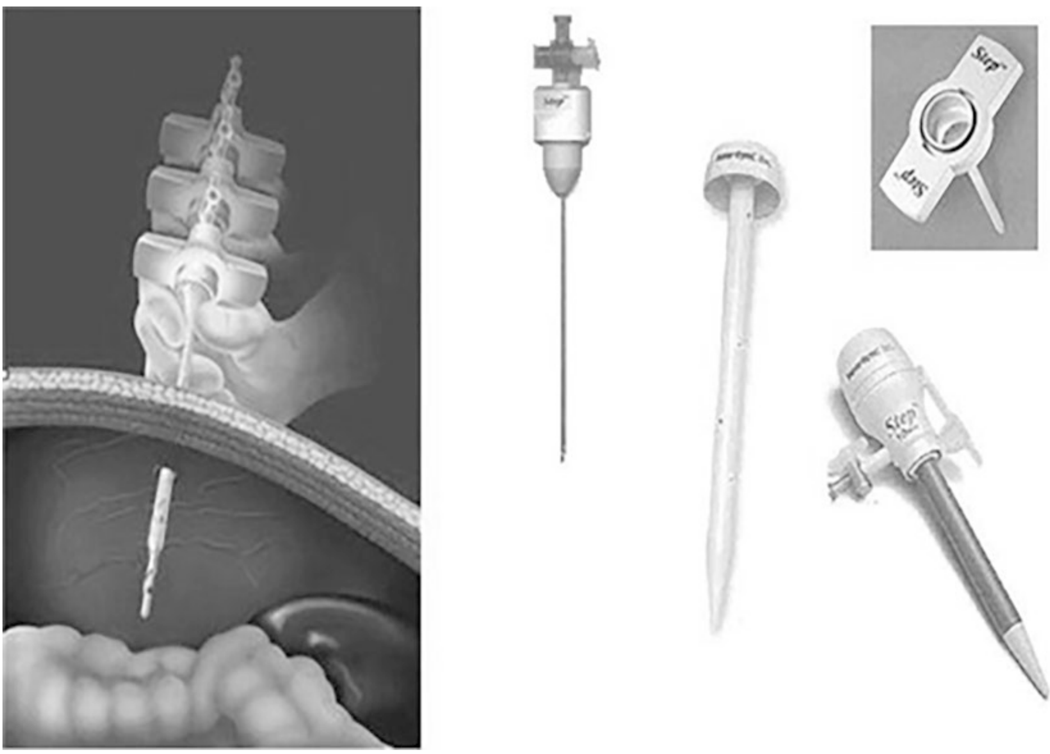

**Fig. 3** Radially expanding trocar

about 3 cm on either side of the umbilicus [27]. See Fig. 5. This technique reduces the steps involved in laparoscopy entry to only one (direct trocar) rather than three steps where Veress needle is used first (Veress needle, pneumoperitoneum and trocar). Once inside the abdominal cavity, as evidenced by the loss of resistance (no hissing sound as there is no prior pneumoperitoneum), further advancement is stopped and the sharp trocar is removed. The laparoscope is immediately inserted to confirm the presence of omentum or bowel in the visual field before the gas cable is connected to the cannula to achieve pneumoperitoneum.

**Fig. 4** Direct trocar entry technique

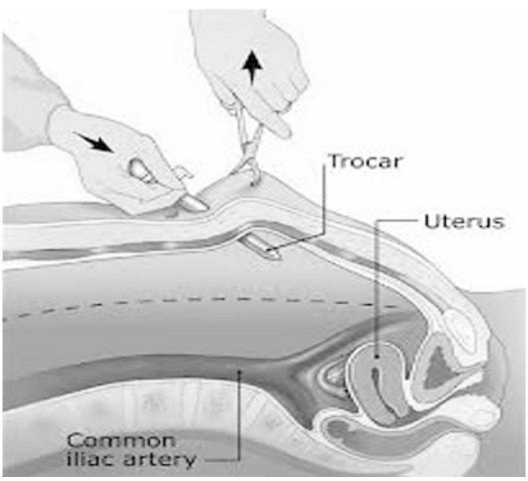


**Fig. 5** Use of towel clip

This direct insertion of the trocar without prior pneumoperitoneum has not been shown to have more entry-associated complications; rather it has fewer insufflation-related complications like gas embolism [28–30]. It has been shown to be faster than other methods of entry [27, 28] and may be considered as a safe alternative to the Veress needle technique [2]. Though direct trocar is the laparoscopic entry technique preferred by the authors, it is still the least performed method in clinical practice [7].

## 5.2 Closed Access with Trocar (Gasless)

Gasless laparoscopic surgery is a laparoscopic procedure that does not require the use of gas (carbon dioxide) to create pneumoperitoneum during the procedure. It was developed in an effort to reduce the risks associated with pneumoperitoneum [29]. Different techniques can be used for the primary trocar insertion like direct sharp trocar, open access or use of the optical trocar system. The laparoscope is introduced once the trocar is inside the abdominal cavity to confirm entry. No gas is required. A special instrument called 'Abdolift/Laparolift/abdominal lift' is used to elevate and suspend the anterior abdominal wall. See Fig. 6.

However, it is associated with greater technical difficulty due to impaired visibility from the bowel in the pelvis [31]. There are several rea-

**Fig. 6** Abdolift

sons for the compromised visibility with the Abdolift device. It unevenly elevates the lower abdomen like a truncated pyramid rather than a dome shape achieved with pneumoperitoneum [31]. The upper abdomen is oftentimes not elevated and the working space laterally is also reduced. All these mean less room for the bowel creating difficulty with exposure of the cul-de-sac and ovarian fossae. The incidence of injury due to this type of access has been reported to be higher [32]. Bleeding due to accidental trauma to the abdominal wall vessels during the application of the lifting device and ischaemia of the wall are some of the dreaded complications of this procedure.

## 6 Visual Access Techniques

The visual access system can either be disposable optical trocars (Endopath Optiview, the VisiPort optical trocar) or trocarless reusable visual access cannula (EndoTIP visual cannula).

### 6.1 Disposable Optical Trocar

Two disposable visual entry systems are available that retain the conventional trocar and cannula push-through design (the Endopath Optiview optical trocar and the VisiPort optical trocar). They are single-use visual trocars where the usual blind sharp trocar is replaced with a hollow trocar housing a zero-degree telescope that transmits real-time monitor images while the distal crystal tip of the trocar goes through the abdominal wall tissue layers [2]. See Fig. 7. It requires significant axial thrust through the surgeon's dominant hand to transect abdominal myofascial layers [2].

**Fig. 7** Disposable optical trocar

### 6.2 Trocarless Reusable Visual Access Cannula (EndoTIP Visual Cannula)

The EndoTIP consists of a stainless-steel cannula with a proximal valve segment and distal hollow threaded cannula section. This system does not require a trocar. The valve segment houses a standard $CO_2$ stopcock and the cannula's outer surface is wrapped with a single thread, winding diagonally to end in a distal blunt notched tip [2]. Incision at the site of primary trocar insertion is made down to the white anterior rectus fascia and Veress needle inserted through a fascial incision for insufflation.

The unit (laparoscope and mounted cannula) with the $CO_2$ stopcock in the closed position is then lowered into the abdominal wound. The surgeon uses the muscles of the dominant wrist to rotate the cannula clockwise while keeping the forearm horizontal to the patient's abdomen. Real-time images are sequentially observed on the monitor as the blunt cannula's notched tip passes through successive tissue layers [2]. See Fig. 8.

The visual entry cannula system may provide an advantage over traditional trocars, because it allows a real-time visual entry, but this advantage has not been fully explored. They also have the advantage of minimizing the size of the entry wound and reducing the force necessary for insertion [2]. However, they are non-superior to other trocars since there is no significant reduction in visceral and vascular injury with their use [2].

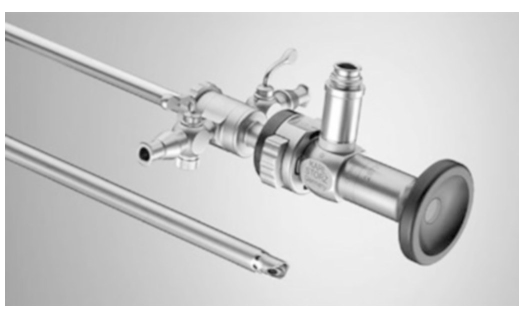

**Fig. 8** EndoTIP visual cannula

## 7 Open-Access Technique

This is a direct entry by open technique, without creating prior pneumoperitoneum. The insufflator is connected once the blunt trocar is introduced inside the abdominal cavity under direct vision. There are different open-access techniques like Hasson, Scandinavian and Fielding techniques.

### 7.1 Hasson Technique

The open-access technique was first described by Hasson in 1971 [33]. The technique involves the use of a cannula fitted with a cone-shaped sleeve, a blunt obturator and possibly a second sleeve to which stay sutures can be attached [33]. See Fig. 9. The entry is essentially a mini-laparotomy. A small incision is made transversely or longitudinally at the umbilicus or any selected site for the primary trocar insertion. The incision is long enough to enable dissection down to the fascia, incise it and enter the peritoneal cavity under direct vision. See Fig. 10.

The cannula is inserted into the peritoneal cavity with the blunt obturator in place. Sutures are placed on either side of the cannula in the fascia and attached to the cannula or purse-stringed around the cannula to seal the abdominal wall incision to the cone-shaped sleeve. The laparoscope is then introduced after the obturator is removed and insufflation is commenced.

The open entry could also be utilized as an alternative to the Veress needle technique, although the majority of gynaecologists prefer the Veress entry. There is no evidence that the open entry technique is superior or inferior to the other entry techniques currently available [2].

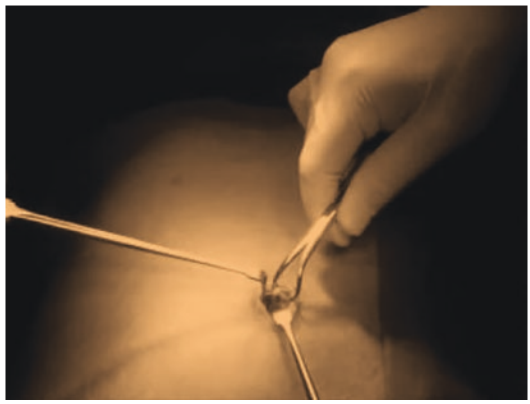

**Fig. 10** Open-access technique

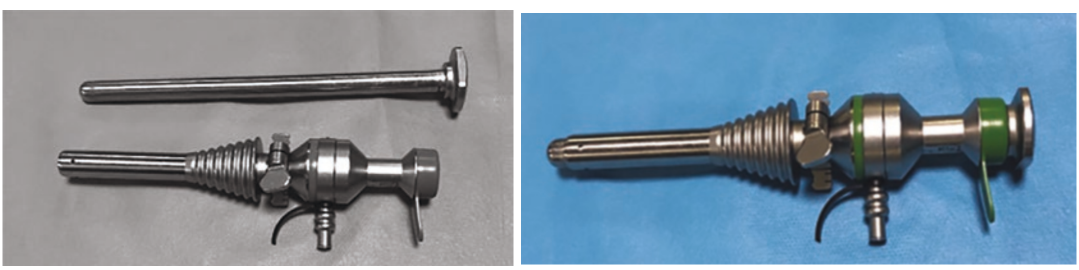

**Fig. 9** Hasson trocar and cannula (reusable)

## 8 Conclusion

Many techniques have been introduced to eliminate laparoscopic entry complications. However, not a single technique has been proven to eliminate these complications. To prevent and decrease complications, surgeons should continue to increase their knowledge of anatomy, their training and their experience. Safe laparoscopy requires good knowledge and familiarity with instruments used for the procedure, careful patient selection and the acquisition of requisite skills. Having good assistance and well-trained theatre staff makes the procedure seamless. Finally, it is important to invest in modern equipment/machines and take care of existing equipment.

### Learning Points

- Make sure the instruments and equipment are functioning well before inserting laparoscopic ports.
- Successful access in laparoscopy highly depends on careful patient selection, good positioning of patient/equipment, surgeon's skill and good knowledge and selection of equipment.
- Laparoscopic surgeons should use the entry approach they are conversant with while performing laparoscopic procedures.
- Secondary laparoscopic ports must be inserted under direct vision.
- All precautionary measures must be observed while inserting laparoscopic ports.

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# Techniques for Laparoscopic Tissue Retrieval

Abubakar A. Panti, Kikelomo T. Adesina, and Sanusi M. Ibrahim

## 1 Introduction

The use of laparoscopic surgery in Nigeria is growing. The advantage of laparoscopic access as opposed to conventional laparotomy includes shorter post-operative hospital stay and recovery period, reduced postoperative discomfort which results in fewer analgesic requirements and ensuing cosmetic gains associated with the avoidance of a laparotomy. The cosmetic advantage of a laparoscopic procedure is greatly diminished if the procedure culminates in a large incision created for the removal of resected tissue. Safe removal of tissue is an important consideration in laparoscopic procedures, whether benign or malignant specimens. One of the challenges of laparoscopic surgery is being able to retrieve the specimen after excision with minimal contamination or injury to surrounding healthy tissue. Risks of spillage include pseudomyxoma peritonei, chemical peritonitis and dissemination of malignancy; they depend on the type and size of the mass, surgical expertise and route of retrieval [1].

There are different techniques to facilitate the retrieval of excised masses without needing to enlarge the abdominal incision; these range from commercially available endoscopic bags (endobags) including improvised endobags with surgical gloves and condoms to the use of tissue morcellators which can be mechanical or thermal. The use of natural orifices and removal of bigger masses through colpotomy and hand-assisted laparoscopic surgery (HALS) are other available options [1–8].

## 2 Tissue Retrieval Techniques

### 2.1 Tissue Retrieval Through the Port

The resected tissue can be retrieved directly through lateral or umbilical ports. This technique is used for small specimens like small ovarian cyst, ectopic pregnancy, salpingectomy, small oophorectomy or foreign body such as an intra-

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uterine device. The umbilicus is the most distensible and thinnest part of the anterior abdominal wall and is a suitable site for the retrieval of small specimens.

#### 2.1.1 Technique

The tissue is held with a grasper and is drawn into the port sleeve as illustrated in Fig. 1, using gentle rotation which opens the flapper valve as the specimen is withdrawn. For specimens too large to fit entirely into the sleeve, the tissue is grasped at its narrowest aspect and drawn partially into the port. The sleeve, grasping instrument and specimen are all drawn out of the abdomen together under direct vision. If the surgeon is not using an operative 10-mm laparoscope, a 5-mm laparoscope may be introduced through one of the lateral ports and the tissue retrieved with grasping forceps under direct vision.

**Advantage**

- This can easily be drawn out through the cannula.

**Disadvantages**

1. This cannot be used for large specimens.
2. Specimen may get impacted within the cannula especially at the level of the valve.
3. Specimen may fall back into the peritoneal cavity and may be difficult to find among bowel loops.

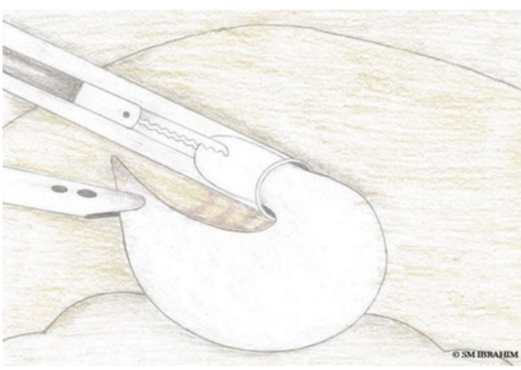


**Fig. 1** (Illustration) Tissue being drawn into the port sleeve

### 2.2 Tissue Retrieval Through the Port Site

Large tissue specimens can be extracted via a cannula site. This can be used for benign tissues like post-menopausal ovaries or small myomas.

#### 2.2.1 Technique

This is mostly done through the umbilical port site. The peritoneum and fascia are visualised under laparoscopic magnification and opened with laparoscopic scissors. The specimen is then removed through this incision using a grasper and the fascia is then approximated in the traditional fashion with delayed absorbable sutures.

**Advantage**

- This can be used in low-resource settings.

**Disadvantages**

1. High risk of port site hernia.
2. It requires a change of telescope which may lead to a less adequate laparoscopic view.
3. Should be used for benign and uninfected tissues.

### 2.3 Retrieval Bags

Tissue retrieval bags are used for specimens or tissues that carry the risk of rupture and spillage of contents which cause contamination. They are also used for malignant tissues or tissues that are big with a risk of fragmentation [8]. Retrieval bags will generally require a 10- to 12-mm port. There are many types of retrieval bags ranging from commercially made endobags to improvised endobags.

#### 2.3.1 Commercial Endobags

These come in different sizes. They are generally made in various shapes which the surgeon chooses from, depending on the size of the specimen encountered. This commercially available bag is usually thick and double-layered.

### Technique

The commercial endobag is lined with soft, flexible metal frames that open up into a basket rim when deployed by pulling the device string outside the abdominal wall, as illustrated in Fig. 2. This metal frame rim makes it easier to drop the specimen into the pouch portion of the bag. The self-opening pouch contained within an introducer sheath is manoeuvred through the port cannula towards the tissue to be removed. The stylet is pushed to drop the bag after which the tissue is placed into the bag and the thread outside is pulled to apply a purse-string suture at the neck of the bag which is then pulled out to the abdominal surface for fragmentation or whole excision of the tissue.

**Advantages**

1. The bag is thick and double-layered and difficult to tear during traction.
2. Can be used for infected and malignant tissues.
3. It provides purse-string sutures for easy closure and reopening.

**Disadvantages**

1. The bags are expensive.
2. They require some skill to manipulate.
3. Available only in standard sizes.

### 2.3.2 Improvised Endobags

Easy-to-make frameless retrieval bags can be fashioned out of sterile powderless surgical gloves, condoms and polythene material [3]. While these pouches are simple, inexpensive to make and available in choice sizes, they are not subjected to quality control, may not be radio-opaque and can tear during traction, with a risk of having a lost foreign body in the abdominal cavity.

## 2.4 Gloves

A sterile glove should be used. The powdered gloves should not be used. The powdered glove should be washed with normal saline.

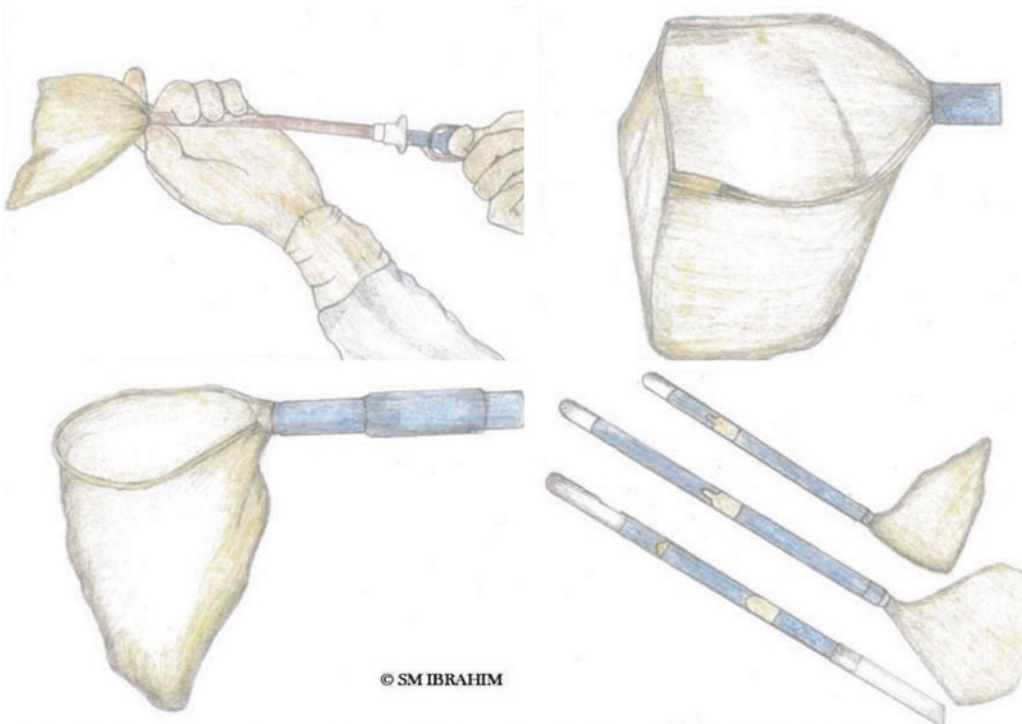


**Fig. 2** (Illustration) Commercially available disposable endobags

### 2.4.1 Technique

Following the step as illustrated in Fig. 3, the glove is stretched, and an assistant will tie a knot in the middle. If it is not kept stretched, a good dumbbell will not form after knotting which will predispose to slipping of the knot inside the abdominal cavity. The finger part of the gloves is cut away distal to the knot. The glove is held at the cut part and kept stretched over the shaft of the grasper to decrease its thickness and then introduced through the port cannula. This is usually introduced through a 10-mm port. Once in the abdominal cavity, the glove is dropped close to the tissue to be retrieved. It is important to keep the bag far away to be able to have a panoramic view of the entire bag and tissue to be retrieved. The rim of the glove is held by a Maryland or grasper forceps by the non-dominant hand and the dominant hand is used to put the specimen or tissue inside the bag. Once the tissue is inside the bag, the edges of the bag are lifted to shift the tissue to the base of the bag. To take out the tissue, the mouth of the bag is pulled inside the cannula and then together with the neck of the bag is pulled outside the abdominal cavity for tissue fragmentation.

**Advantages**

1. Easily accessible.
2. Cheap and easy to make.
3. Choice sizes can be made.

**Disadvantages**

1. It is made of latex material and weak.
2. It can tear during pulling leading to spillage of infected material.
3. If a piece is torn off inadvertently and lost inside the peritoneal cavity, it may cause tissue reaction leading to infection.
4. It may not be radio-opaque.

## 2.5 Condom

This can be used as an endobag, but if the condom is lubricated, it should be washed because it can cause a tissue reaction. The condom is made of latex and has the same disadvantages as discussed under gloves. The technique of use is almost the same except that you do not need to tie and cut the condom. The whole condom pouch is used.

**Fig. 3** Steps in making a glove endobag

## 3 Removal and Fragmentation of Tissues from the Endobag outside the Abdomen

The neck of the endobag is exteriorised and held open with two or three grasping forceps. The tissue is removed in piecemeal using ovum forceps. Large specimens can be removed in piecemeals after fragmentation using scissors, a morcellator or a harmonic scalpel. They can also be removed by specially designed retrieval forceps together with the endobags. During tissue fragmentation, the laparoscope is used to visualise the endobag so that if it inadvertently ruptures it can be visible.

### 3.1 Morcellation

The extirpation of large tissue specimens has created the need to cut masses of solid tissue into smaller pieces for laparoscopic retrieval. This is achieved by the use of morcellators. There are various types of morcellators (see Fig. 4). They are broadly classified into two: disposable morcellators and reusable morcellators (autoclavable). Morcellators could be electrical or battery driven (rechargeable morcellators). Morcellators have different types of accessories like myoma screw, cutting blade, reducers, tenaculum, etc. [3]. This is an important tool for tissue retrieval in myomectomy.

**Technique**

This is accomplished using a 5-mm laparoscope placed either through a lateral or left upper quadrant (Palmer's point port) while the morcellator is introduced through the umbilical port. The morcellator can also be introduced through the low lateral abdominal port, while the 10-mm umbilical port is kept for laparoscope and camera use. Tissue morcellation should be performed within the pelvis with the patient in a steep Trendelenburg position. One most vital caution in using morcellators is that the morcellator must be visualised always when in use. During morcellation, caution must also be taken as there can be an inadvertent injury to the surrounding tissues. This can be avoided by bringing the tissues towards the morcellator using tenaculum forceps rather than

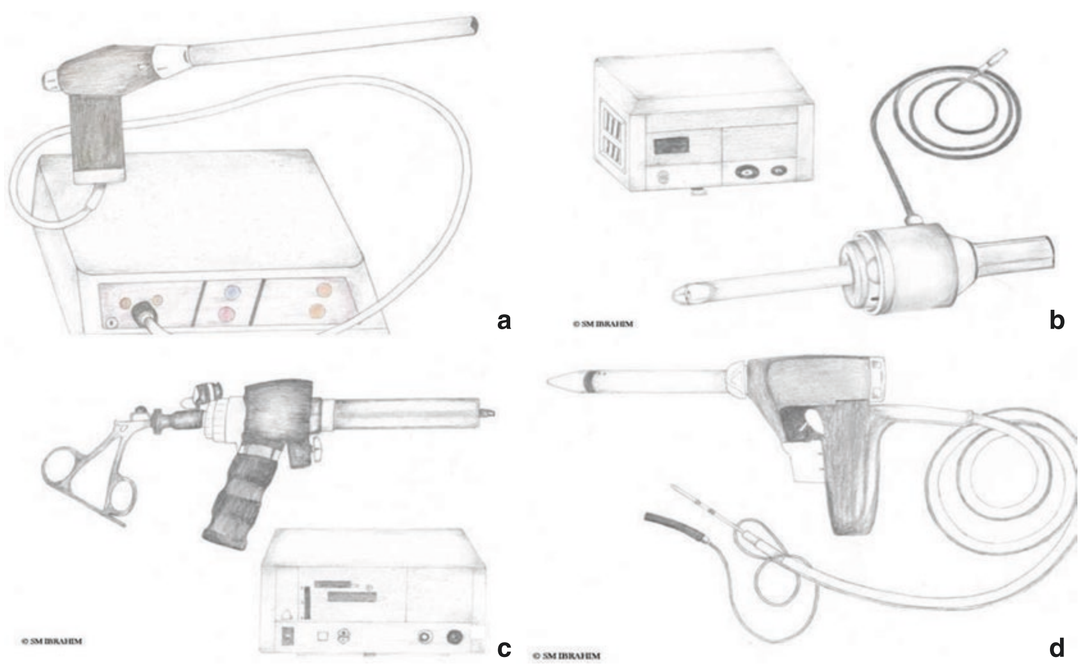


**Fig. 4** (Illustration) Different types of morcellators. (**a**) Morcellator system (Assembled). (**b**) Power morcellator. (**c**) Morcellator machine. (**d**) Electric Moecellator

moving the morcellator towards the specimen. An assistant can facilitate proper technique by stabilising and guiding the specimen into the morcellator. In this way, the surgeon skins the specimen by removing strips of tissue from the edges. Depending on the type of morcellator, the speed of morcellation is set as rotation per minute (RPM). The RPM is usually from 2 to 8, i.e. 200–800 RPM. The slower the rotation per minute, the better the prevention of accidental injury to surrounding tissues.

During myomectomy, the morcellator brings out the fibroid just like a curly orange peel from knife-peeling. Following morcellation, the surgeon should ensure that all tissue fragments are removed to minimise the chance of tissue necrosis, infection, tumour implantation and peritonitis.

**Advantages**

1. It facilitates the removal of large solid tissue.
2. It removes tissue in less time; it decreases operation time.
3. It decreases the risk of port site hernia.

**Disadvantages**

1. It should not be used for known malignant tissues because it may lead to intraperitoneal dissemination.
2. There is the risk of inadvertent injury to surrounding tissues. Such injuries can be extensive.

## 3.2 Colpotomy

Incising the vagina for retrieval of specimens during laparoscopy has been used for many years and allows for the removal of large-sized structures, such as the uterus and its appendages, without reduction of size, but sometimes in pieces when intra-vaginal morcellation is performed using a knife or scissors. It is easy to perform and morbidity following the procedure is minimal. Tissue retrieval is usually under both direct vision and laparoscopically and use of endobags can be employed to avoid spillage.

This is carried out with the patient in a Trendelenburg position to ensure that the pelvic cul-de-sac is free of other structures. The incision is made on the posterior vaginal wall and tissue to be removed is then positioned close to the site. The surgeon picks up the tissue with a grasper and pushes it through the incision carefully to avoid extension of the incision, while the assistant grasps the specimen. To avoid loss of pneumoperitoneum, counter-pushing with an instrument is done by the assistant, and the posterior wall is also sutured laparoscopically to preserve pneumoperitoneum [7]. Similarly, the excised specimen can be placed in a retrieval bag to minimise the risk of spillage; this is done under laparoscopic view.

There can be injuries to nearby structures such as the bladder, bowel, ureter, vaginal wall laceration and haematoma. Other complications include vaginal bleeding, wound infection, abscess of the pouch of Douglas, incisional hernia, scarring and sexual dysfunction. To avoid complications, perioperative antibiotics and good haemostasis should be employed [6, 7].

Contraindications to colpotomy are fixed incarcerated/retroverted uterus, obliteration of the pouch of Douglas by endometriosis and pelvic inflammatory disease. It is also limited to females. Colpotomy has the benefits of easy accessibility; it is also useful in morbidly obese patients.

## 3.3 Hand-Assisted Laparoscopic Surgery

Hand-assisted laparoscopic surgery (HALS) combines the insertion of a surgeon's hand inside the abdominal cavity via a small incision, following the initial laparoscopic approach. The average incision size for HALS corresponds to the surgeon's glove size. The surgeon passes his hand through a hand device for tissue removal. It combines the tactile sensation with the minimal tissue trauma of laparoscopic resection. Examples of hand port devices are GelportÔ, OmniportÔ and LapDiscÔ, among others. An important feature of a laparoscopic-assisted device is that it retains the pneumoperitoneum [5].

After creating the pneumoperitoneum, laparoscopic assessment of the whole abdomen is done via a telescope introduced through the umbilical port, and an incision for retrieval of the specimen is made thereafter for the placement of the hand port device. This depends on the size of the surgeon's gloves and the location of the tissue to be removed. The operating surgeon usually inserts his non-dominant hand into the abdomen via the hand-assisted device. After reaching the specimen, it is placed into an extraction bag with the help of the hand and extracted through the hand port which is closed with absorbable suture after ensuring haemostasis. HALS bridges the gap between open and laparoscopic procedures. Tissue retrieval is less traumatic or protracted and can be used to retrieve either benign or malignant tissue.

### 3.4 Natural Orifices, Transluminal Endoscopic Surgery (Notes)

This technique involves approaching the peritoneal cavity via the lumen of a natural body orifice for tissue resection and retrieval without an abdominal wall incision. Suitable and demonstrated orifices include oral, anal, vaginal or urethral orifices. Although the optimal access route for NOTES is not established, the vagina offers an easily accessible, distensible and widely used route for pelvic and other procedures. Culdoscopy has been in practice for decades and therefore offers a good route for specimen removal as well [6].

The urinary bladder is catheterised and drained continuously. Initial peritoneal insufflation and procedure are done laparoscopically. Access to the peritoneal cavity is achieved by dissecting the posterior fornix to enter the pouch of Douglas through which a trocar is placed. The specimen is then removed, and the vagina is closed conventionally under direct vision with absorbable sutures. Perioperative antibiotic therapy is advisable to decrease the risks of peritonitis and fistula formation. Any form of obliteration or inaccessibility of the pouch of Douglas and fixation of the uterus are contraindications to transvaginal NOTES for tissue retrieval.

## 4 Conclusion

On-going progress in the design and availability of surgical devices and techniques for tissue retrieval in minimally invasive surgery has contributed significantly to easier tissue retrieval and specimen management in appropriately selected patients.

**Learning Points**

- One of the challenges of laparoscopic surgery is being able to retrieve the resected specimen with minimal spillage.
- There are different techniques to facilitate the retrieval of excised tissue masses without needing to enlarge the abdominal incision, excepting very large tissue or fragile specimens.
- While small tissues can be extracted via the port, large specimens may get impacted especially at the level of the valve.
- Large tissue specimens can be extracted via a cannula site. This can be used for benign tissues like post-menopausal ovaries or small myomas, especially in a low-resource setting.
- When specimens or tissues carry the risk of rupture and spillage of contents that cause contamination or are malignant, tissue retrieval bags are the device of choice; if unavailable, the specimen should be retrieved through an extended incision site, for patient safety.
- Improvised tissue retrieval bags are useful in a low-resource setting. It is important to remember that their use can be associated with risks; they are not pre-manufactured with the usual quality control checks and can tear during traction.
- Morcellators facilitate the removal of large solid tumours within a short time; however,

the risk of inadvertent injury to surrounding tissues is a concern.

- The use of natural orifices and removal of bigger masses through colpotomy and hand-assisted laparoscopic surgery (HALS) are other available options.

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# Diagnostic Laparoscopy and Dye Test

Amos A. Akinbiyi, Jude Ehiabhi Okohue, and Ikechukwu I. Mbachu

## 1 Introduction

The aim of this chapter is to describe the benefits of diagnostic laparoscopic procedures in relation to methylene blue dye insufflation as an investigative tool for infertile patients. The role of laparoscopy in the evaluation of infertility might be considered controversial, especially due to availability and local prevalent pelvic causatives of infertility. Hysterosalpingography (HSG) is still considered the first-line diagnostic modality in the evaluation of tubal factor infertility.

Undoubtedly, laparoscopy is invasive and expensive, while at the same time local training skills may be a limiting factor in developing countries. Rich nations of the developed world are hampered also by cost to some extent and thereby do not feel that it is justified for laparoscopy to be used as an initial investigative tool. Another argument is that the findings at laparoscopy usually do not alter the initial treatment of the infertile couple when the initial infertility evaluation is normal or when it shows severe male factor infertility.

A perspective that favours laparoscopy and dye test as an initial investigative tool especially in affluent countries is that endometriosis may be present in up to 50% of women who present with a complaint of infertility [1]. The clinician must therefore decide when women who present for the evaluation of infertility undergo surgical exploration for endometriosis and other pathology as part of their workup. Since the advent of artificial reproductive technology, it should be stated that finding endometriosis and treatment do not usually lead to improved pregnancy outcomes [2–4].

Laparoscopy may be indicated in women in whom endometriosis or pelvic adhesions/tubal disease is suspected based on physical examination, HSG or history (e.g. current dysmenorrhea, pelvic pain, or deep dyspareunia; previous complicated appendicitis, pelvic infection, pelvic surgery or ectopic pregnancy). When we perform laparoscopy, we also perform methylene blue dye test to assess tubal patency and sometimes hysteroscopy to evaluate the uterine cavity. For these reasons, if laparoscopy is already planned, then HSG can be omitted [4–7].

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## 2 Preoperative Procedures

### 2.1 Informed Consent

Informed consent must be obtained from the patient after the details of the procedure have been explained to his/her either in the office setting or in the hospital visit, prior to the surgical procedure. This must include alternative procedures such as a hysterosalpingogram or hysteroscopy if it has not been done prior to the office appointment. In some centres in the developed world, office hysteroscopy is performed under intravenous conscious sedation with reduced risk of general anaesthesia which may occur in an operating room setting.

### 2.2 COVID-19 Era and Testing

Until the pandemic is brought under control, patients scheduled for elective surgery should be screened for exposure to or symptoms of coronavirus disease 2019 (COVID-19). The N95 mask is mandatory for the anaesthesiologist, but not for the rest of the staff because of the risk of aerosol spread of COVID-19. The surgeon must leave the operating room prior to the intubation procedure to allow for the settling time which varies from one room to another.

Protocols for preoperative testing vary by institution and geographic region, and in areas of high prevalence, testing prior to non-emergency surgery is advised [8, 9].

As a routine in our practice, we perform a pregnancy test prior to gynaecologic surgeries, including laparoscopy and dye test, in all women of reproductive age.

### 2.3 Wrong Person, Site, Procedure Prevention

Practicing safe, high-quality operating room care begins with accurately identifying the patient, surgical site and procedure. We routinely perform a checklist which is done on three separate occasions to ensure that the team and the patient understands the nature of the procedure.

### 2.4 Piercings and Tattoos

Oral and nasal jewellery (e.g. tongue and nose rings) can interfere with intubation during the administration of general anaesthesia, and body piercing at any site can conduct electric current if electrosurgery is performed [10].

### 2.5 Preoperative Skin Preparation

Preoperatively, the Centers for Disease Control and Prevention advises that the entire body be washed (shower or tub) with either soap (antimicrobial or non-antimicrobial) or an antiseptic agent on the night prior to surgery. Some practices give patients chlorhexidine gluconate solution at their preoperative evaluation to facilitate appropriate preoperative skin cleansing [10]. We do not practise this. In a meta-analysis of seven trials including over 10,000 participants, preoperative bathing or showering with chlorhexidine or other products was not associated with reduced rates of surgical site infection [11]. The patient is advised to fast for about 8 h prior to the operative procedure and instructed to use her regular medications such as antihypertensive medications even on the morning of the operation. Patients who are on anticoagulants are usually told to avoid its usage based on the advice of the internist.

Depending on other comorbid factors, an anaesthetic consult may be necessary. In our centre at the University of Saskatchewan, in Canada, we do not seek a routine preoperative consult unless it is indicated by her medical history. We have our accepted departmental screening criteria such as obesity, previous abdominal surgery and other medical disorders prior to inclusion on the operating list.

History of allergies must be obtained because some patients may be allergic to methylene blue or other medications that may be used during the surgical procedure. The patient must be accompanied by someone and avoidance of driving for 24 h.

Possible complications which may be early or delayed related to the procedure must be discussed with the patient and written consent is mandatory detailing possible complications on the consent form.

## 3 Operative Procedure

### 3.1 Instruments

1. Laparoscope (Fig. 1)
2. Trocar: 5/10 mm
3. Veress needle
4. Suction/cannula
5. Carbon dioxide
6. Graspers
7. Surgical knife
8. Absorbable suture materials
9. Scissors
10. Foley catheter
11. Tenaculum—double tooth preferred
12. Uterine manipulator
13. Sterile drapes
14. Intravenous fluids.
15. Methylene blue dye

In our centre, nearly all our laparoscopic instruments are disposable, but disposable instruments are typically less cost-effective, although this may not be possible in some developing parts of the world.

**Fig. 1** A laparoscope

### 3.2 Instruments for Single-Incision Laparoscopy

Flexible and articulating instruments are available in resource-rich countries but do not offer any substantial advantage in our practice in almost every centre in Canada.

### 3.3 Instruments for Mini-Laparoscopy

Mini-laparoscopy, also referred to as needlescopic surgery, utilizes instruments with shaft diameters ranging from 1.9 to 3.5 mm (trocar diameters from 2.2 to 4.2 mm) and may be advantageous for use in an office setting under intravenous conscious sedation.

Despite being a simple procedure, adequate anatomical knowledge and proper surgical techniques are important to reduce the risk of complications. Some centres advocate for an open procedure for trocar insertion; however, no significant differences in overall complication rates have been documented when open techniques for primary abdominal insufflation were compared with a blind technique in experienced surgeons [12].

### 3.4 Insufflation Needle

It is recommended to be trained on how to use the Veress needle for initial carbon dioxide insufflation, while secondary trocars are inserted under direct laparoscopic visualization.

### 3.5 Suction and Irrigation

Suction and irrigation are important for all types of laparoscopic surgery. Irrigation is used to clear debris, spilled methylene blue dye or blood when bleeding is encountered. A variety of laparoscopic suction instruments have been designed to remove irrigation fluid or intraperitoneal air and smoke but the cheapest and the simplest should

**Fig. 2** Suction and irrigation tube

be chosen. The type used by the corresponding author is shown in Fig. 2.

There are combination suction/irrigation devices that are available and should be used because of unforeseen circumstances. The methylene blue dye should be irrigated and the leftover removed from the pelvis for it may cause pelvic irritation.

### 3.6 Grasping Instruments

Grasping forceps may be necessary when the fallopian tubes are deeply buried in pelvic adhesions or endometriosis. Salpingostomy may be performed at the same time for fimbria occlusions/phimosis especially in a low-resource setting. Forceps with pointed ends are used for salpingostomy and the dye leakage could be evident in such circumstances.

## 4 Technique of Methylene Blue Dye Test

The patient is first placed in the supine position for induction of anaesthesia following which he/she is placed in the dorso-lithotomy position under general anaesthesia. This could be done under intravenous conscious sedation because it is a very short procedure. A small longitudinal incision is made in the infra-umbilical region and the Veress needle is inserted and insufflation pressure is preset at 25 mmHg. This usually requires about 4–5 l of carbon dioxide in an average-sized patient. Another small incision is made in the lateral abdominal position and a 5-mm trocar is inserted. The probe would then be introduced through this incision while another assistant is introducing methylene blue through

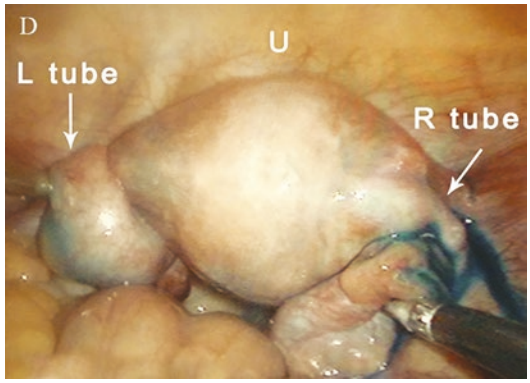


**Fig. 3** Methylene blue insufflation

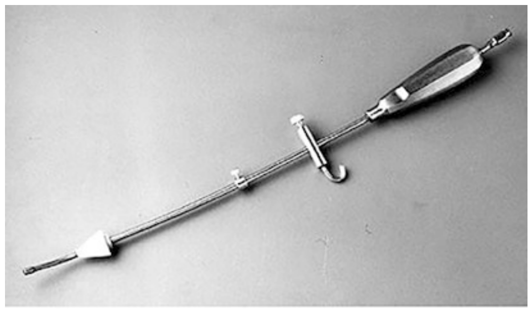

**Fig. 4** Uterine manipulator

the uterine manipulator via the vaginal route. Dye spillage from each tube is a confirmation of tubal patency, as shown in Fig. 3. There are different types of uterine manipulators but the one that we commonly use in our centre is as shown in Fig. 4.

The steps can be summarized as follows [13]:

1. In the supine position, the patient is anaesthetized.
2. The abdominal wall and perineum are cleaned and draped separately.
3. The bladder is emptied and an assistant introduces a uterine manipulator vaginally.
4. The surgeon stays on the patient's left-hand side (right-hand side if left-handed).
5. The Veress needle is inserted at the appropriate site after making a stab incision. (In the direct trocar insertion method, this step is omitted.)
6. Tests are carried out to confirm correct Veress needle placement. Insufflation pressure of

20–25 mmHg is used at the initial trocar entry.

7. When the desired abdominal pressure has been achieved, the incision is increased and a 10-mm trocar and cannula is inserted.
8. The insufflation tube is reconnected, and gas flow restarted with the preset pressure adjusted appropriately.
9. The laparoscope, connected with the fibre-optic cable from the light source and the camera head, is introduced.
10. A panoramic view is carried out: The area below the primary port and the abdominal and pelvic organs are inspected.
11. Insert at least one secondary port under direct vision.
12. In an appropriate Trendelenburg position, move the bowels away.
13. The assistant injects the methylene blue dye via the uterine cannula.
14. The fallopian tubes are observed carefully for any spillage which signifies tubal patency.
15. Ensure there is no reflux of dye through the cervical canal especially in the absence of dye spill.
16. After the procedure, suck out the dye from the peritoneal and pelvic cavities.
17. Remove the secondary port(s) under direct vision.
18. Remove the laparoscope and allow for the escape of gas.
19. Reintroduce the laparoscope via its original port and remove the laparoscope and cannula simultaneously to prevent inadvertent herniation of bowel or omentum.
20. Suture port wound and apply a sterile dressing.
21. Document all findings.

## 5 Procedure-Related Complications

The rate of complications associated specifically with a laparoscopic approach is overall very low, but the procedure still requires adequate training and practice before performance. Most of the complications have to do with initial abdominal access.

### 5.1 Conversion to an Open Procedure

This may be required to manage complications of abdominal access but this is quite uncommon with laparoscopy and methylene blue dye test. This should not be seen as a sign of weakness but strength since challenges are inevitable in any surgical procedure**.**

### 5.2 Bleeding

Partial lacerations of the inferior epigastric artery may not spontaneously stop bleeding, because the vessel is tethered and cannot retract and undergo spasm. Similar to the inferior epigastric vessels, other abdominal wall vessels can be injured, particularly if the trocar is not placed under direct vision and if secondary trocars are placed without prior transillumination of the abdominal wall to identify the presence of superficial vessels.

Bleeding due to a vascular injury at a port site may not be obvious initially and be delayed as a result of tamponade. This is usually recognized in the recovery room within about an hour. Unusual oozing from the trocar site or swelling should not be ignored. Late or delayed abdominal wall hematomas can present 2–3 days later with an abdominal wall or flank bruising around the trocar insertion site [12].

### 5.3 Bladder Puncture

Bladder injury is rare but reported during abdominal access for laparoscopy. A history of prior pelvic surgery increases the risk of bladder injury. Injury to the bladder is more commonly associated with primary or secondary trocar insertion, rather than related to dissection during the course of the procedure.

In general, puncture of the bladder results when a midline, suprapubic trocar is placed in a patient with an overdistended bladder.

When anticipating port placement below the level of the umbilicus or in the suprapubic region, a Foley catheter should be placed to decompress the bladder. Although it is commonplace for patients to void immediately before the procedure, it is safer to drain the bladder with a catheter after the induction of anaesthesia.

The urinary bladder may be distended with bloody urine as a result of bladder injury which should be promptly diagnosed and treated. Instillation of methylene blue dye is advised to identify the injury [12].

Observation is all that is necessary for 3–5-mm injury size, but larger defects will require a suture closure with absorbable sutures with either an open or laparoscopic approach, depending on the skill and experience of the operator. The bladder should then be drained for a few days to 10 days depending on the size and location of the injury.

### 5.4 Port-Site Hernia

Port-site hernia following laparoscopic surgery is less common compared with incisional hernia occurring after open surgery. We always close any trocar site that is 10 mm and above.

## 6 Conclusion

The high prevalence of tubo-peritoneal factors and additional pelvic pathology in some parts of the world have made some authors conclude that laparoscopy and methylene blue dye should be the first investigative tool for tubal patency [14]. In our centre in Canada, a hysterosalpingogram is considered the first choice for tubal patency. If the hysterosalpingogram is nonconclusive/difficult or the ultrasound scan is suspicious of a pelvic pathology, then we proceed to laparoscopy, hysteroscopy and methylene blue dye test. Eventually, what dictates the approach is the prevalence of pelvic pathology, availability of operative equipment and necessary surgical skills.

**Learning Points**

- Diagnostic laparoscopy and dye test is a safe and useful evaluation for female infertility.
- Good techniques on the part of the gynaecologist are necessary to avoid complications.
- Use entry techniques you are comfortable and well trained on.
- Ensure dye injection is properly done avoiding leakage at the external cervical os.
- Follow the procedure step by step to minimize errors.
- Accurate reporting of your findings is very important with video recording of the procedure for evidence.

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# Laparoscopic Suturing Techniques

Uche A. Menakaya and Haleema Olalere

## 1 Background

Proficiency in laparoscopic suturing is an essential component of a surgeon's competency to perform minimal access surgery. Laparoscopic suturing was first introduced by Kurt Semm in the 1970s [1]. Suturing is a complex area in the field of laparoscopic surgery and has a steep learning curve [2]. In certain instances, this hurdle is sufficiently great that laparoscopic procedures are abandoned for laparotomy [3]. However, laparoscopic suturing should be mastered by every surgeon with an interest in developing their minimally invasive surgical approach [4].

There are two types of laparoscopic suturing:

1. Extracorporeal suturing
2. Intracorporeal suturing

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## 2 Extracorporeal Suturing

This refers to the technique of developing the suture knot outside of the body and then slipping the knot snugly inside the body using a knot pusher. There are many variants of the extracorporeal knot including Roeder knot, Duncan loop, Nicky's knot, Tennessee slider, SMC knot, Weston knot, Meltzer knot and Tay side knot (see Fig. 1) [5].

These knotting techniques are essentially variations in turn around the axis or the number of reversed half hitches on alternating post [5, 6]. Each technique has its proponents, and some have been modified for improvement.

A good extracorporeal knot should be simple, easy, quick and reliable and be able to secure proper tissue approximation [5]. The characteristics of a good extracorporeal knot must also include the ability to be easily tightened to ensure maximum strength (loop security) and ability to resist slippage when load is applied (knot security) [7, 8].

The safety of extracorporeal knots depends on knot configuration, suture material and suture size [5, 8]. Thus, challenges with extracorporeal suturing would include choosing the appropriate size of suture material, the numbers of knots that can be applied at once and the ease of sliding in the extracorporeal knot [9].

In gynaecology, extracorporeal suturing may be simple interrupted sutures or figure-of-eight sutures and can be useful in solid tissue repair (vagina, uterus),


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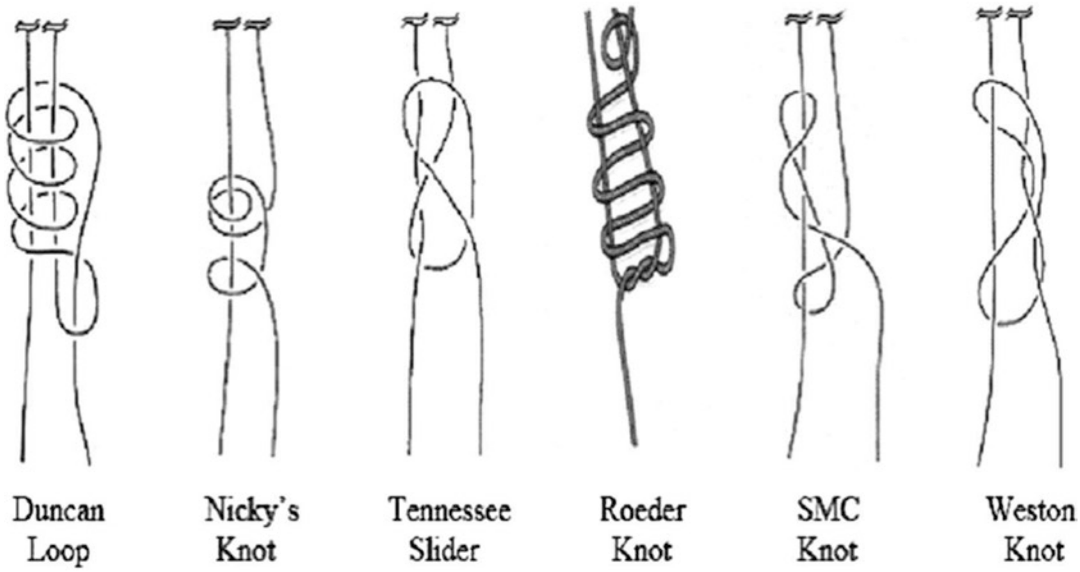



**Fig. 1** Different types of extracorporeal knots [5]. Image reproduced with permission from the Society of Laparoscopic and Robotic Surgeons, publishers of JSLS

homeostasis (infundibulopelvic ligament, uterine artery, tubal ectopic pregnancy) and deep surgery.

### 2.1 The Roeder Knot

The Roeder knot is one of the basic extracorporeal knots. It was initially used as a slip knot for tonsillectomies in children and was later modified by Simms who introduced a push rod application system for use in endoscopic surgery [7]. The Roeder knot is now available commercially as the Endoloop by Ethicon. Other knots like the Meltzer knot and Mishra knot are modifications of the Roeder knot to improve its security [10].

### 2.2 Instruments for Extracorporeal Suturing

- Knot pusher
- Scissors
- Suture material (monofilament sutures preferred for ease of sliding)

## 3 Intracorporeal Suturing

This refers to the technique of developing the suture knot inside the abdominal cavity using laparoscopic suturing instruments. It can be efficiently performed by the systematic manipulation of the relationships between laparoscopic suturing instruments, needle and anatomic area of interest [11].

Key factors to address prior to undertaking laparoscopic suturing would include ensuring adequate endoscopic visualization, understanding the challenges of laparoscopic depth perception and the limitations imposed by the fixed range of laparoscopic ports [11].

### 3.1 Instruments for Laparoscopic (Intracorporeal) Suturing

The laparoscopic instruments required to successfully execute intracorporeal suturing include the following:

1. Needle holder/driver
2. Needle receiver/assisting instrument
3. Laparoscopic scissors
4. Suture material

### 3.1.1 Needle Holder/Driver

Needle holders are an important piece of instrument for performing laparoscopic suturing. The reliability and performance of the needle holder depend on its jaw strength which helps prevent the needle from slipping or rotating [11].

Needle holder jaws/tips are available in a variety of models that include curved and straight needle drivers (see Fig. 2). A straight needle driver tip can be used from both sides and for both forehand and backhand suturing [11]. A curved tip allows for better visualization and aids in the intricate manoeuvres required for intracorporeal knot tying [11].

Needle holder handles are also important to reduce hand fatigue during suturing with the axial handles more ergonomically suited to suturing compared to pistol-grip-type handles (see Fig. 3). The addition of a ratchet system can also help to reduce hand fatigue during laparoscopic suturing.

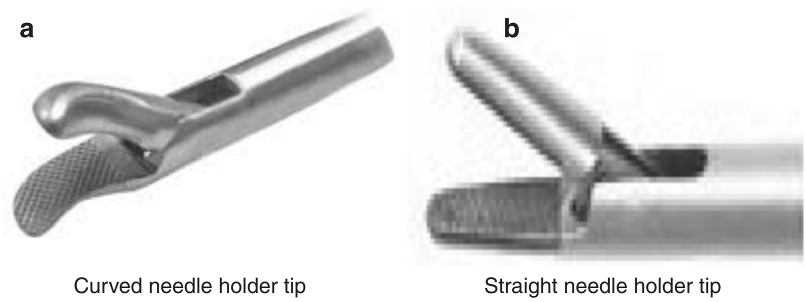



**Fig. 2** Type of needle holder tips: (**a**) Curved needle holder tip, (**b**) Straight needle holder tip

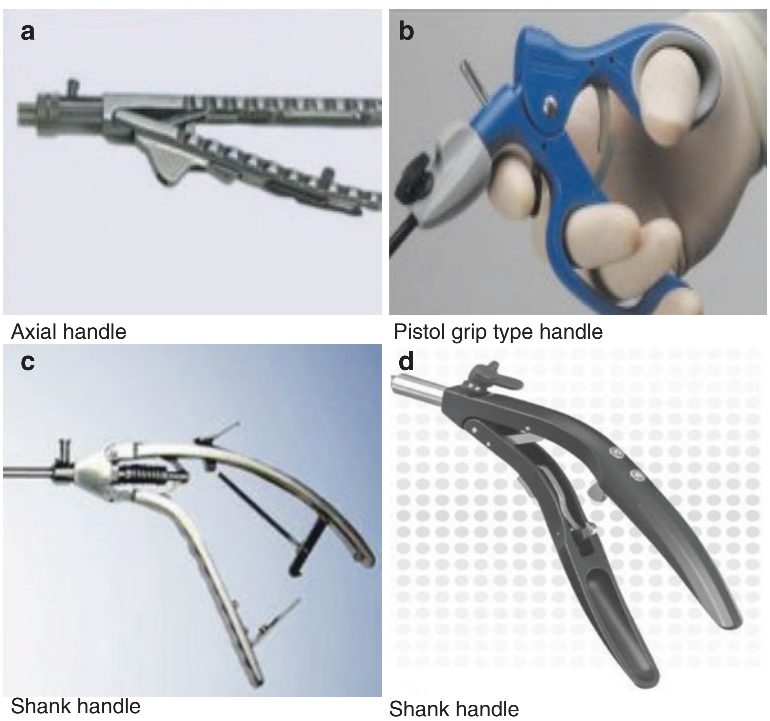



**Fig. 3** Different types of needle holder handles: (**a**) Axial handle, (**b**) Pistol-grip-type handle, (**c**) Shank handle, (**d**) Shank handle

### 3.1.2 Needle Receiver/Assisting Instrument

An ideal laparoscopic suturing assisting instrument should be capable of manipulating the needle and suture without slippage. It should also be able to grasp the tissue of interest without trauma [11]. In addition to the needle receiver, laparoscopic scissors should also be available for cutting the excess suture length (see Fig. 4). Laparoscopic scissors could have a curved (Metzenbaum), hook or straight tip.

### 3.1.3 Suture Material

Most suture materials used in open surgery are also suitable for laparoscopic suturing. However, the length of the suture material is important as it is different for different applications, e.g. for interrupted intracorporeal suturing (10–12 cm), figure-of-eight stitches (15 cm), and continuous running stitches (30 cm) [9]. Another important characteristic of suture materials is their memory [11]. This is especially so for monofilament sutures like PDS or Monocryl. Their memory can aid in spontaneously forming the loops needed for performing intracorporeal knotting [11].

## 3.2 Steps in Laparoscopic Suturing

The key steps in laparoscopic suturing include the following:

- Introducing the suture into the abdomen
- Loading the needle
- Going through tissue
- Preparing for knot tying
- Knot tying
  - The first knot
  - Subsequent knots
- Removal of needle from the abdomen

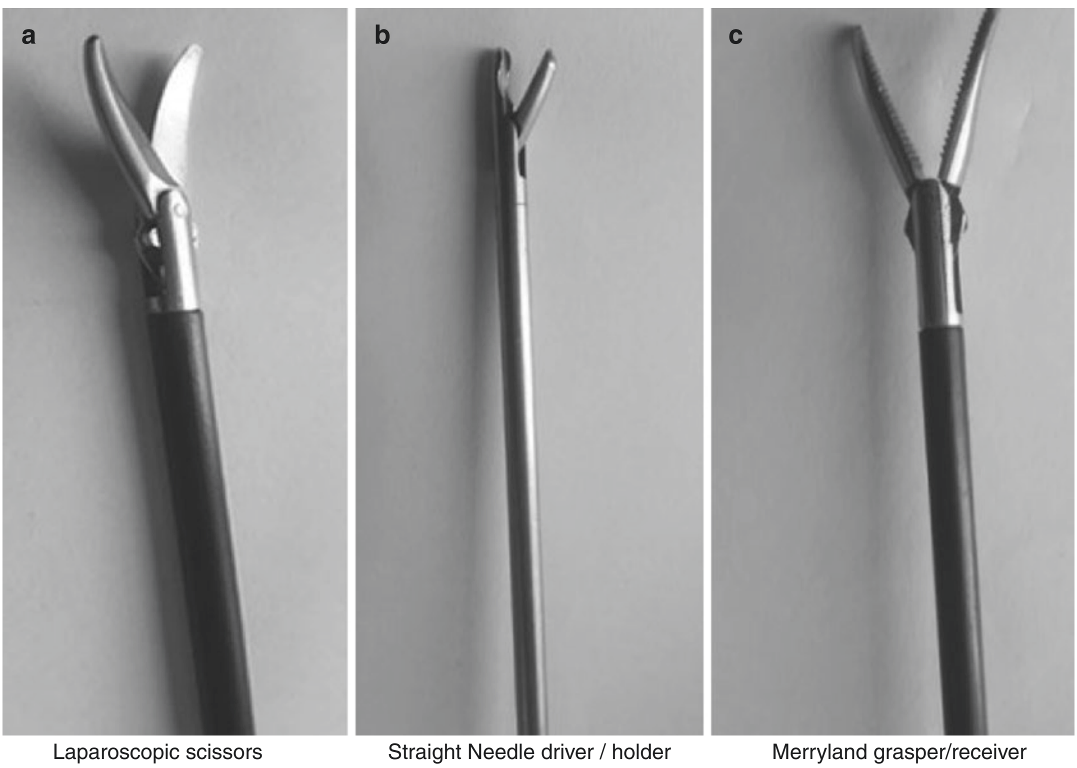



**Fig. 4** Images of instruments required for laparoscopic suturing: (**a**) laparoscopic scissors, (**b**) straight needle driver/holder, (**c**) Maryland grasper/receiver

### 3.2.1 Introducing the Suture into the Abdomen

Introducing the selected suture into the abdomen is the first step in laparoscopic suturing. The suture can be introduced into the abdomen via a number of ways, viz.:

1. Direct trocar entry
2. Back loading
3. Directly through the abdominal wall
4. Through the open vagina cuff

**Direct Trocar Entry**

This is a commonly used technique and depends on the size of the needle and the diameter of the trocar. With an appropriate diameter of the trocar, the needle is grasped on its suture 1–2 cm from the suture swedge and inserted into the abdomen through the selected trocar. For this type of entry, the needle diameter should be smaller than the trocar diameter. Most curved needles used for laparoscopic suturing can easily be introduced using this technique through a standard 10-mm trocar.

**Back Loading**

The back loading technique is another option for introducing the suture into the abdominal cavity. It is usually employed when the curved needle diameter is larger than the trocar diameter, for example, when introducing the suture through a 5-mm trocar port site (see Fig. 5).

Back loading involves the following steps:

- Remove the trocar from the abdomen and pass the needle holder through the trocar.
- Grasp the tail of the suture and pull it through the trocar.
- The needle will now be at the intra-abdominal end of the trocar.
- Grasp the suture 1–2 cm from its swedge with the needle holder.
- Then, reinsert the needle holder with the held suture into the abdomen through the port site under laparoscopic vision.
- Finally, slide the trocar back into place.

**Directly through the Abdominal Wall**

The needle could also be introduced directly through the abdominal wall. This option could be used in women with a thin abdominal wall or where there is a requirement for traction sutures. Both curved and straight needles can be used.

**Through the Open Vagina Cuff**

Following a total laparoscopic hysterectomy, the suture could be introduced into the abdominal cavity through the open vaginal cuff for vault closure (see Fig. 6).

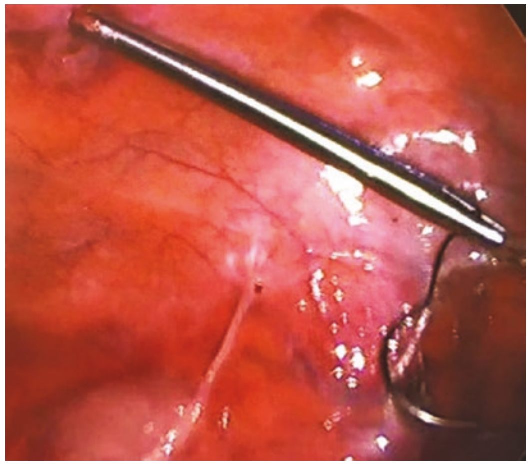


**Fig. 5** Needle holder grasping the suture about 2 cm from the swedge and introduced into the abdomen through a 5-mm trocar port site. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

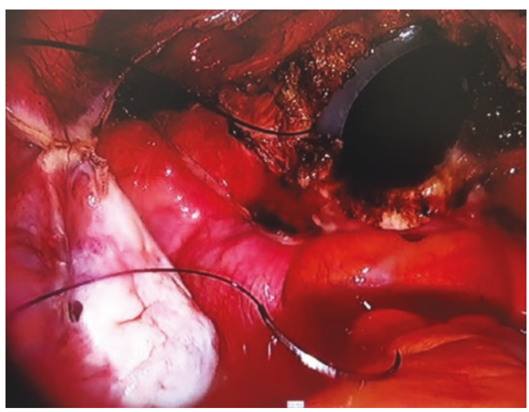
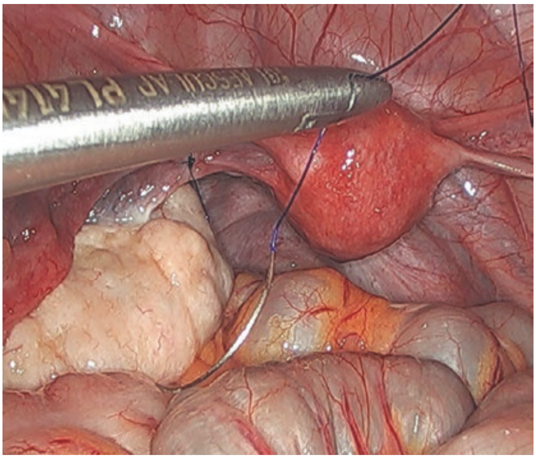


**Fig. 6** 0 Monocryl suture introduced into the abdominal cavity through the open vaginal vault during a total laparoscopic hysterectomy. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

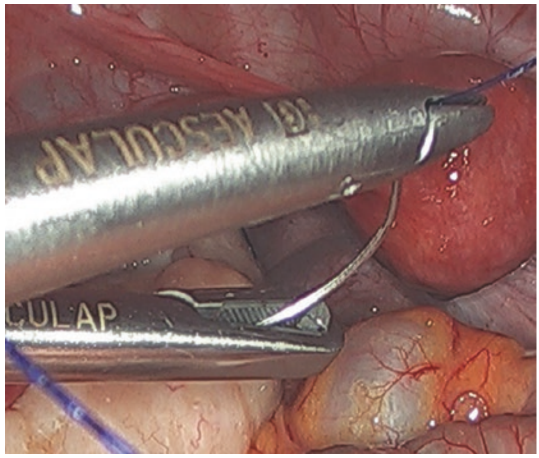
### 3.2.2 Loading the Needle on the Driver

The goal of this step in laparoscopic suturing is to orient the body of the needle to lie perpendicular to the needle driver. With the suture now introduced into the abdominal cavity, the steps will include the following (see Fig. 7):

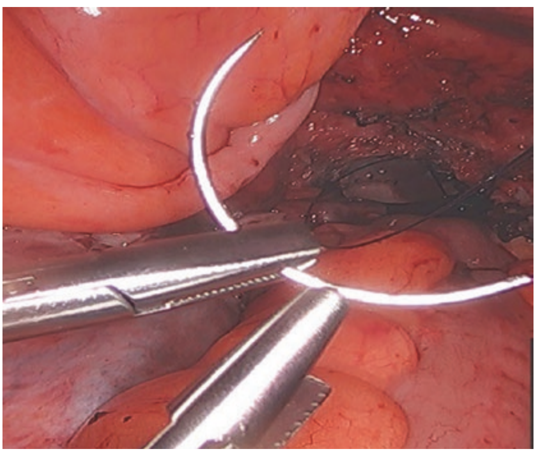
1. Pick up the suture with the needle holder, holding the suture about 1–2 cm from the suture swedge.
2. With the needle receiver in the other hand, grasp the body of the needle about a third of the way from the tip of the needle to stabilize the needle in the direction required to pass through tissue.



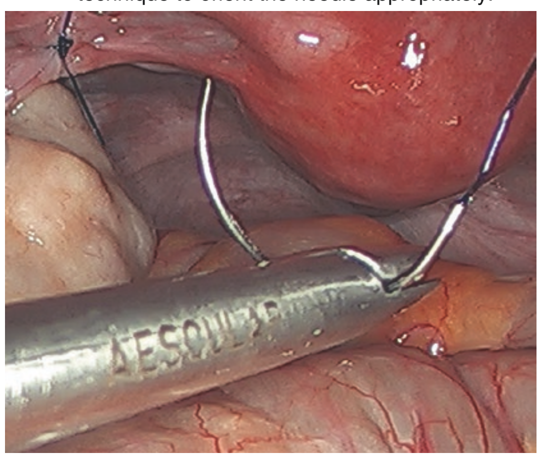
Step 1: Needle driver holding the suture 1-2cm from the suture swedge



Step 2: needle receiver on the other hand grasping the body of the needle. Then use push and pull technique to orient the needle appropriately.



Step 3: Sharp reflection of light from needle Suggesting appropriate set up for needle loading.



Step 4: needle driver grasping the body of the needle about a third of the way from the suture swedge and now ready to go through tissue

**Fig. 7** Steps to successful loading of the needle. *Step 1*: Needle driver holding the suture 1–2 cm from the suture swedge. *Step 2*: The needle receiver on the other hand grasping the body of the needle. Then use the push and pull technique to orient the needle appropriately. *Step 3*: Sharp reflection of light from the needle suggesting appropriate set-up for needle loading. *Step 4*: The needle driver grasping the body of the needle about a third of the way from the suture swedge and now ready to go through tissue. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

3. With the needle receiver holding firmly onto the body of the needle, use the needle holder (holding the suture 1–2 cm from the swedge) to orient the needle until it is perpendicular to the endoscope (using the push-pull technique). This geometry is usually suggested when the body of the needle sharply reflects the light from the endoscope.
4. Using the needle holder, grasp the body of the needle about a third of the way from the suture swedge.

### 3.2.3 Going through Tissue (Fig. 8)

### 3.2.4 Preparing for Knot Tying

This is a critical part of laparoscopic suturing. For beginners, it is important to use the needle as

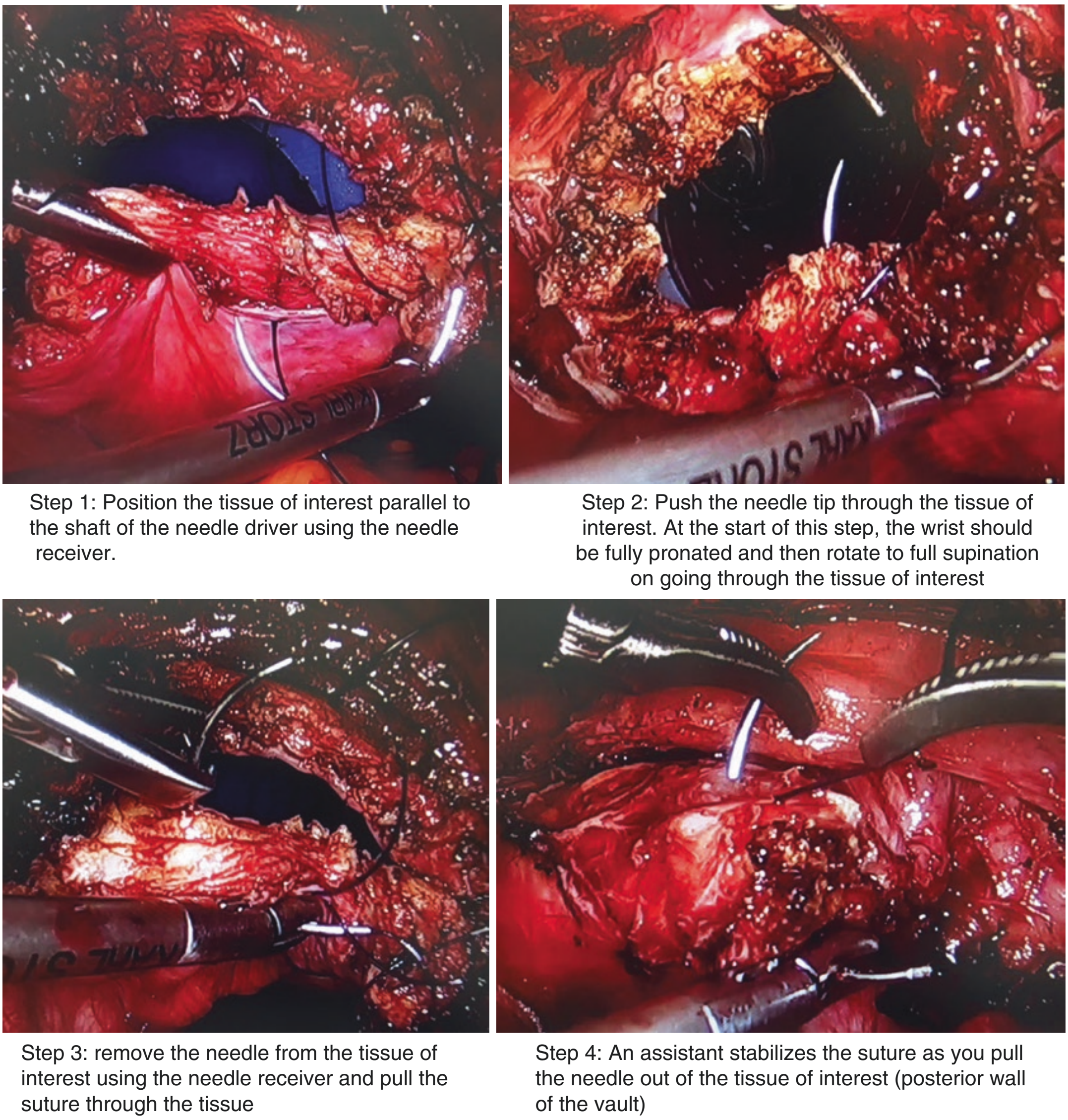



**Fig. 8** *Step 1*: Position the tissue of interest parallel to the shaft of the needle driver using the needle receiver. *Step 2*: Push the needle tip through the tissue of interest. At the start of this step, the wrist should be fully pronated and then rotate to full supination going through the tissue of interest. *Step 3*: Remove the needle from the tissue of interest using the needle receiver and pull the suture through the tissue. *Step 4*: An assistant stabilizes the suture as you pull the needle out of the tissue of interest (posterior wall of the vault). Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

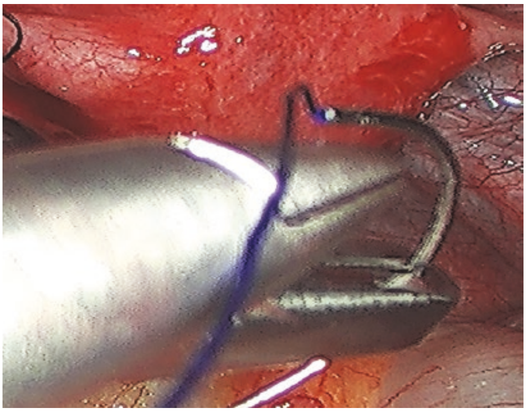


**Fig. 9** The left hand with the needle receiver holding the body of the needle in reverse C position with the swedge directed towards you. The needle driver is then directed between the suture thread and the concavity of the body of the needle in its reverse C position to throw the first knot. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

your fulcrum for knot tying. To do this, the surgeon should manipulate the needle into a reverse C position with the needle receiver grasping the body of the needle and the suture swedge directed towards you (see Fig. 9).

**Throwing the First Knot**

To throw the first knot, pass the needle driver between the suture thread and the concavity of the body of the needle in its reverse C position and make a minimum of two loops as shown in Fig. 10.

For a secure first knot, you should make a minimum of two loops as shown above. Thereafter, the assistant presents the short tail of the suture to the needle driver. The needle driver should grasp the short tail of the suture and pull it through the formed loops to create the first knot. To tighten the first knot securely, you should pull the short tail in an opposite direction to where it was prior to going through the formed suture loops. For example, if the short tail was located at the South Pole when the assistant presents it to you, tighten and secure the first knot by pulling the short end towards the North Pole once it has passed through your formed loops.

#### 3.2.5 Subsequent Knots

Subsequent knots are thrown by repetition of the same process of prepare, throw and secure. For subsequent knots, a single loop will suffice to throw the knot. To secure the knot, tighten the knot by pulling the short tail of the suture in alternating directions, e.g. North Pole and then South Pole directions. For monofilament sutures, up to four subsequent throws may be required. For multifilament sutures up to two subsequent throws may be required.

### 3.3 Removal of Needle from the Abdomen

At the end of the suturing process, the needle is cut off with laparoscopic scissors. It is important to cut the needle with up to 1–2 cm of suture length attached at the swedge. To remove the needle, a number of techniques can be utilized.

#### 3.3.1 Through a 10-Mm-Sized Port

This is possible when a 10-mm-sized port is used during the laparoscopic procedure. Most curved needles used in laparoscopic suturing can be removed through these 10-mm-sized ports. To do this, insert the needle holder through the 10-mm port and securely grasp the 1–2 cm remnant thread holding the needle at the swedge. Then pull the thread out of the port. This process should be done under laparoscopic vision; thus, you will need to insert the laparoscope through a different port. It is important to remember not to hold on the body of the curved needle for this process as the needle will not be able to pass through the port. Do not forget to remove all suture remnants from the abdomen at the end of your suturing.

#### 3.3.2 Through a 5-Mm-Sized Port

You can also remove the needle through a 5-mm-sized port at the end of the laparoscopic procedure. As the diameter of the curved needle is larger than a 5-mm-sized port, the first step in this technique is to straighten the curved needle. To do this:

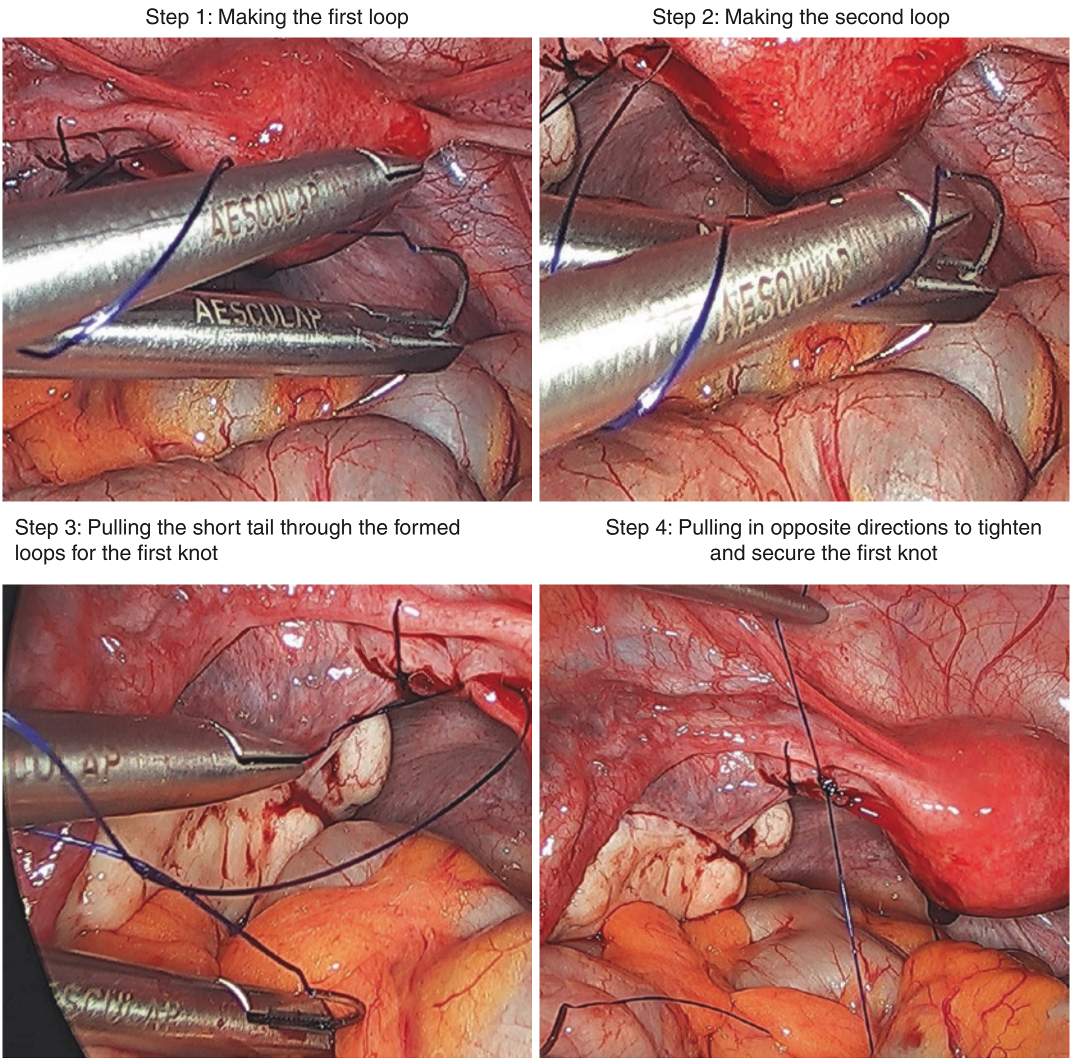



**Fig. 10** *Step 1*: Making the first loop. *Step 2*: Making the second loop. *Step 3*: Pulling the short tail through the formed loops for the first knot. *Step 4*: Pulling in opposite directions to tighten and secure the first knot. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia

- Grasp the body of the curved needle about 1 cm from the needle tip as well as about 1 cm from the swedge with your needle holder and the receiving grasper.
- Straighten the curve needle by applying appropriate pressure at both ends of the curved needle with your laparoscopic instruments.
- Convert the curved needle to a straight needle.
- Grasp the remnant suture attached to the needle about 1–2 cm from the swedge and pull the needle through your 5-mm port (see Fig. 11).

*Step 1*: Showing the curved needle at the end of procedure. *Step 2*: Grasping both ends of the curved needle with your laparoscopic equipment. *Step 3*: Straightening the curved needle by apply-

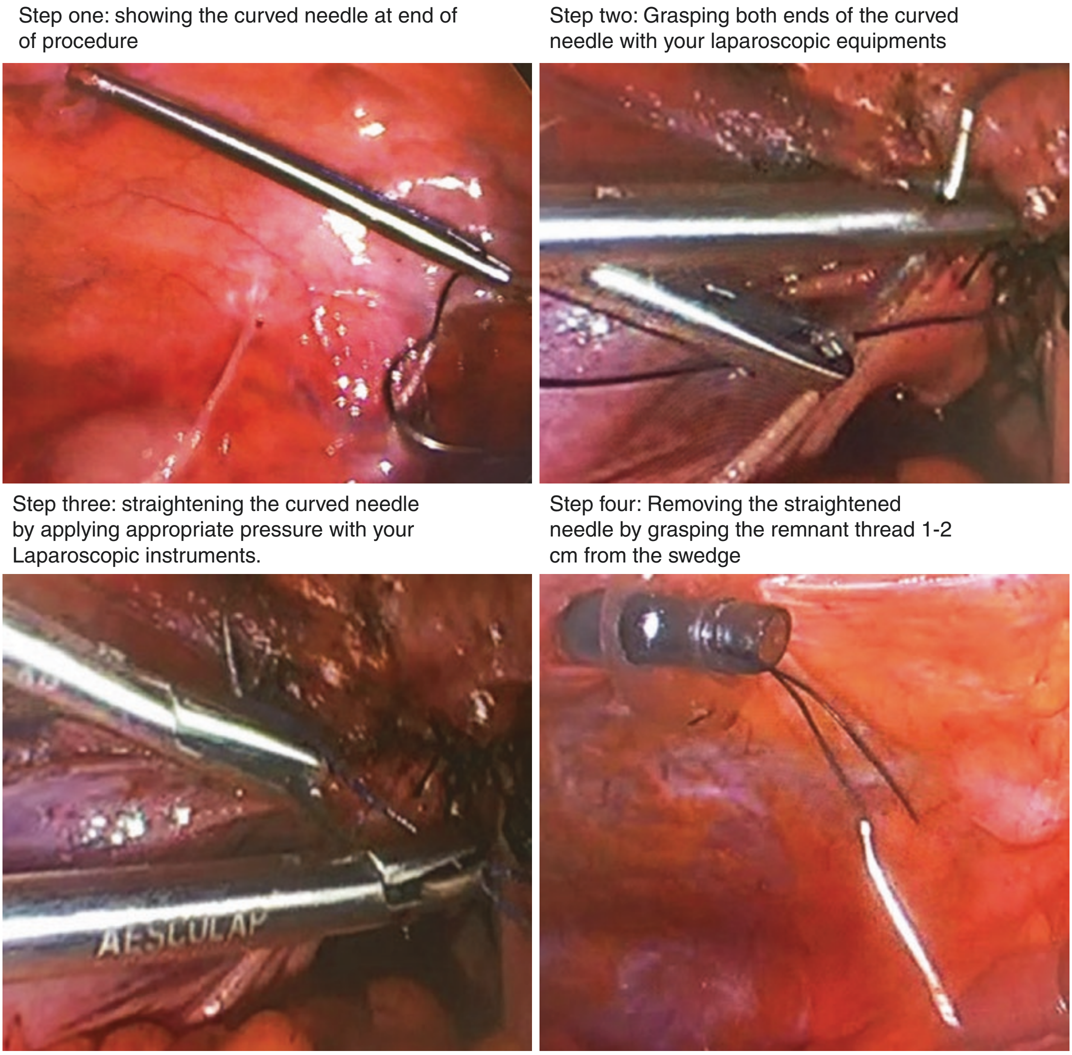



**Fig. 11** Techniques for straighening a curve needle prior to removal from a 5-mm port

ing appropriate pressure with your laparoscopic instruments. *Step 4*: Removing the straightened needle by grasping the remnant thread 1–2 cm from the swedge. Images courtesy of Dr. Uche A. Menakaya and JUNIC Laparoscopy, Australia.

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# Laparoscopic Management of Benign Ovarian Tumours

Adebiyi Gbadebo Adesiyun, Nkeiruka Ameh, and Hajaratu Umar-Sulayman

## 1 Introduction

The place and uniqueness of laparoscopy in the management of benign ovarian tumour are not in doubt. However, the task of the attending gynaecologic laparoscopic surgeon is proper case evaluation to ensure that the tumour is not malignant. Intraoperative spill of tumour cells could lead to spread of the tumour which may accelerate disease progression resulting in poor prognostic outcome. Laparoscopic surgery for benign ovarian tumour is associated with reduction in surgical injury, post-operative complications (fever, urinary tract infection), post-operative pain, hospital stay and total cost. Besides these known merits of laparoscopic surgery, the attainment of normal fertility after laparoscopic treatment for benign ovarian mass in premenopausal women is impressive.

## 2 Types of Benign Ovarian Tumour

Benign ovarian tumours include functional ovarian cysts (follicular cysts and corpus luteum cysts), epithelial cysts (serous cysts, mucinous cysts, endometrioma), germinal cysts (dermoid cysts, ovarian stroma) and solid ovarian masses (ovarian fibroma, benign Brenner tumour).

## 3 Clinical Evaluation

A good assessment of patients with suspected ovarian tumour is a pertinent step towards confirming that the mass is indeed benign. Firstly, it is important to take into cognisance the menopausal status of the patient. Postmenopausal patients are women that have not menstruated in the last one year or patients aged 50 years and above who have had hysterectomy. History to be sought for include the following: irregularities in menstruation, pelvic pain, urinary symptoms, bowel symptoms, weight loss, abdominal fullness/swelling, easy satiety and family history of ovarian, bowel and breast cancer.

Examination should include the general outlook of the patient for signs of chronic disease, anaemia and leg oedema. Abdominal and pelvic examination should be carried out to check for abdominopelvic masses, hepatomegaly, splenomegaly, lymph node and ascites. The mass should be characterized in size, consistency, regularity, tenderness and mobility and if it is unilateral or bilateral. Benign ovarian masses are usually unilateral, smooth surfaced and mobile. The sensitivity of clinical examination in detecting an

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ovarian mass is as low as 15–51% which is based on tenderness, mobility, nodularity of the mass and demonstration of ascites. Malignant features that may be detected clinically are masses that are fixed, irregular, nodular, bilateral and hard with associated ascites.

## 4 Investigations

Specific investigations may include ultrasound scan, colour Doppler, tumour markers, computerized tomography (CT), positron emission tomography (PET) and magnetic resonance imaging (MRI). The relevance of these diagnostic methods will be discussed based on the menopausal status of the patient. Ancillary investigations like full blood count, liver function test and renal function test are also important.

### 4.1 Investigation of the Premenopausal Patient

Ultrasonography: Transvaginal scan (TVS) is most preferred in the evaluation of ovarian masses; however, transabdominal scan (TAS) may be complimentary in instances where the mass is big and there is need to assess for disease that may have gone beyond the ovary [1]. Employing colour Doppler has been found to be of limited use because the accuracy of diagnosis is not increased significantly, though when the mass is complex, there may be better accuracy when combined with 3-D imaging [1].

It is important to ascertain the following features of an ovarian mass from an ultrasound scan: unilocular or multilocular, evidence of solid areas, evidence of metastasis, ascites, bilateral or unilateral lesions. The International Ovarian Tumour Analysis (IOTA) Group (Table 1) came up with ultrasound findings classified into B-rules and M-rules, which are pointers to benign and malignant lesions, respectively. The IOTA group rules have sensitivity and specificity as high as 95% and 91%, respectively.

**Table 1** IOTA group simple ultrasound rules

| Types of rules | Ultrasound rule |
|---|---|
| B-rules | Unilocular cyst, presence of solid components with the largest less than 7 mm, presence of acoustic shadowing, smooth multilocular tumour with the largest less than 100 mm in diameter, no blood flow on colour Doppler |
| M-rules | Irregular solid tumour, ascites, at least four papillary structures, irregular solid multilocular tumour with the largest diameter greater than 100 mm, prominent blood flow on colour Doppler |

**Table 2** Causes of raised CA-125

| S/N | Causes |
|---|---|
| 1 | Pelvic inflammatory disease |
| 2 | Uterine fibroid |
| 3 | Endometriosis |
| 4 | Adenomyosis |
| 5 | Torsion ovarian cyst |
| 6 | Haemorrhage into ovarian cyst |
| 7 | Irritation of peritoneum from non-gynaecological causes: Tuberculosis, liver cirrhosis, hepatitis, pancreatitis, peritonitis, pleuritis, ascites |
| 8 | Irritation of peritoneum from primary tumour metastasis from breast, pancreas, lung, colon |

CA-125: The place of CA-125 in premenopausal women with ultrasound findings of simple ovarian cyst is limited [1]. CA-125 level of 35 IU/mL is the cut-off reference value used routinely. When the ovarian cyst is not simple and the serum CA-125 is high but less than 200 IU/mL, further assessment is advocated to rule other pathologies that may cause raised CA-125 levels. Other than ovarian tumour, CA-125 may be high in premenopausal women because it is equally secreted by pathologies like endometriosis, adenomyosis, fibroids, pelvic infections and conditions that cause peritoneal irritation whether from benign non-gynaecological causes or primary tumours with metastasis to the peritoneum (Table 2).

At the other end of the spectrum, low levels of CA-125 are found in situations like smoking, caffeine intake and hysterectomy. This brings to the fore that the interpretation of high and low levels of CA-125 should be cautiously done. Serial measurement of CA-125 is suggested when the value is raised but less than 200 IU/mL and other causes

**Table 3** Risk of malignancy index I (RMI I)

| |
|---|
| RMI I = U × M × CA-125 |
| U is ultrasound result and a score of 1 point each is given for the following when present: Multilocular cyst, solid areas, metastases, ascites and bilateral lesion. |
| U = 0 for an ultrasound score of 0 |
| U = 1 for an ultrasound score of 1 |
| U = 3 for an ultrasound score of 2 to 5 |
| M is menopausal status: 1 = premenopausal, 3 = postmenopausal |
| CA-125 is measured in the serum in IU/mL. |

of high CA-125 are excluded, as evidence of rapidly rising levels may be a pointer to a malignant lesion. Very high levels of CA-125 would need referral to an oncologist. However, if there is presence of complex ovarian mass with a suspicion that it might be a germ cell tumour, it is important to assay for alpha-fetoprotein, human chorionic gonadotrophins and lactate dehydrogenase [1].

Imaging: The place of imaging like CT and MRI for routine evaluation of benign ovarian mass shows no added merit of improved accuracy over TVS in the diagnosis of malignancy, [2] though benefits may accrue with CT and MRI should the ovarian mass be complex.

It is essential to assess for risk of malignancy in patients with ovarian mass. The use of the risk of malignancy index I (RMI I) has been favoured because of its simplicity and reproducibility [2]. In spite of the odd against RMI I (Table 3) from other causes of raised CA-125 levels in premenopausal women, its sensitivity and specificity are as high as 78% and 87%, respectively, in detecting ovarian malignancy.

### 4.2 Investigation of the Postmenopausal Patient

Ultrasound: TVS is important and invaluable in the evaluation of ovarian cyst and TAS could be employed when the mass is beyond the field of view of TVS. Ultrasonic features of a simple ovarian cyst are round/oval shape, thin wall and absence of septations, anechoic fluid and acoustic enhancement posteriorly [2]. A complex ovarian cyst features one or more of the following: multilocular cyst, solid nodules and papillary projections, if present, which are linked to the likelihood of malignancy. Accentuation of sonography with colour Doppler, pulse and spectral Doppler and 3-D sonography is not important in the routine and initial assessment because it is not associated with increased diagnostic accuracy [2]. Likewise, CT, MRI and PET-CT SCAN are not recommended for initial assessment of postmenopausal women with ovarian cyst [2, 3]. However, their place in the investigation of complex ovarian mass and where metastasis is suspected is not disputable.

CA-125: In postmenopausal women, CA-125 is the only tumour marker recommended for the initial routine assessment of ovarian cyst [2]. More so, because of its inclusion in the calculation of RMI I, which has a value of 78% pooled sensitivity and specificity in differentiating between benign and malignant, it is therefore still important to exclude other causes of raised CA-125. Use of other tumour markers are not routinely employed in the evaluation of postmenopausal ovarian cyst. In cases where the RMI I is 200 IU/mL and above, it is advisable to refer the patient to the gynaecology oncology unit.

## 5 Laparoscopic Surgical Treatment

Before arriving at a decision for surgical intervention, the patient should be considered for possible conservative management. In the premenopausal patient with simple ovarian cyst of less than 5 cm in diameter, which is likely a physiological cyst, a follow-up may not be required. However, if the simple ovarian cyst measures 5–7 cm, a follow-up every year is advocated [3, 4].

Further evaluation with imaging is required for larger cyst. In postmenopausal patients, simple unilateral and asymptomatic ovarian cyst of diameter less than 5 cm and normal CA-125 value may be managed conservatively and reevaluated in 4–6 months [3, 5].

## 5.1 Options of Laparoscopic Procedures

Aspiration, cystectomy, oophorectomy and salpingo-oophorectomy are possible surgical procedures that could be performed laparoscopically for benign ovarian tumours. In premenopausal patients, management of benign ovarian mass by laparoscopy is preferred because of the advantages of reduced postoperative morbidity and its cost-effectiveness, quick recovery and early discharge from the hospital. However, large-sized tumours and presence of solid components may warrant a decision to perform laparotomy. Although surgeons have reported successes in the management of huge benign ovarian tumours laparoscopically by placing the Veress needle in the left hypochondrium, safeguarding against inadvertent cyst rupture. However, some surgeons are of the opinion that the process of operating on a huge ovarian mass negates or diminishes the merits of laparoscopic surgery [3, 5]. In postmenopausal patients with benign ovarian cysts, patients with a low risk of malignancy based on RMI I less than 200 IU/mL can be managed laparoscopically by performing a bilateral salpingo-oophorectomy and not aspiration or cystectomy [4].

### 5.1.1 Aspiration

Laparoscopic or vaginal aspiration of ovarian cyst is associated with recurrence due to re-accumulation. Aspiration of cyst to reduce tension and accidental spillage may be performed before cystectomy for large ovarian cysts. The surgeon may consider using tissue retrieval bags to avert spillage of cyst content. In postmenopausal women, aspiration of ovarian cyst is not recommended because of poor diagnostic value of cyst fluid cytology, recurrence of cyst and spillage of cancer cells in cases misdiagnosed as benign [4].

Technique: Immobilize the ovary by using an Endo Clinch grasper forceps to hold the ovarian ligament (Fig. 1).

Via the anti-mesenteric side of the ovary, the cannula or 5-mm aspiration needle for suction is introduced into the cyst. After suction the cavity of the cyst may be lavaged.

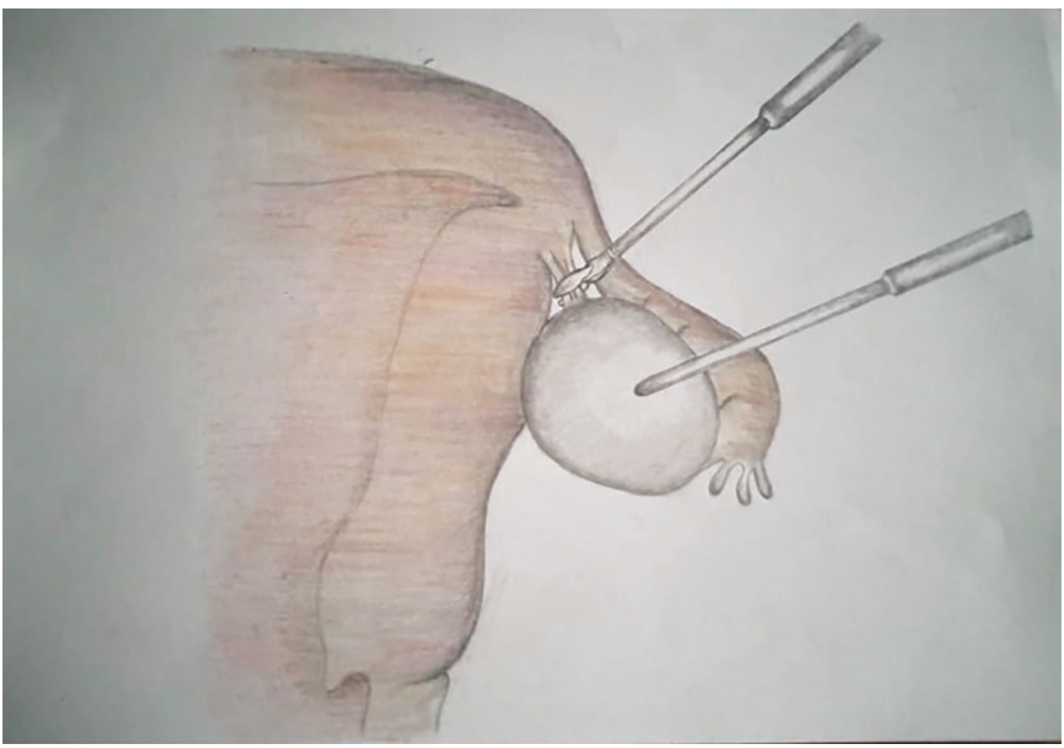

**Fig. 1** Ovarian ligament stabilization before aspiration procedure for ovarian cyst

### 5.1.2 Cystectomy

In premenopausal patients, cystectomy is favoured for preservation of ovarian parenchyma around the hilum for future fertility [1]. In post-menopausal patients, cystectomy is not an option [2]. Inadvertent cyst rupture is of higher incidence at laparoscopy than laparotomy [4].

Technique: Uterine manipulator is put in place for ease of visualizing the adnexae. The ovary is mobilized from any adhesions and the ovarian fossa. An Endo Clinch grasper is used to hold the ovarian ligament; this is to allow for good exposure. Opposite the ovarian hilum, unipolar scissors is used to make an incision to reach the cyst wall. By grasping the ovarian cortex with atraumatic Markowitz or Dorsey grasping forceps, the cleavage plane is identified and dissection done with round-ended curved scissors (Fig. 2).

Bipolar coagulation of vessels supplying blood to the cyst is done before the cyst is removed intact. In instance of huge ovarian cysts, aspiration of the cyst is done followed by cold-scissors incision into the ovarian cortex and cyst wall. The edges of the incision at opposite ends are grasped by atraumatic forceps for stabilization. Following identification of cleavage plane, the cyst capsule is stripped from the ovarian parenchyma using a Manhes forceps.

Bipolar energy is used to ensure haemostasis. Should ovarian tissue be found protruding, it is coagulated. Finally, if the ovarian margin overlaps, it can be left for spontaneous healing and if otherwise suture is applied to oppose the edges.

Caution should be taken when performing laparoscopic ovarian cystectomy for dermoid cyst. This is because the content of the cyst may inadvertently spill into the peritoneal cavity resulting in chemical granulomatous peritonits [6]. Excising the cyst intact in a lap sac or endo pouch is advocated and subsequent removal of the cyst with a salvage bag [6]. Should iatrogenic rupture of the cyst occur, it is recommended to try

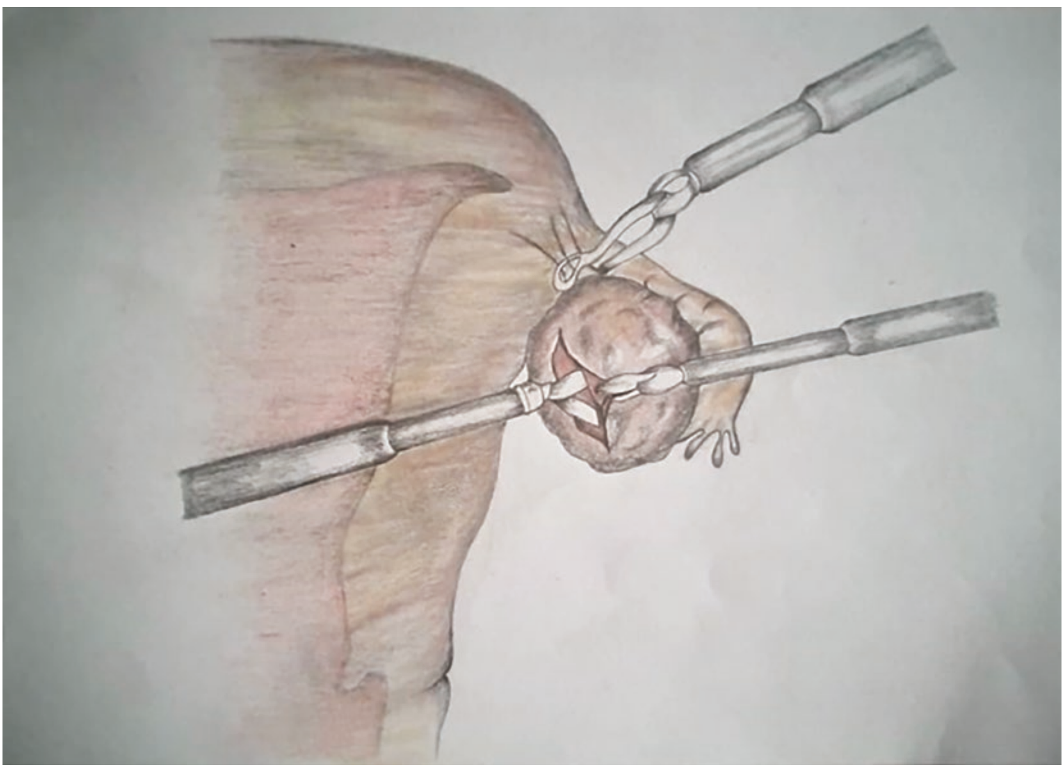

**Fig. 2** Assess of cleavage plane during ovarian cystectomy procedure

to restrict the spill to the lower pelvis and not allow advancement to spaces in between the intestinal loops [6]. It is important to lavage with sodium chloride solution at body temperature until there are no fatty particles in the effluent. Lavage will decrease inflammatory reaction and adhesion formation [6].

### 5.1.3 Oophorectomy

For benign ovarian masses, oophorectomy in a premenopausal patient is only recommended when there is markedly insufficient or absent ovarian tissue to conserve [1]. The use of a laparoscopic retrieval bag is advised preferably through an umbilical port.

Technique: The ovary is immobilized with an Endo Clinch forceps. Bipolar forceps with a wide jaw is used to coagulate the ovarian pedicle. Starting from the uterine side, the mesovarium and mesosalpinx are held and coagulated in small portions till the fimbrial end is reached.

### 5.1.4 Salpingo-Oophorectomy

Salpingo-oophorectomy for benign ovarian masses is recommended in postmenopausal patients. In premenopausal patients, it could be an indication when the tube is taken up by the benign ovarian pathology.

Technique: The adnexa is lifted with traction and all efforts should be put into identifying the course of the ureter through the peritoneum. The ureter is displaced laterally away from the infundibulopelvic fold. The latter which contains the ovarian vessel is grasped with a wide-jaw bipolar forceps and coagulated. Cold knife is used to transect the vessel. The ovarian ligament and tubal isthmus are then clamped, coagulated and transected.

## 6 Conclusion

Benign ovarian tumours are common gynaecological conditions that may need surgical intervention. Contemporary management of benign ovarian tumour is by laparoscopy once malignancy is ruled out. Patients with malignancies should be referred to the gynaecology oncology unit. Preservation of the ovary for reproduction is best achieved by laparoscopic management.

**Learning Points**

- Benign ovarian tumours are best managed by laparoscopy.
- Evaluation to rule out malignancy is essential before subjecting a patient to laparoscopic surgery.
- It is important to know the menopausal status of the patient and if the mass is simple or complex as a guide for subsequent evaluation.
- Where available, operative specimen should be subjected to frozen section to exclude malignancy.
- Where applicable, use of a laparoscopy retrieval bag is recommended to prevent intraperitoneal spillage of cyst content and subsequent peritonitis.
- If iatrogenic rupture and spillage of dermoid cyst content occur, copious lavage with normal saline solution at body temperature should be performed.

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# Laparoscopic Ovarian Drilling

Lilian Ugwumadu and Emmanuel Kalu

## 1 Introduction

Polycystic ovary syndrome (PCOS) is a common endocrine disorder that affects about 10% of women in the population. Clinical symptoms include oligomenorrhoea/amenorrhoea, clinical/biochemical features of hyperandrogenism and anovulation [1]. About 55–75% of patients with PCOS are infertile because of chronic anovulation [2–4]. In the 1930s, Stein and Leventhal introduced ovarian wedge resection as the first ovulation induction method in women with anovulatory PCOS [5]. The introduction of clomiphene citrate in the 1960s as an effective method for ovulation induction meant ovarian wedge resection was largely abandoned due to its associated morbidity and high rates of pelvic adhesions [6]. Clomiphene citrate remains the recommended first-line choice for ovulation induction in women with anovulatory PCOS [7, 8]. The ovulation rate in anovulatory women treated with clomiphene citrate ranges between 75% and 80% with a six-cycle cumulative pregnancy rate of 60% [9]. About 20% of women with PCOS would not respond to clomiphene citrate (Clomid-resistant). Treatment options for clomiphene-resistant patients include ovulation induction (OI) using gonadotropins or laparoscopic ovarian diathermy (LOD). Both treatment options have similar efficacies. However, OI with gonadotropin is associated with risk of multiple follicular development, ovarian hyperstimulation and multiple pregnancy. Patients require regular ultrasound scan monitoring and this increases treatment cost. On the other hand, laparoscopic ovarian drilling eliminates the risk of multiple pregnancy as usually there is unifollicular development. It also provides the opportunity to assess the pelvis for other surgically treatable comorbidities that may enhance spontaneous conception. LOD is however invasive and so not recommended as first-line treatment for anovulation.

## 2 Mechanism of Action of LOD

Although the technique has been widely used in the last two decades, the exact mechanism of action remains largely unknown. The most plausible theory is the destruction of androgen-producing tissue within the ovary. The resulting decrease in circulating androgen concentrations may result in a fall in oestrone (E1) due to

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decreased peripheral aromatization of androgens. This fall in E1 may result in decreased positive feedback on LH and decreased negative feedback on FSH at the level of the pituitary, allowing follicular recruitment and development to proceed to subsequent ovulation [10]. Production of inflammatory growth factors like insulin-like growth factor-1 in response to ovarian thermal injury and increased blood flow to the ovary provoked by surgery affects the ovarian-pituitary feedback mechanism and facilitates increased delivery of gonadotropins [11, 12].

## 3 Patient Selection and Predictors of Success

On average, 20–30% of anovulatory PCOS women fail to respond to LOD possibly due to inadequate destruction of ovarian stroma or inherent resistance of the ovaries [13]. Poor prognostic factors include marked obesity (BMI ≥35 kg/$m^2$), significant hyperandrogenism (testosterone ≥4.5 nmol/L or FAI ≥15) and/or long duration of infertility (>3 years). However, a high level of preoperative LH concentration (≥10 IU/L) in women who ovulated after LOD appeared to predict higher probability of pregnancy. Age, the presence or absence of acne, the menstrual pattern, LH/FSH ratio and ovarian volume did not seem to influence the outcome of LOD [14]. Serum levels of anti-Müllerian hormone negatively correlate with the clinical outcome of LOD. A serum AMH concentration higher than 7.7 ng/mL was found to predict poor outcome in PCOS women undergoing LOD [15].

## 4 Operative Technique

A three-port laparoscopy is performed; the pelvis is assessed for other coexisting pathology that may be amenable to surgical treatment. The utero-ovarian ligament is grasped with a pair of atraumatic grasping forceps and the ovary is lifted up and stabilized in position away from the pelvic side wall and bowel to avoid direct or indirect thermal injury. A laparoscopic (traditionally) monopolar diathermy with a double insulated retractable needle is used to penetrate the ovarian capsule at a number of points. When the needle penetrates the capsule of the ovary, the insulated cone controls the depth of penetration and minimizes thermal damage to the ovarian surface. It is important that the site of application is away from the ovarian hilum to avoid damage to ovarian vessels (which may increase the risk of ovarian failure). The site of drilling should also be well away from the fallopian tubes for obvious reasons.

**Fig. 1** Technique of laparoscopic ovarian drilling (courtesy of Mr. E Kalu)

After insertion of the needle through the ovarian capsule, monopolar coagulation electricity current is activated typically for 4 s with a power setting of 40 Watts. Electricity should not be activated before penetrating the surface of the ovary to avoid arcing and to minimize damage to the ovarian surface due to the charring effect which may later cause adhesion formation. However, a short burst of diathermy may be necessary to facilitate the needle insertion. Four puncture holes are traditionally made on each ovary. The ovary is then cooled down by irrigation using normal saline before releasing it to its normal position (Fig. 1).

## 5 Dose Response

The amount of thermal energy and number of punctures made on each ovary vary considerably in different studies. In a retrospective review of 161 women who underwent LOD, two punctures resulted in poor outcome and three punctures

(450 J/ovary) seemed to represent a plateau dose, above which no further improvement of the outcome was observed. Seven or more punctures seemed to be associated with reduction of the ovarian reserve suggesting excessive ovarian destruction [16]. In a prospective study involving 30 women with anovulatory PCOS undergoing LOD, four punctures (600 J) per ovary at 30 W for 5 s (150 J) per puncture were found to represent the optimum number required to achieve the best result with an ovulation and pregnancy rate of 67%, respectively [17]. In a more recent RCT of 60 women on each arm who received an adjusted thermal dose based on ovarian volume of 60 J/cm$^3$ of ovarian tissue versus a fixed thermal dose of 600 J per ovary through four ovarian holes regardless of size, respectively, women who received an adjusted dose based on ovarian volume had a better reproductive outcome compared with fixed thermal dosage [18]. A thermal dose based on ovarian volume is therefore recommended. A dose of 60 J/cm$^3$ ovarian volume resulted in better ovulation, pregnancy rates and better cycle regulation and with similar rate of adhesion formation compared to a fixed dose of 600 J/ovary [18].

## 6 Choice of Electrocautery

Several authors have utilized the technique by Gjonnaess [19], making craters on the ovarian surface using biopsy forceps and delivering monopolar current [20–23]. Pelosi and Pelosi used monopolar diathermy needle [24] and Merchant used low-watt bipolar current to penetrate the ovarian capsule and coagulate all the visible cysts [25]. The overall results of these techniques are comparable. In a small study, Darwish et al. compared the safety and efficacy of utilizing monopolar versus bipolar needle in a randomized controlled trial. The authors found bipolar needles to be superior to monopolar LOD with a significantly higher rate of resumption of spontaneous ovulation and spontaneous pregnancy [26]. Study size was however small as there were only 20 patients on each arm of the trial.

## 7 Unilateral (ULOD) or Bilateral Ovarian Drilling (BLOD)

The concept of unilateral ovarian drilling was first introduced by Balen and Jacobs to minimize the potential effect on the ovary [27]. The authors concluded that unilateral ovarian drilling gave comparable results with bilateral ovarian drilling with resultant reduction in serum LH concentration [27]. These findings have also been confirmed by other studies [28–31].

## 8 To re-Drill or Not?

Amer et al. investigated the effectiveness of a repeat LOD in women with PCOS. In a retrospective study comprising of 20 women who had undergone LOD 1–6 years prior [32], the authors reported an overall ovulation and pregnancy rates of 60% and 53%, respectively, with better outcomes in LOD-sensitive than LOD-resistant cases (83 and 67% vs. 25 and 29%, respectively). However, there are obvious concerns about the risk of adhesion formation and reduced ovarian reserve with repeat LOD. Much larger randomized controlled trials are needed to address this issue before it could become routine practice [8].

## 9 Laparoscopic Ovarian Drilling Prior to IVF Treatment

A single trial of 50 women that compared laparoscopic ovarian drilling before IVF treatment did not find a significant difference in pregnancy, multiple pregnancy, live birth, miscarriage and OHSS rates [33]. Similar findings were described by Eftekhar et al.; however, there was significant reduction in OHSS in women who had LOD prior to IVF and this may be considered as a useful technique in the management of patients who have previously developed OHSS [34].

## 10 Complications of LOD

Apart from complications associated with laparoscopy, complications specific to the LOD procedure include formation of peri-ovarian/pelvic adhesions and the potential risk of ovarian damage that may lead to reduced ovarian reserves or ovarian failure.

Greenbalt et al. found ovarian adhesions in all eight patients, who had a second-look laparoscopy [35]. Gurgan et al. [36] described adhesions in six out of seven patients after electrocautery and in eight out of ten patients after Nd/YAG laser. In studies by Gurgan et al., pregnancy rates in 19 and 20 patients without second-look laparoscopy were not different after 6 months [36, 37]. Liguori et al. [38] also performed 30 s look laparoscopies after 90 cases of ovarian drilling and found minimal to moderate adhesions in seven of the 30 cases (23%). In a study by Felemban et al. [21], a rate of 27% postoperative adhesions was reported in a total of 17 patients. Overall, the incidence of adhesions following LOD varies significantly between 0% and 70% [39]. A Cochrane review concluded that there is no sufficient evidence that the laparoscopic technique influences the grade of adhesion formation [40]. Another potential risk of LOD is iatrogenic ovarian damage that may cause reduced ovarian reserves or premature ovarian failure. This complication is extremely uncommon but may occur following excessive destruction of normal ovarian follicles or following inadvertent damage of the ovarian blood supply. It is reassuring that Amer et al. did not find any cases of premature ovarian failure in a 9-year follow-up of 116 patients who had LOD [41, 42]. This theoretical risk of ovarian failure can be largely avoided by minimizing the number of punctures made and by exercising caution to avoid the ovarian hilum during delivery of energy.

## 11 Conclusion

Laparoscopic ovarian drilling is a safe and useful surgical option for ovulation induction in women with clomiphene citrate-resistant anovulatory PCOS. In well-selected cases, ovulation rates could be as high as 80% with cumulative pregnancy rates of up to 70%. Delivery of thermal dose based on ovarian volume seems to be more effective than using a fixed thermal dose. Application of good basic surgical principles, including ensuring excellent haemostasis and cooling the ovaries after drilling, would minimize the risk of adhesion formation. The risk of ovarian failure with laparoscopic ovarian drilling is extremely small. Deep and excessive application of thermal energy especially involving the ovarian hilum region must be avoided as this may have implications on ovarian reserves and risk ovarian failure.

**Learning Points**

Outline of Technique of Laparoscopic Ovarian Drilling and Learning Points

- Ovarian ligament is grasped with a pair of atraumatic forceps.
- The ovary is lifted up away from the bowel and stabilized.
- A monopolar electrocautery needle probe is used.
- The needle should be away from the ovarian hilum and fallopian tube.
- Power is set at 40 W.
- The full length of the needle is pushed into the capsule.
- Electricity is activated for 4 s.
- Four punctures are made in each ovary.
- The ovary is cooled with saline at the end of the drilling procedure.
- Avoid excessive/deep cautery.
- Avoid drilling around the ovarian hilum.
- A thermal dose based on ovarian volume is recommended. A dose of 60 J/cm$^3$ ovarian volume resulted in better ovulation, pregnancy rates and better cycle regulation than a fixed dose of 600 J/ovary.

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# Laparoscopic Tubal Surgery and Laparoscopic Management of Ectopic Pregnancy

Adebayo Alade Adewole, Oluseyi Ayoola Asaolu, and Abdulhakeem Olajide Akintobi

## 1 Introduction

The fallopian tube is a critical component of the female reproductive organ that conveys the egg and the fertilized ovum to the uterine cavity. It can acquire diseases that could affect both its anatomical and physiological functions. This condition constitutes a significant cause of infertility, most especially in Africa, where a high premium is on childbearing, and the inability to procreate can be a significant family challenge. Fallopian tubal disease is responsible for 25–35% of female infertility cases in developed countries [1, 2]. In Nigeria, tubal factors contribute about 42–63.6% due to infertility [3–5]. The struggle to conserve these anatomical and physiological functions in managing various tubal diseases has posed tremendous challenges to the gynaecologist. Historically, tubal surgery was done as an open procedure, and this gradually evolved into microsurgery with gentle tissue handling and, more recently, laparoscopic tubal surgery [2].

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## 2 Advances in Laparoscopic Tubal Surgery

Dr. Kurt Semm, a German gynaecologist who specialized in infertility, was perhaps the most influential early advocate of modern operative laparoscopy. He developed laparoscopic techniques for ovarian cystectomy, myomectomy, treatment of ectopic pregnancy, appendectomy and hysterectomy. Despite Dr. Semm and other remarkable pioneers' work, gynaecologic laparoscopy continued to be used primarily for diagnosis and tubal ligations into the 1980s [2, 6].

The first laparoscopic tubal surgery performed was the bilateral tubal ligation as a form of contraception. Presently, it is indeed the most common method of female surgical contraception worldwide. It has evolved from the use of the monopolar technique by Palmer and Steptoe to the use of the bipolar technique by Rioux and Kleppinger and currently Silastic bands and spring clips as occlusive methods of sterilization for easy reversal [2, 6, 7]. Tubal surgery has gradually evolved to include reversal of tubal sterilization, tubal blockage operations and tubal ectopic pregnancy. These procedures include fimbrioplasty, neosalpingostomy, laparoscopically guided hysteroscopic tubal cannulation, salpingectomy, salpingotomy/salpingostomy and milking of tubal pregnancy [2].


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## 3 Brief Anatomy of the Adnexa and the Laparoscopic Perspective

There are two fallopian tubes within which fertilization usually occurs close to its ovarian end (Fig. 1). Each tube is 10–12.5 cm long, pursuing a tortuous course along the broad ligament's free border. Components of each fallopian tube are the intramural (interstitial or uterine segment), the lumen of which continues laterally, into the lumen of the isthmus, and medially into the uterine cavity. The isthmic portion continues laterally with the ampulla, which eventually terminates at the infundibulum with finger-like fimbriae [8–10].

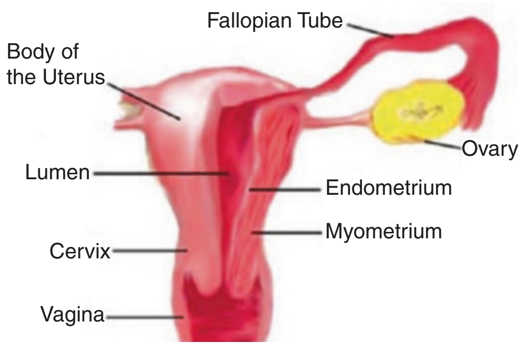
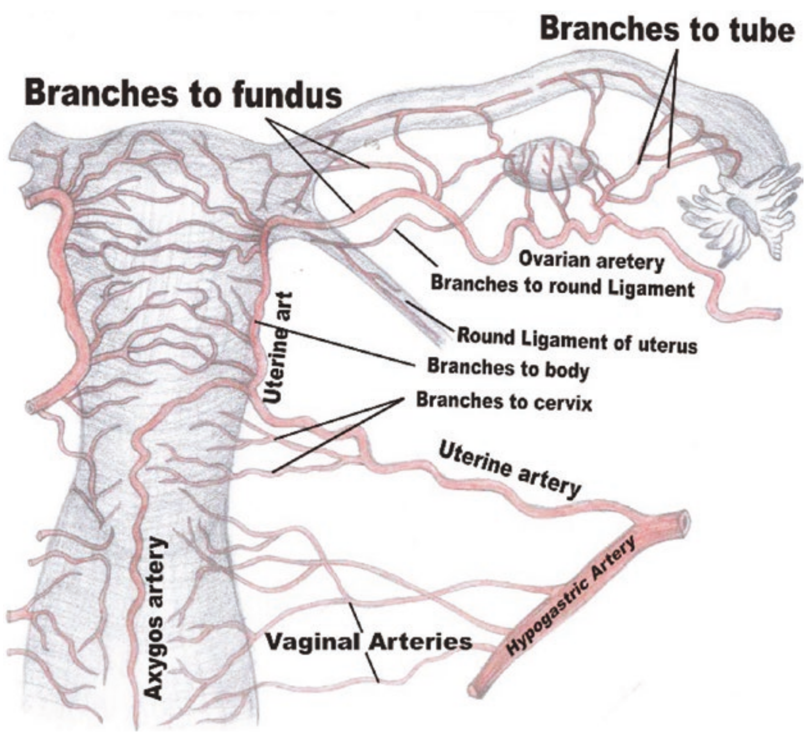



**Fig. 1** Anatomy of the fallopian tube. (Source: Internet. https://histologyblog.com/2013/07/13/histoquarterly-fallopian-tube/; Permission to reuse the image: https://commons.wikimedia.org/wiki/File:Uterine_anatomy.jpg)

Major blood supplies to the fallopian tubes are from the ovarian and uterine arteries (Fig. 2). Veins leaving the tubes enter the broad ligament parallel with the arteries and drain to the ovary's pampiniform plexus and the uterine veins. Lymphatic drainage is to the lateral aortic and pre-aortic nodes [8–10]. The isthmus drains into the superficial inguinal nodes. The fallopian tubes derive their nerve supply from both sympathetic and parasympathetic nerve fibres. The sympathetic fibres are derived from the hypogastric plexus. The parasympathetic fibres are arranged such that the lateral part of the tube gets its supply via the vagal fibres, while the medial part of the tube gets its supply via the pelvic splanchnic fibres. Afferent fibres enter the spinal

**Fig. 2** Blood supply of the fallopian tube



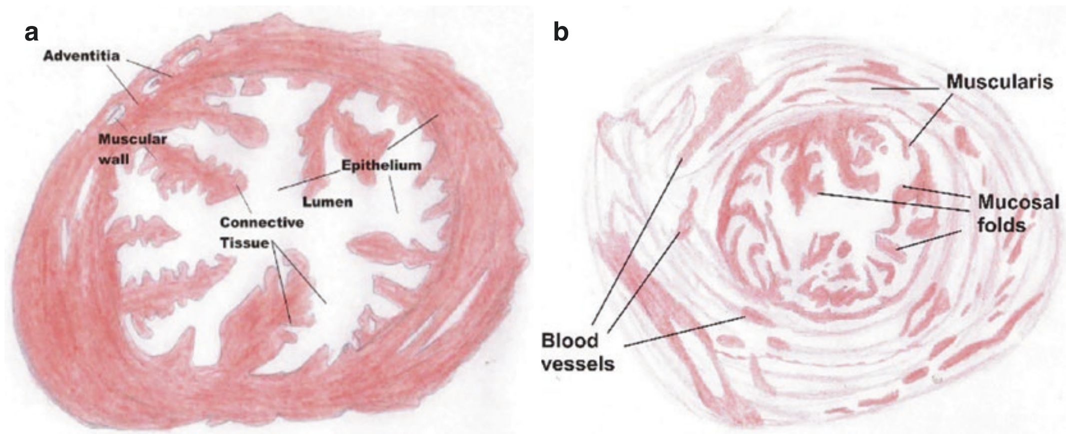



**Fig. 3** (**a**, **b**) Histology of the fallopian tube

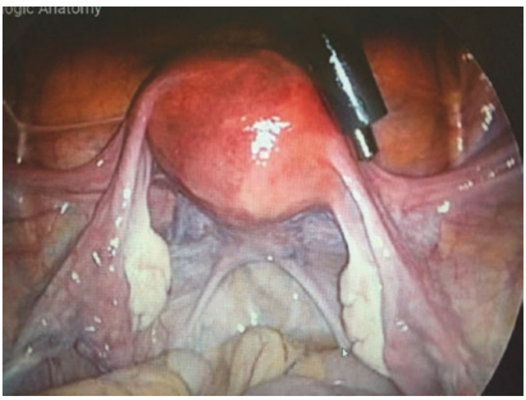


**Fig. 4** Laparoscopic overview of the pelvic anatomy

cord at the level of T11 to L2 dorsal nerve roots [8–10]. Each fallopian tube comprises the outer muscular coat consisting of an incomplete outer longitudinal layer and an inner circular layer (Fig. 3a, b).

The mucosal folds are covered by columnar epithelium, which bears two types of cells, the motile cilia-bearing cells predominantly towards the infundibulum and glandular secretory cells in the isthmus and intramural portion [8–10].

Laparoscopically, the fallopian tube is found slightly above and behind the round ligament and sometimes requires some uterine or round ligament manipulations to bring it into focus (Fig. 4). The fallopian tubes are found between the round ligaments anteriorly and the ovarian ligaments posteriorly, extend medially from the cornual end of the uterus on both sides and curve out laterally towards the pelvic sidewall running above the ovary and medial to the infundibulopelvic ligament and arch partially over the ovary with their fimbriated ends [7–10].

## 4 Types of Laparoscopic Tubal Surgery

These include bilateral tubal ligation and reversal of tubal ligation (tubo-tubal anastomosis, tubo-uterine anastomosis, ampullary salpingostomy or fimbrioplasty). Others are tubal blockage operations (fimbrioplasty, neosalpingostomy/salpingostomy, salpingectomy, laparoscopically guided hysteroscopic tubal recanalization) and operations for ectopic pregnancy (salpingectomy, salpingostomy, salpingotomy, fimbrial milking, cornuostomy, excision of the rudimentary horn, ovariectomy and hysteroscopic resection of cornual/interstitial ectopic pregnancy under laparoscopic guidance).

Generally, for most laparoscopic tubal surgeries, the patient is usually placed in a Lloyd-Davies position with one assistant between the legs of the patient and a 15°–20° head-down tilt to reflect bowels away from the pelvic cavity to enhance the visibility of the tubes as well as other pelvic organs and to reduce bowel injury. Various gynaecologists have adopted different positions such as the steep Trendelenburg, lithotomy and supine position with a slight head-down tilt for some. However, one should learn to adopt the position that gives the fallopian tubes the best exposure while performing any tubal surgery.

## 4.1 Laparoscopic Bilateral Tubal Ligation

Bilateral tubal ligation is performed when there is either desire for permanent contraception or to overcome the detrimental effect of hydrosalpinges on IVF pregnancy rates in patients who are not candidates for corrective tubal surgery. However, benefits have grown to include improved embryo quality following in vitro fertilization. The methods of tubal ligation are broadly divided into destructive methods (electrocautery, e.g. monopolar or bipolar coagulation; cutting, e.g. fimbriectomy, Pomeroy's procedure, or partial salpingectomy) and occlusive methods (Filshie, Falope, Hulka clips) [7, 9–12].

The bilateral tubal ligation procedure is usually performed under general anaesthesia (GA) and typically takes about 20–30 min. It is better performed after 6 weeks postpartum (interval ligation) on an outpatient basis because of the risks associated with immediate postpartum tubal ligation with the uterus approximately 20 weeks' size, making it prone to injury during insertion of Veress and laparoscopic trocar and cannula.

### 4.1.1 Contraindications

These include concerns about patient's decision for a permanent method of sterilization, pregnancy, other conditions requiring hysterectomy or bilateral salpingo-oophorectomy, morbid obesity, previous multiple abdominal surgeries with adhesion formation, immediate postpartum period, luteal phase of the menstrual cycle because of medico-legal reason where fertilization could have occurred, diaphragmatic hernia, severe heart or lung disease and any contraindication to laparoscopic surgery.

## 4.2 Laparoscopic Tubal Ligation Procedures

### 4.2.1 Procedures

Place the patient in a dorsal lithotomy position under GA. Insert the uterine manipulator and safely obtain laparoscopic access to the peritoneal cavity. Create pneumoperitoneum in the usual manner for better visibility and access to the pelvic organs. Inspect the abdomen and pelvis. Several techniques could be used: single port, double ports, single incision two ports, electrocautery or use of bands, rings and clips. Identify the whole length of the fallopian tubes and the round ligament. Insert accessory port(s) under vision as necessary for hand instruments, except when a single-port technique is being used. Carry out tubal ligation based on the techniques below:

(a) *Single-port technique*: This is usually indicated in tubal ligation using the Filshie clip or Falope ring with the aid of a Laprocator (Fig. 5).
(b) *Double-port technique*: This is performed using a primary 10-, 7- or 5-mm port and a secondary supra-pubic 7-mm port for the clip applicator.

**Fig. 5** Laprocator for single-port technique

(c) *Single-incision two-port technique*: This is performed with the aid of two 5-mm trocars inserted in a 10-mm supra- or infra-umbilical incision (Fig. 6) [12].
(d) *Unipolar electrocautery*: No longer recommended.
(e) *Bipolar electrocautery*: Grasp the entire width of the fallopian tube and gently lift it away from surrounding structures to avoid thermal injury. Use a coagulation waveform with a power of at least 25 W against a 100-V load to desiccate a 3-cm segment of the fallopian tube. The fallopian tube is grasped with bipolar forceps such as Rubin's/harmonic/Thunderbeat at the narrow isthmic end of the tube, and the forceps are activated to coagulate the tubal segment. The activation of the bipolar forceps should be intermittent, and the jaws slightly opened in between activation to avoid sticking together of the jaw of the bipolar forceps with the tube. Coagulation at about three points and division of the tube in between the coagulated area can also be done. Avoid desiccating the tube 2 cm closer to the uterine cornu to avoid utero-tubal fistula and thermal vascular injury to the ovaries. However, tubal recanalization risk is higher in single-point coagulation compared with excision of the tubal segment following three-point coagulation.
(f) *Falope ring*: The Falope ring is loaded into the ring applicator, which is introduced through the ring applicator aperture of the Laprocator (single-port technique) or through another 7-mm suprapubic port (Fig. 7a–c). The fallopian tube is located and grasped with the aid of the jaws of the Falope ring applicator. This step is carried out at the

**Fig. 6** Single-incision two-port laparoscopic tubal ligation. (Permission obtained from Asst. Professor Nicel Tasdemir (16 June 2020) [12])


**Fig. 7** (**a**) Extended tip Falope ring applicator loaded with one ring. (**b**) Loaded with one ring. (**c**) Loaded with two rings

narrow isthmic end of the tube, about 1–2 cm from the uterus' cornual end. The tube is drawn up into the applicator's cylinder, and the applicator is fully fired to apply either one or two silicon rings to the grasped segment of the fallopian tube. The grasped segment is released, and the same procedure is repeated on the contralateral side. Blanching of the tubal segment above the clip is an indication of total occlusion due to ischaemia.

(g) *Spring clip*: Manipulate the uterus to straighten out the fallopian tube (Figs. 8 and 9). Load the clip into the applicator externally and introduce it into the abdomen in a partially closed position. Carefully place the spring clip perpendicularly to the isthmic portion of the fallopian tube, ensuring that the clip's lower edge can be visualized in the mesosalpinx. Ensure that the clip is completely closed and locked in place.

(h) *Filshie clip or Hulka-Clemens clip*: The application is like that of the spring clip (Figs. 8 and 9). However, once the applicator's end is in the abdomen, release the pressure on the handle to open the clip before placing it perpendicularly to the fallopian tube at the narrow isthmic end. Blanching between the two clips is also an indication of total occlusion at this point.

(i) *Pomeroy's procedure (partial salpingectomy)*: In this method, two lateral 5-mm ports are required. Extracorporeal Roeder's knot is made with Vicryl suture externally and inserted through an accessory port to tie the base of a loop of fallopian tubes, or Endoloop is introduced for the same purpose. The loop is placed over the isthmic portion of the fallopian tube and gently pulled using a laparoscopic grasper to form a loop. The suture is navigated to the base of the loop and pulled to tighten the knot. Laparoscopic scissors are used to cut the suture and the looped portion of the fallopian tube. At least a minimum of a 1-cm segment of the fallopian tube is removed to reduce the failure rate (Fig. 9).

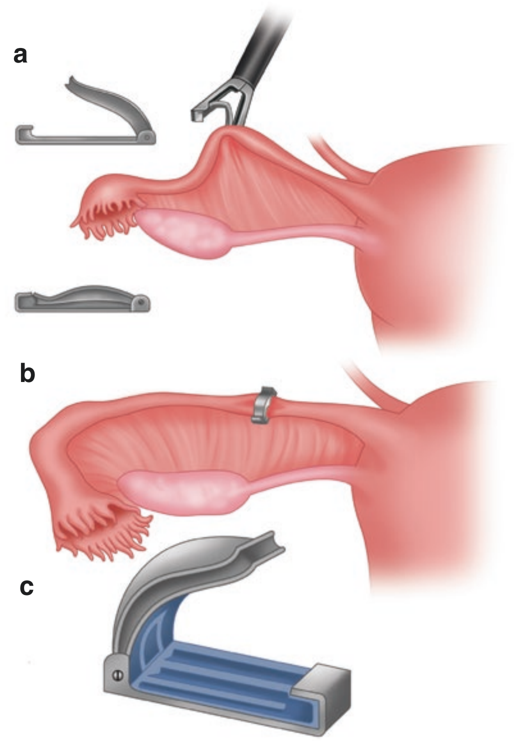


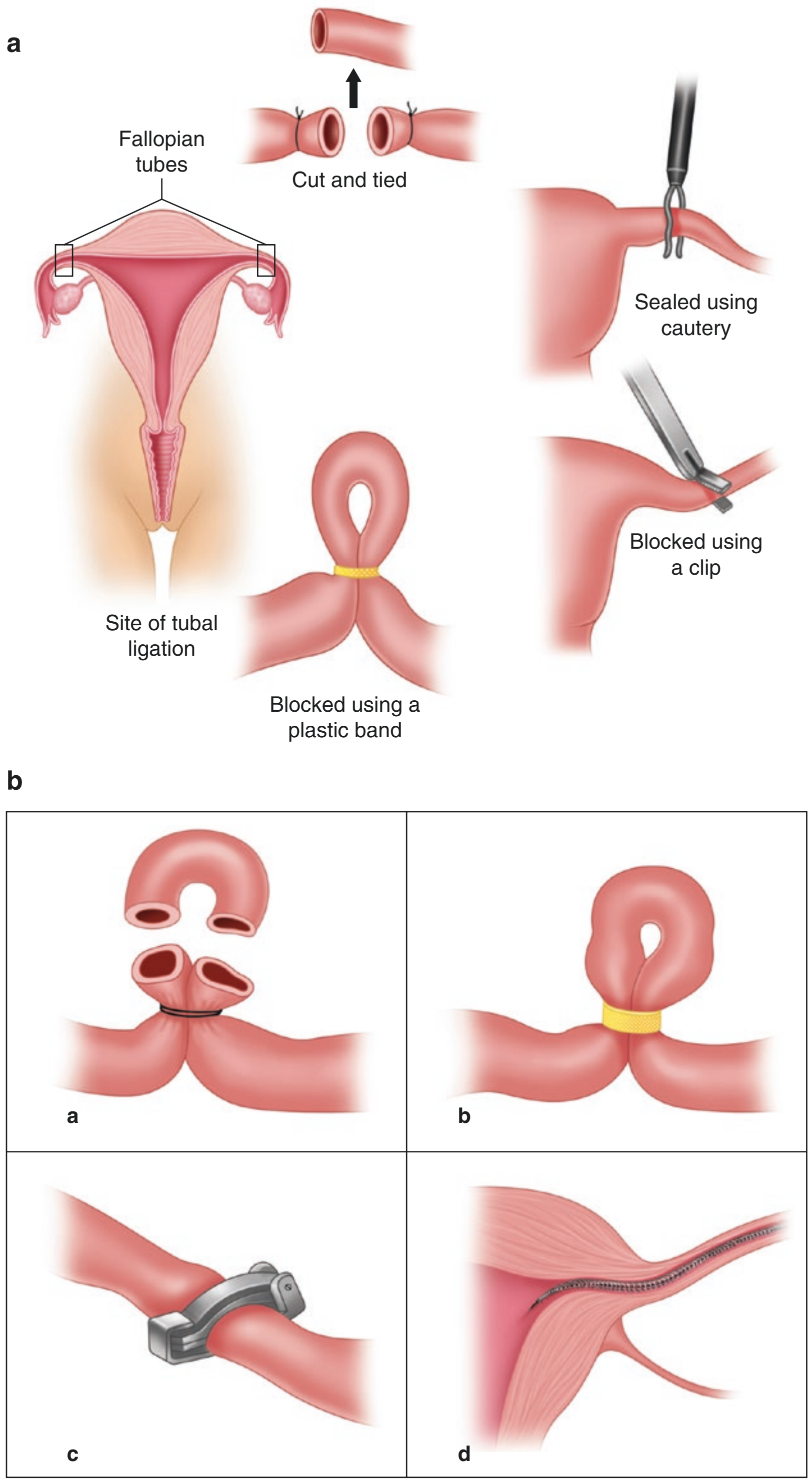

**Fig. 8** (**a**–**c**) Images showing stepwise laparoscopic clip application using Hulka-Clemens clip

The same procedure is repeated on the contralateral tube. Haemostasis is ensured, and the accessory ports and uterine manipulator are removed under vision. The primary port is also removed, and the wound is closed appropriately.

### 4.2.2 Complications

Apart from complications related to laparoscopy, others include ligation of the round ligament instead of the fallopian tube, thermal injury, failure, regret, clip or ring complication, ectopic pregnancy, tubo-peritoneal fistula, menstrual irregularities, conversion to laparotomy, hysterectomy and mortality.

**Fig. 9** (**a**, **b**) Overview of all occlusive and destructive methods



## 5 Laparoscopic Tubal Ligation Reversal

This procedure is also called tubal re-anastomosis or recanalization. Tubal ligation is meant to be a permanent procedure to achieve sterilization in a woman, but certain circumstances may cause women to regret their decision and ask for a reversal of the procedure. These include events such as the death of a child, divorce, death of spouse or remarriage and desire for sons. Regret is also more in immediate postpartum sterilization, where the decision for tubal sterilization may have been made in haste, without really considering the implications. Among those who express regret after sterilization, 14.3–30% have been reported to ask for tubal reversal, with only 1.1% eventually operated [2, 13–16].

The main risk following a tubal ligation reversal procedure is the possibility of an ectopic pregnancy, rising to 6.7% [2, 13–16]. Pregnancy rates following tubal ligation reversal after sterilization are usually quite good and better than tubal surgery (salpingostomy/fimbrioplasty) for occlusive distal tubal disease from pelvic infection and endometriosis [2, 13–16]. However, the success of ligation reversal or chances of pregnancy afterward will depend on certain factors (Table 1).

Macro-surgical tubal repair technique has become obsolete as most tubal recanalization operations are performed with the aid of magnification (operating microscopes or loupes), which ensures accurate apposition of anatomic layers.

**Table 1** Showing the determining factors for successful tubal reversal

| Factor | Best success | Worst success |
|---|---|---|
| Women's age | <35yo | >35yo |
| Type of tubal ligation | Clip, band | Tie, cut, burn |
| Years since tubal ligation | <10 years | >10 years |
| Final tube length | >6 cm | <6 cm |
| Fimbria | Healthy | Diseased |
| Ovulation | Normal | Subnormal |
| Semen analysis | Normal | Subnormal |
| Weight | <175 lb | >175 lb |
| Pelvic adhesions | Absent | Present |

Source: https://www.fertilitymemphis.com/fertility-treatments/tubal-ligation-reversal/

The use of fine sutures (6-0, 4-0), gentle handling of tissues and good haemostasis produced impressive outcomes in post-surgery pregnancy rates. Laparoscopy has, however, created an improvement over macro-surgical techniques by virtue of the magnification it affords, enabling the use of microsurgical instruments with fine, non-reactive sutures, making its outcome like that of microsurgical technique [2, 11, 13–16].

Laparoscopic tubal sterilization reversal is usually performed under general anaesthesia. Benefits include shorter operation hours, few hours of hospital stay, quicker recovery, less tissue damage and bleeding. It requires laparoscopic surgeons specially trained in the procedure [2, 11, 13–16].

### 5.1 Procedure

Laparoscopic tubal anastomosis applies the conventional microsurgery principle used in laparotomy. Under GA, diagnostic hysteroscopy is performed to exclude any intrauterine pathology, and a uterine manipulator with space for dye test is then placed. Pneumoperitoneum is created in the usual manner, and the primary port is placed. The procedure requires a minimum of three accessory ports for effective and gentle tissue manipulation. A manipulating probe or suction-irrigation is used to position the tube and apply traction. A laparoscopic Babcock's clamp can also be used, but this can tear the mesosalpinx and lacerate vessels. The fimbrial end should be avoided as much as possible because it is very vascular and can bleed with little provocation.

If desired, an injection of 2–5 mL of dilute vasopressin (5 mL diluted with 20 mL of normal saline, 1 in 10,000 dilutions) is instilled in the mesosalpinx to reduce bleeding and raise a weal that helps to define tissue plains easily. Examine the obstruction area (ligation, burn, ring or clip) and remove the occlusion. Excise the proximal and distal segment of the fallopian tubes perpendicularly 0.5–2 cm away from the ligated scar to remove the fibrosed and damaged portion of the tube depending on the method of occlusion with the aid of sharp fine laparoscopic scissors or uni-

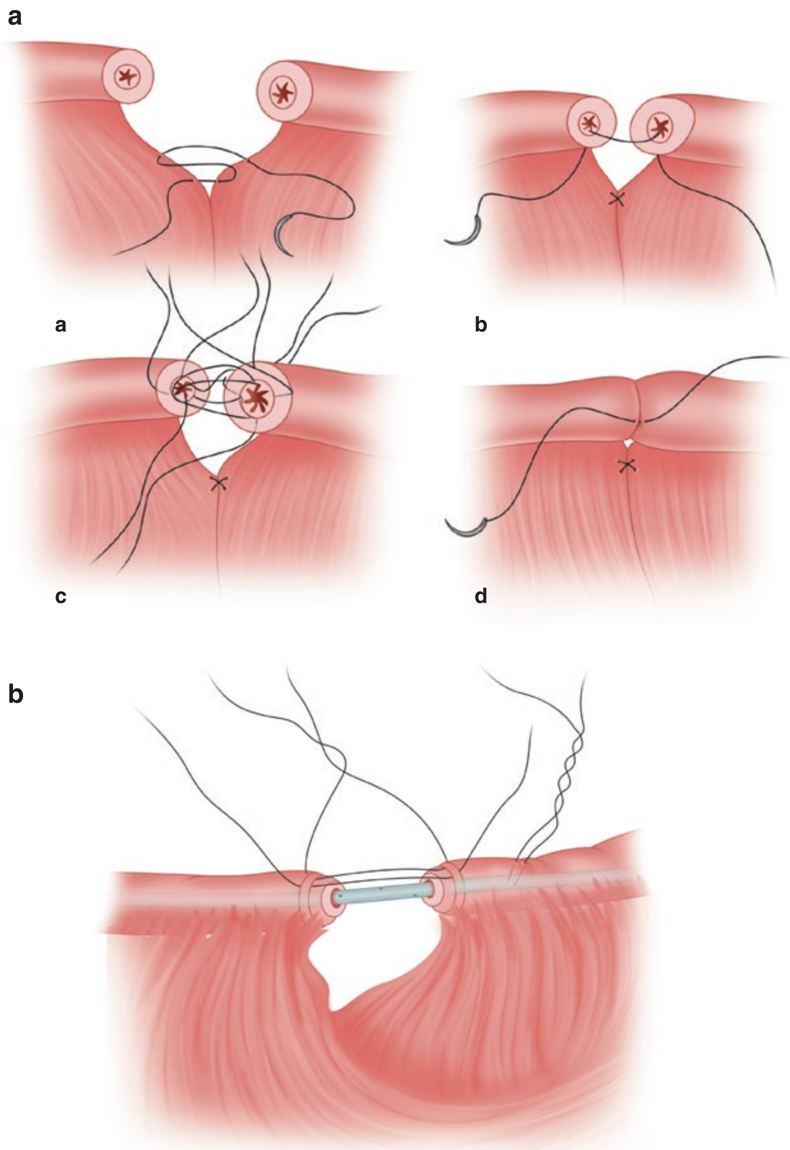



**Fig. 10** (**a**, **b**) Tubal re-anastomosis as described by Sotrel G [2]

polar ovarian drilling needle in cut mode at 10 W which can also be used to maintain haemostasis. The tubal lumen is identified on both ends. Hysteroscopically guided backward catheterization of the proximal tubal stump and intubation of the prepared distal stump with a Teflon catheter (Cook, Charenton, France) of 1-mm diameter may be performed. The mesosalpinx is approximated using a 6-0 or 4-0 absorbable suture. This helps to reduce the traction on the two ends of the tube during the repair. There are different techniques, but the most preferred is the 'four-stitch technique'. Sutures are placed on the muscular layer, and the inner mucosal layer is avoided. Re-anastomosis of the tubal ends starts at 6 o'clock using the same fine absorbable suture following outer to inner and inner to outer directions, to place the knots outside the lumen and approximate the two ends with the mucosa well. Four throws are made, and the same steps are performed at positions 3 o'clock, 9 o'clock and 12 o'clock, respectively. Methylene blue dye is injected to confirm tubal patency and ensure no leakage at the anastomosis site. A tubal splint or glue may be applied to the site if necessary (Fig. 10a, b).

## 5.2 Types of Tubal Reversal or Anastomosis

(a) Tubo-tubal anastomosis

Tubal ends are joined as described above (Fig. 10).

(b) Tubo-uterine implantation

This procedure is performed when there is a desire for fertility following Essure or Adiana methods of sterilization or complication of uteroperitoneal fistula following tubal sterilization. The intrauterine part of the tube, the scarred portion of the uterus and the blocked tubal ends must be removed (Fig. 11). The healthy portion of the tube is then implanted into a newly created opening in the uterus using the technique described above.

(c) Ampullary salpingostomy (fimbrioplasty)

This operation is necessary when the fimbrial portion of the tubes has been removed during tubal sterilization. Reversal involves opening the tubal end and folding the inner lining outwards and fixing it with fine sutures or coagulation so that it does not close back again.

### 5.2.1 Procedure

The four-port technique is used for this procedure. Under GA, pneumoperitoneum is created in the usual manner, and a diagnostic laparoscopy is done, most especially to identify adhesions between the fallopian tubes, ovaries and uterus. A uterine manipulator helps manipulate the uterus, giving traction, affording a good view of the fallopian tube.

Adhesiolysis between the fallopian tube, ovary and round ligament is done to free the fallopian tube. Care must be taken not to de-vascularize the ovary, and the use of a low-energy source is preferable. A dye test is done with a methylene blue solution instilled through the uterine manipulator. The dye helps to distend the blocked end of the fallopian tube, clearly highlighting the hydrosal-

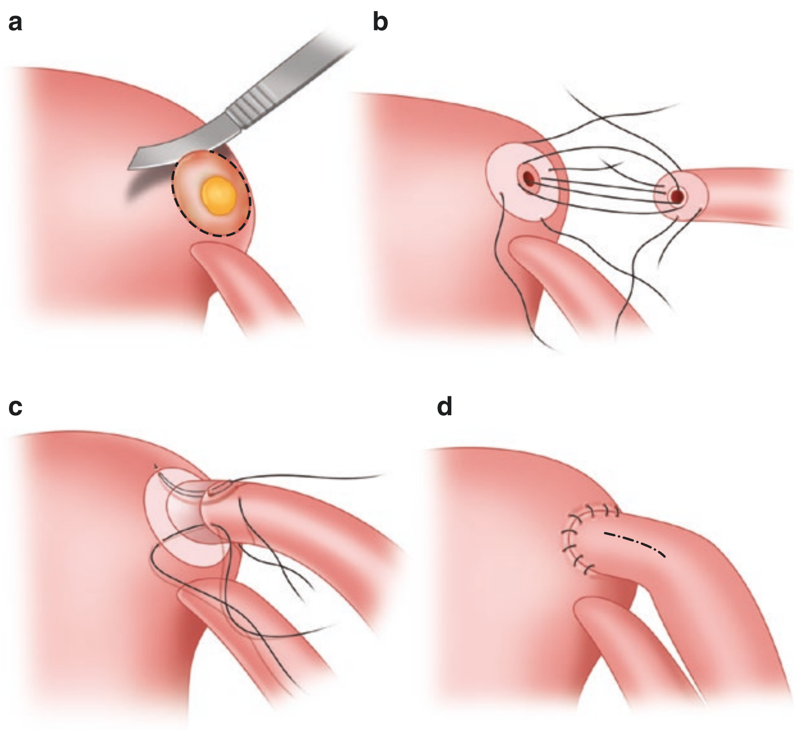



**Fig. 11** Tubo-cornual anastomosis **a** to **d**. or tubo-uterine anastomosis as described by Sotrel G

pinx. Simple fimbrial de-agglutination can be done by gently picking the fimbrial end of the fallopian tube and probing it with a pointed grasper to achieve tubal patency. When the fimbrial end is completely occluded, a cruciate incision is made on the tube's blocked end using monopolar electrocautery on a low setting at 10 watts cut mode. The scarred tissue is transected till dye spillage is observed from the fallopian tube.

A 6-0 or 4-0 absorbable suture is used to suture the opened end of the fallopian tube back to the serosa of the fallopian tube in such a manner as to free the fimbriae and keep the fallopian tubes patent. Tubal patency is confirmed by spillage of methylene blue dye instilled again into the uterine cavity.

## 6 Tubal Blockage Operations

These are the types of operations performed when the fallopian tube is blocked. The surgery scope depends on whether the blockage affects the proximal, middle or distal segment of the tube and the severity of the tubal disease (PID, post-surgical adhesions or endometriosis) causing tubal blockage [2, 11, 13–16].

(a) Fimbrioplasty
(b) Neosalpingostomy/salpingostomy
(c) Salpingectomy
(d) Laparoscopically guided hysteroscopic tubal recanalization

### 6.1 Fimbrioplasty

The aim is to create an opening into the fallopian tube by repairing the damaged fimbria end. These could range from simple adhesiolysis and de-agglutination of fimbria fringes to salpingostomy, for severe lesions extending to the tubal serosa (Figs. 12 and 13).

Meticulous haemostasis is essential if this procedure is to succeed. Care must be exercised not to jeopardize the fallopian tube's vascularity by excessive dissection of the mesosalpinx from the ovary. Also, irrigation, suction and needle-point electrocautery should be used to control haemostasis rather than sponging, clamping and tying off bleeding blood vessels.

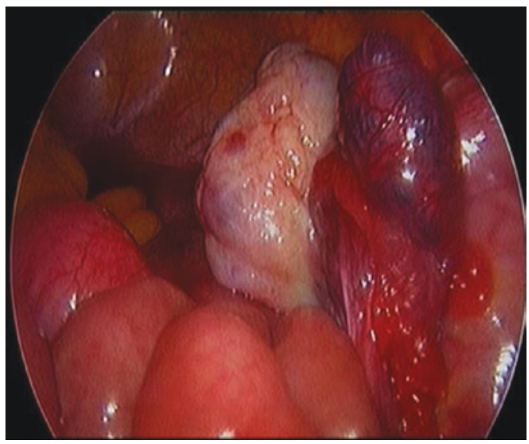


**Fig. 12** Hydrosalpinx on the right fallopian tube because of fimbrial agglutination. (Source: Authors)

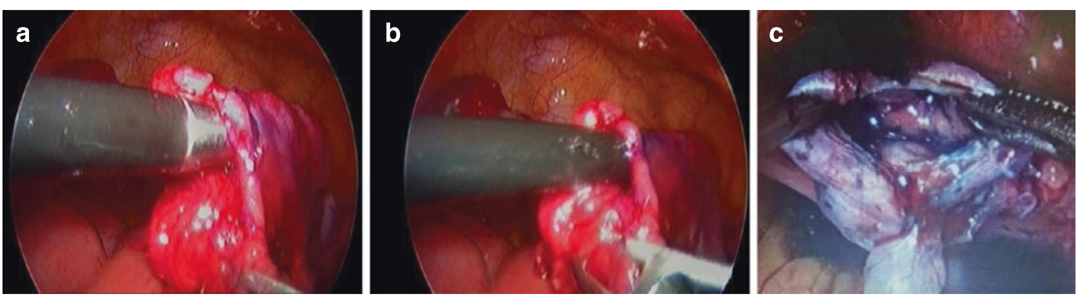


**Fig. 13** (**a**–**c**) Fimbrioplasty showing the opened end of the fallopian tube and dye spillage to confirm tubal patency. (Source: Authors)

#### 6.1.1 Procedure Is As Described Above

The intrauterine pregnancy rate following fimbrioplasty has been as low as 26.1% and as high as 51.4%, with the take-home baby rate of 37.1% (considering only the first pregnancy) and ectopic pregnancy rate of 22.9% [2, 17, 18]. With the advent of IVF in the 1980s, surgical repair of severe distal tubal occlusion with hydrosalpinx and waiting for spontaneous conception has become obsolete, giving way to bilateral proximal occlusion or salpingectomy followed by IVF procedure. Laparoscopic repair via fimbriolysis and fimbrioplasty are acceptable alternatives for the non-occlusive distal tubal disease.

Studies have shown that the laparoscopic approach provides results similar to those obtained by microsurgery to treat mild to moderate fimbrial occlusions with normal endosalpinx and represents an acceptable alternative to in vitro fertilization (IVF) in selected cases [2, 17, 18].

### 6.2 Neosalpingostomy/Salpingostomy

Salpingostomy is the creation of a new opening in an occluded distal fallopian tube (hydrosalpinx). The term neosalpingostomy, salpingostomy and fimbrioplasty are sometimes used interchangeably (Fig. 14). The new opening can be at the fimbria end of the fallopian tube (fimbrioplasty) or the ampullary or isthmic portions of the tube. The purpose of fimbrioplasty is to open the obstructed fallopian tube and help the fimbria retain its function of oocyte transport; hence, it is performed in patients whose fallopian tubes are patent up to the fimbria end. Ampullary and isthmic neosalpingostomy, however, have little clinical significance because the likelihood of pregnancy with limited tubal length (less than 6 cm) is extremely low [2, 11, 13–18].

Since the advent of assisted conception, the practice of tubal surgery in women with hydrosal-

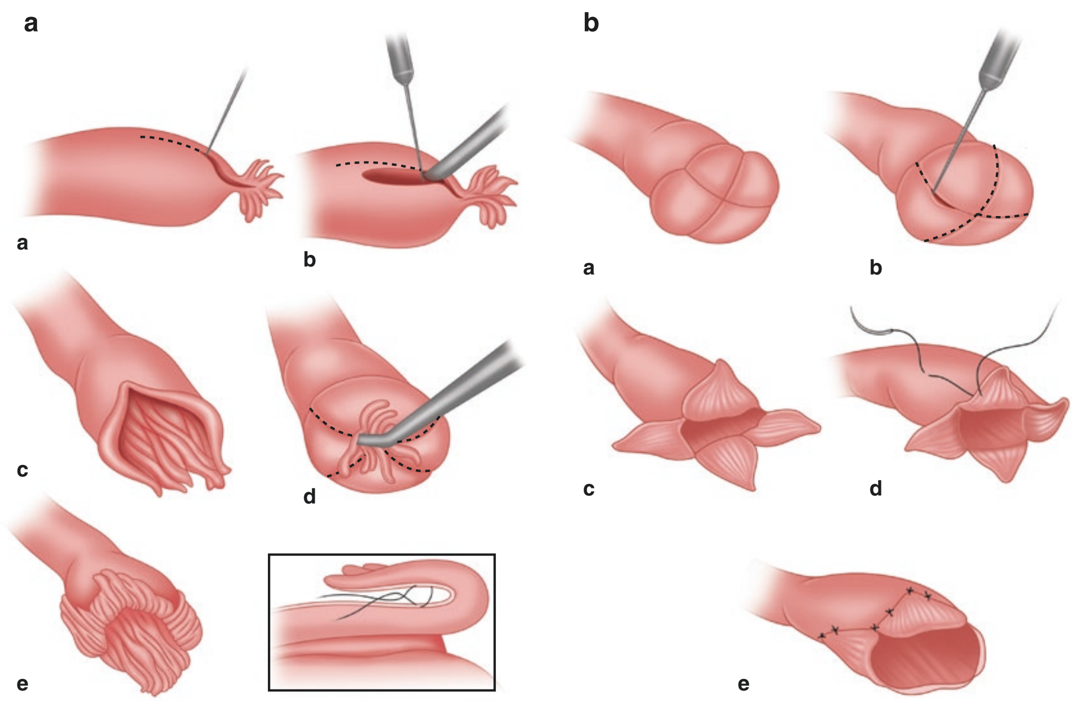



**Fig. 14** (**a**, **b**) Showing fimbrioplasty and neosalpingostomy as described by Soltrel G

**Table 2** Natural pregnancy rates after salpingostomy treatment for hydrosalpinx by date of publication

| | Clinical pregnancy | Patients undergoing salpingostomy |
|---|---|---|
| *Studies published pre-2000* | | |
| Audebert AJM—1980 | 29 | 96 |
| Beyth Y—1982 | 5 | 31 |
| Boer-Meisel ME—1986 | 31 | 108 |
| Chong AP—1991 | 9 | 34 |
| Cohen J—1992 | 89 | 467 |
| Dubuisson JB—1995 | 34 | 123 |
| Dubuisson JB—1994 | 26 | 81 |
| Jansen RPS—1980 | 24 | 107 |
| Kosasa TS—1988 | 37 | 93 |
| Mage G—1983 | 18 | 68 |
| Singhal V—1991 | 33 | 97 |
| Smalldridge J—1993 | 9 | 30 |
| Teoh TG—1995 | 20 | 96 |
| Tulandi T—1984 | 24 | 91 |
| Winston RML—1991 | 106 | 323 |
| **Subtotal ($t^2 = 47.9\%$, $P = 0.020$)** | | |
| *Studies published post-2000* | | |
| Audebert AJM—2014 | 125 | 434 |
| Bayrak A—2006 | 2 | 40 |
| Bontis JN—2000 | 44 | 258 |
| Chanelles O—2011 | 3 | 10 |
| McComb P—2011 | 10 | 23 |
| Milingos SD—2000 | 14 | 61 |
| Taylor RC—2001 | 34 | 139 |
| **Subtotal ($t^2 = 65.5\%$, $P = 0.008$)** | | |

Source: Chu et al., Salpingostomy in the treatment of hydrosalpinx: a systematic review and meta-analysis [19]

pinges has been in the background. The current systematic review and meta-analysis of 22 observational studies with 2810 patients undergoing salpingostomy for hydrosalpinges and attempting natural conception; showed a clinical pregnancy rate of 27%, a live birth rate of 25% and a 10% risk of ectopic pregnancy. The clinical pregnancy rates are not dramatically different pre- and post-2000 when a shift from open microscopic and laparotomy for treating tubal disease to laparoscopic surgeries occurred (Table 2). Case selection, the surgeon's expertise and diverse surgical techniques are some of the factors that may be responsible. The cumulative pregnancy rate reached 25.5% and 26.3% at 24 and 36 months, respectively (Fig. 15). These findings suggested a plateau of the clinical pregnancy rate at 24 months post-operation. Therefore, it is wise to move on to an artificial reproductive technique after 24 months of waiting to conceive [19]. However, in a recent Cochrane review aimed to determine the effectiveness and safety of surgery compared with expectant management or IVF in improving the probability of live birth in the context of tubal infertility, the authors concluded that the effectiveness of tubal surgery relative to expectant management and IVF in terms of live birth rates for women with tubal infertility remains unknown [20].

### 6.2.1 Procedure

This operation requires a minimum of three ports. Under GA, with save peritoneal entry and pneumoperitoneum created in the usual manner, a diagnostic laparoscopy is done to identify all pelvic and peri-adnexal adhesions. Adhesiolysis is done to free any adhesions between the ovary and the fallopian tube to ensure that the new opening will be appropriately located at the most distal portion of the tube.

With the aid of a suction-irrigation and grasping forceps, the distal portion of the tube is manipulated into position. Fluid distension of the tube is achieved using transcervical chromoper-

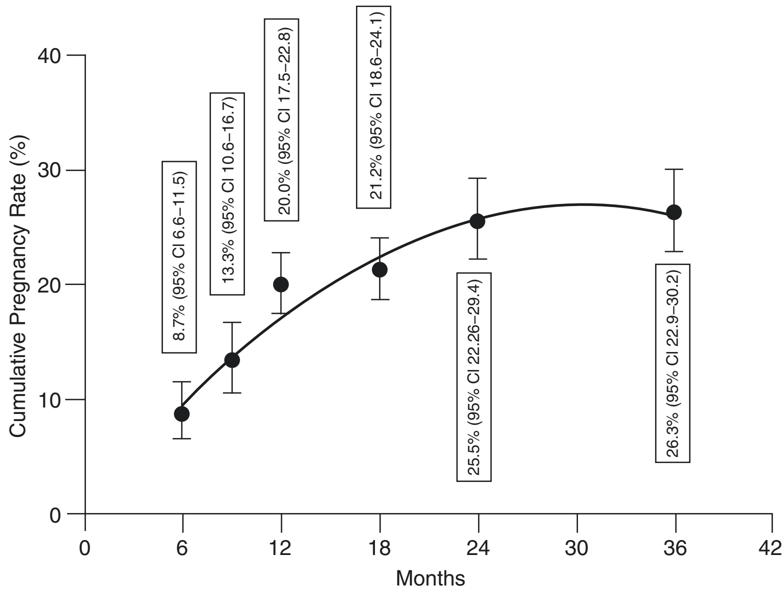



**Fig. 15** Cumulative natural pregnancy rates after salpingostomy treatment for hydrosalpinx. (Source: Chu et al., Salpingostomy in the treatment of hydrosalpinx: a systematic review and meta-analysis [19])

tubation, which allows the identification of the avascular central point. A cruciate incision is then made using scissors or monopolar electrocautery on a low setting at 10 W in cut mode.

Neosalpingostomy is performed by opening the distended end of the tube and then grasping the endosalpinx with an atraumatic grasping forceps, pulling it out and back over the tube like a sleeve. The defocused laser may be used to avert the edges further. The condition of the tubal mucosa can be evaluated by salpingoscopy.

In this manner, the new opening forms a new fimbria-ovary relationship. Bleeding is controlled with careful desiccation using a microelectrode. Once a reasonably sized stoma is attained, the flaps created in the process are secured by desiccating their serosal surface or suturing the edges to the serosa's surface using 6-0 or 4-0 absorbable suture, which allows them to fold back upon themselves. Tubal patency can be confirmed by dye spillage after instilling methylene blue dye. Thorough irrigation of the peritoneal cavity with complete removal of foreign body, blood and debris reduces the risk of adhesion formation.

### 6.2.2 Contraindications

- Advanced maternal age
- A failed attempt at conception following previous tubal surgery

In cases where neosalpingostomy is contraindicated, IVF is the better treatment option.

### 6.2.3 Prognosis

In a retrospective study of 434 infertile women who underwent laparoscopic salpingostomy, Audebert et al. [17] found evidence that the procedure should not be utilized in certain patients, based on factors such as tubal or adhesion stage (Table 3) and chlamydial serology. The investigators, who measured outcomes in terms of intrauterine pregnancy, delivery and ectopic pregnancy rates (as achieved without IVF), reported poor prognosis patterns in association with the following:

- Severe tubal adhesions stage 3 and above
- Previous ectopic pregnancy
- Repeated salpingostomy
- Positive chlamydial serology test

The cause of the tubal disease is considered when determining successful surgery prognosis (Tables 4 and 5). The location, type and degree of tubal injury impact the chance of surgical success. The presence of tubal rugae on HSG, the absence of or presence of small hydrosalpinges (<15 mm in diameter), the absence of significant pelvic adhesions and the presence of fimbriae

**Table 3** 'H and R' classification of severity of tubal damage

| Class | Name | Description |
|---|---|---|
| 1 | Minor/grade I | Tubal fibrosis absent even if tube occluded (proximally)<br>Tubal distension absent even if tube occluded (distally)<br>Mucosal appearances favourable<br>Adhesions (peritubal-ovarian) are flimsy |
| 2 | Intermediate or moderate/grade II | Unilateral severe tubal damage with or without contralateral minor disease<br>'Limited' dense adhesions of tubes and/or ovaries |
| 3 | Severe/grade III | Bilateral tubal damage<br>Tubal fibrosis<br>Extensive tubal distension >1.5 cm<br>Abnormal mucosal appearance<br>Bipolar occlusion<br>'Extensive' dense adhesions |

Author(s): Rutherford, Anthony J; Jenkins, Julian M
Source: Human fertility (Cambridge, England); Feb 2002; vol. 5 (no. 1), publication date: Feb 2002 [21]

**Table 4** Pregnancy rates following tubal surgery

| Procedure | *N* | IUP (%) | EP (%) |
|---|---|---|---|
| Tubo-cornual anastomosis | 626 | 57 | 5 |
| Mid segment re-anastomosis | 3112 | 79 | 4.8 |
| *Distal occlusion* | | | |
| Adhesiolysis | 752 | 52 | 5.7 |
| Fimbrioplasty | 340 | 47 | 3.5 |
| Neosalpingostomy | 1728 | 26 | 8.3 |

*EP* ectopic pregnancy, *IUP* intrauterine pregnancy
Source: Sotrel G. Is Surgical Repair of the Fallopian Tubes Ever Appropriate? Rev Obstet & Gynecol. 2009;2(3):176–185 [2]

during laparoscopy are all associated with a good prognosis following tubal reconstructive surgery [2, 17–20].

## 6.3 Salpingectomy

This operation entails removing the fallopian tube when there is severe destruction of the fallopian tube with hydrosalpinx or pyosalpinx, especially when the patient requires an IVF procedure.

### 6.3.1 Procedure

Procedure is as described below under tubal ectopic pregnancy.

**Table 5** Monthly fecundability and cumulative pregnancy rates following tubal microsurgery

| Treatment | Monthly fecundity *f* (%) | Cumulative pregnancy rate *F* (%) |
|---|---|---|
| Tubo-cornual anastomosis | 7 | 57 |
| Midsegment re-anastomosis | 12 | 79 |
| *Distal occlusion* | | |
| Adhesiolysis | 6 | 52 |
| Fimbrioplasty | 5 | 47 |
| Neosalpingostomy | 2.5 | 26 |
| IVF (three cycles, all stages) | 35 | 72 |

*IVF* in vitro fertilization
Postsurgical cumulative pregnancy rates assume that all the pregnancies occurred in a year
Calculations are based on the formula $F = 1 - (1 - f)n$, where $n$ is the number of months of exposure
Source: Sotrel G. Is Surgical Repair of the Fallopian Tubes Ever Appropriate? Rev Obstet & Gynecol. 2009;2(3):176–185 [2]

## 6.4 Laparoscopically Guided Hysteroscopic Tubal Recanalization

Tubal diseases could be intrinsic (as seen in chlamydia infection or salpingitis isthmica nodosa) or extrinsic (from previous pelvic surgery, endometriosis). Intrinsic tubal pathologies are usually

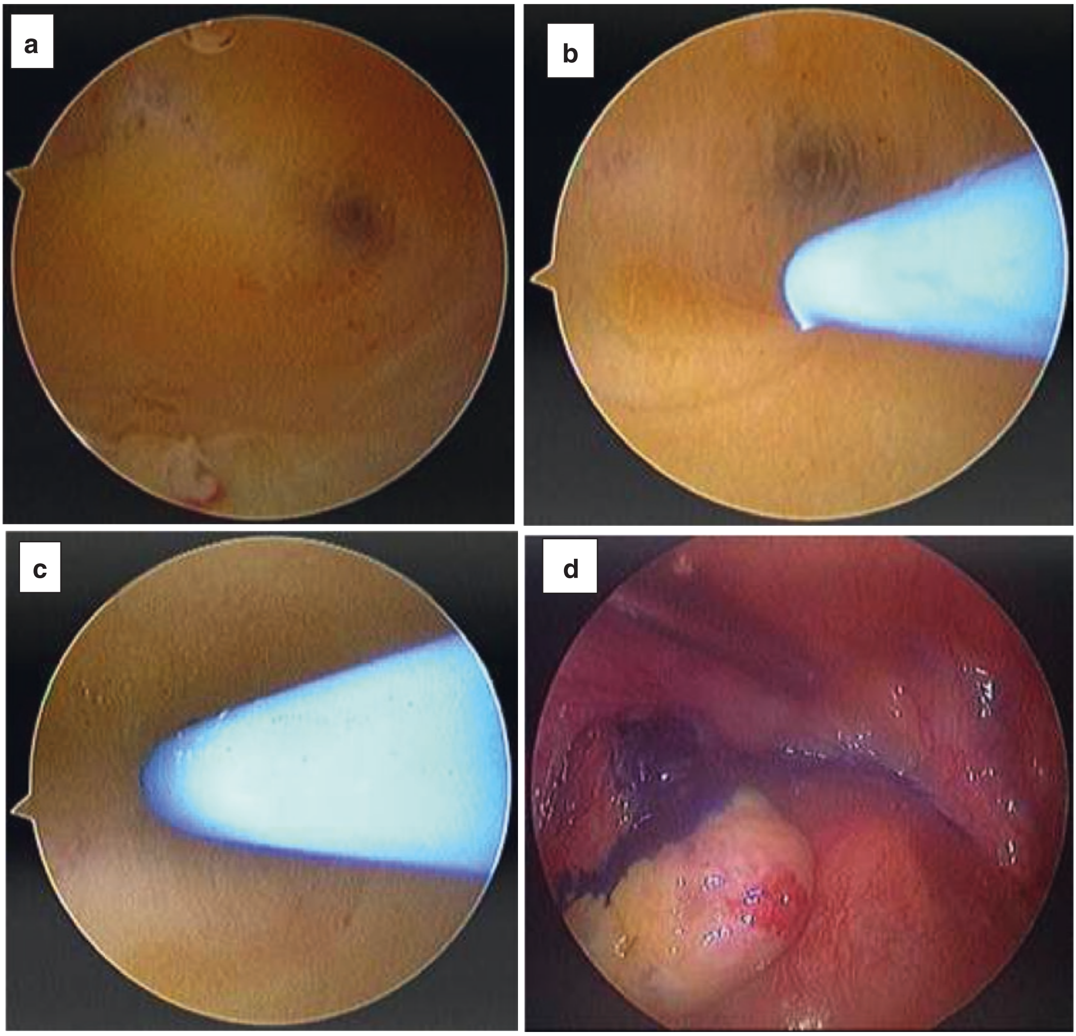



**Fig. 16** (**a**) Hysteroscopic view showing the tubal catheter and the guide wire in situ. (**b**) Laparoscopic view following hysteroscopic tubal cannulation to confirm tubal patency

more challenging to treat. However, hysteroscopic cannulation has opened a gateway to the resolution of some intrinsic tubal pathology. Hysteroscopic tubal recanalization is indicated in proximal tubal obstruction (Fig. 16). The addition of laparoscopic guidance in hysteroscopic tubal cannulation further helps assess tubal patency following dye test, while other pelvic, peritoneal and tubal pathologies that can affect tubal patency are also assessed and treated [22, 23].

This procedure is rarely performed in Nigeria, despite being undertaken for many years in the Western world, with varying results. It may be because few laparoscopic gynaecologists are familiar with the procedure or take an interest in tubal surgery. Hysteroscopic cannulation of the fallopian tube is a safe diagnostic procedure used to identify those patients with true proximal occlusion and may also serve as a therapeutic procedure in some of them [22, 23].

The procedure is usually done as a day case and preceded by an HSG and laparoscopy and dye test to confirm proximal tubal blockage.

### 6.4.1 Procedure

With the patient in a lithotomy position under GA, an operative hysteroscope is introduced into the uterine cavity with normal saline as a distending medium and the tubal ostium identified. A tubal cannulation catheter consisting of a 50-cm-long 3-FR Teflon catheter or flexible guide cannula and a steel or hydrophilic guidewire of 0.018 mm in diameter is introduced via the operating hysteroscope channel into the ostium to enter the cornual segment to about 1 cm. Once the cornual segment is cannulated, withdraw the guidewire, and inject diluted methylene blue dye directly through the catheter or cannula. The recanalization success is assessed with the dye's evidence of spillage into the peritoneal cavity on laparoscopy. Laparoscopy was used to monitor the procedure and assess the success of tubal recanalization.

#### 6.4.2 Contraindications

Conditions causing extensive scarring of the fallopian tube, salpingitis isthmica nodosa, tuberculosis, previous tubal surgery, distal tubal blockage or severe blockage that is difficult for a catheter to pass through.

#### 6.4.3 Complications

Uterine perforation (3–11%), bleeding, infection, organ damage and anaesthetic complication.

Studies have shown that successful tubal cannulation led to significant improvement in the pregnancy rate, which suggests that women with a proximal tubal block could be considered for laparoscopy-guided hysteroscopic cannulation, which is still a viable alternative to in vitro fertilization. In a preliminary study in Nigeria by Ikechebelu et al., the successful tubal recanalization rate was 90.2% per tube and 88.9% per patient with a conception rate of 33.3% [22].

## 7 Advances in Laparoscopy Tubal Surgery

### 7.1 Robotic Tubal Recanalization

Robotic tubal sterilization reversal uses a combination of high-definition 3D magnification, robotic technology and miniature instruments to enhance a reproductive surgeon's skills when reconstructing a woman's fallopian tube.

Advantages of robotic tubal cannulation include the following:

(a) Enhanced visualisation, precision and dexterity while delicately reconstructing the fallopian tube.
(b) Reduction in the surgeon's fatigue during the procedure.
(c) Enables steady, smooth and effortless movements.
(d) Others include less blood loss, less post-surgical pain, scarring and quicker recovery to normal activities.

## 8 Laparoscopic Management of Ectopic Pregnancy (Conservative and Radical, Prognosis and Complications)

### 8.1 Introduction

Ectopic pregnancy is an early pregnancy complication defined by implantation of the fertilized embryo outside the endometrial cavity [24, 25]. The incidence of ectopic pregnancy varies across the globe. It is associated with significant morbidity and mortality, especially in resource-poor settings where most of the patients present late with ruptured ectopic gestation. Worldwide, cases are being diagnosed early with high-resolution ultrasound and sensitive biochemical tests incorporated into diagnostic algorithms. Salpingectomy via laparotomy has been the main treatment for ectopic pregnancy by the early twentieth century [24, 25]. Medical therapy evolved by the 1980s and 1990s. Treatment modality is shifting towards minimally invasive surgeries since 1973 that Shapiro and Alder described the use of laparoscopy for ectopic pregnancy, but laparotomy and salpingectomy are still the main treatment options in most developing countries [24, 25].

Transvaginal sonography is the diagnostic tool of choice with several criteria for identifying ectopic pregnancy. Supplementation with magnetic resonance imaging (MRI) can be helpful in some cases where the facility exits, and diagnosis is difficult. Serum β-hCG and progesterone are adjunct in diagnosis. Laparoscopy has a dual purpose of both diagnostic and therapeutic functions [24, 25].

Sites of ectopic pregnancy includes the ampulla (78%), isthmus (12%), fimbria (5%), ovary (4%), cornua (2%), caesarean section scar (1%), cervix (1%) and abdomen (<1%) [23–33]. Contraindications to laparoscopic salpingectomy/salpingotomy/salpingostomy include all contraindications to laparoscopy, the surgeon's insufficient experience, massive intraperitoneal bleeding and severe pelvic adhesions making it difficult to access the pelvis.

Treatment options depend on the site of ectopic pregnancy, the surgeon's experience and the facilities available. Except when there is a massive intraperitoneal haemorrhage with haemodynamic instability, the laparoscopic approach is supported [24–34].

## 8.2 Evidence-Based Treatment Approach

### 8.2.1 Tubal (Ampullary/Infundibulum/Isthmic)

(a) A laparoscopic surgical approach is preferable to an open approach—Grade A evidence.
(b) When there is a healthy contralateral tube, laparoscopic salpingectomy is preferred over salpingotomy—Grade B evidence.
(c) Laparoscopic salpingostomy is done when there is a history of fertility-reducing factors—Grade C evidence:

- Risk of persistent trophoblast
- Need for serum β-hCG follow-up
- Small risk of further treatment with methotrexate/salpingectomy

### 8.2.2 Cornual/Interstitial Pregnancy

(a) Laparoscopic excision of the rudimentary horn—Grade D evidence.
(b) Laparoscopic cornual resection with or without salpingectomy—Grade D evidence.
(c) Laparoscopic salpingostomy or cornuostomy—Grade D evidence.
(d) Hysteroscopic resection under laparoscopic or ultrasound guidance—Grade D evidence.

### 8.2.3 Caesarean Scar Pregnancy

(a) There is no sufficient evidence to recommend any specific intervention, although current literature supports an open surgical approach—Grade D evidence.
(b) Excision via laparoscopy or hysteroscopy—Grade D evidence.

### 8.2.4 Ovarian Pregnancy

(a) Laparoscopic enucleation/wedge resection of the trophoblastic tissue.
(b) Laparoscopic ovariectomy.

### 8.2.5 Abdominal Pregnancy (Early)

(a) Laparoscopic excision/removal of abdominal pregnancy—Grade D evidence.

### 8.2.6 Cervical Pregnancy

(a) Medical management is preferred over surgical methods, except when there is life-threatening bleeding—Grade D evidence.
(b) Medical management followed by hysteroscopic removal—Grade D evidence.

### 8.2.7 Other Treatment Adjuncts/Postoperative Counselling Options

(a) Patient monitoring with serum β-hCG when conservative surgery is performed or with corneal/interstitial and caesarean section scar ectopic pregnancy to detect persistent trophoblast.
(b) Anti-D immunoglobulin for Rh D-negative women—Grade D evidence.
(c) Long-term fertility prospects and tubal patency:

- There is no difference in the fertility rate, the risk of future tubal ectopic pregnancy or tubal patency rates between the different management methods—Grade D evidence.

- A previous history of subfertility, expectant or medical management is associated with improved reproductive outcome compared with radical surgery—Grade C evidence.
- There is no effect on ovarian reserve with women on methotrexate—Grade D evidence.
- Future fertility prospects are good with laparoscopic management of ovarian pregnancies—Grade D evidence.

(d) Women should wait for at least 3 months before trying to conceive.

#### 8.2.8 Evidence to Support Minimal Invasive Surgery Over Open Surgery (Cochrane Database)

(a) Salpingectomy has comparable efficacy via laparoscopy or laparotomy in terms of intrauterine pregnancy rate and positive tubal patency test. However, laparoscopy offers other advantages over laparotomy, i.e. reduced operating time, reduced blood loss, decreased requirement for analgesia, shorter hospital stay and early recovery and return to regular activity.

(b) Laparoscopic conservative surgery versus open conservative surgery (Cochrane database).

- Laparoscopic conservative surgery is significantly less successful than the open surgical approach in eliminating tubal pregnancy due to the higher persistent trophoblast rate of laparoscopic surgery.
- There is no significant difference in overall tubal patency.
- The number of subsequent intrauterine pregnancy was comparable.
- The number of repeat ectopic pregnancies was lower with laparoscopy, although not significantly different.
- Advantages of laparoscopy over open surgery include shorter operation time (73 min vs 88 min), reduced blood loss (62–79 mL versus 115–195 mL), reduced analgesia requirement (26 mg versus 58 mg morphine), shorter duration of hospital stay (1 and 2 days versus 3 and 26 days), shorter convalescence time (11 and 17 days versus 24 and 62 days) and lower cost (28,058 versus 32,699 Swedish krona).

(c) Salpingostomy with and without tubal suturing is comparable.

(d) The incidence of persistent trophoblast necessitating additional intervention was reduced when laparoscopic salpingostomy combined with postoperative prophylactic single-dose intramuscular methotrexate was compared with salpingostomy alone.

(e) The need for electrocoagulation for haemostasis was significantly reduced when laparoscopic salpingostomy using vasopressin was compared with laparoscopic salpingostomy alone.

(f) Laparoscopic salpingotomy with an intra-mesosalpingeal injection of 20 IU oxytocin diluted in 20 mL saline significantly reduced intra- and postoperative blood loss with easier removal of the tubal pregnancy without side effects compared with laparoscopic salpingotomy with an intra-mesosalpingeal injection of 20 mL saline alone.

## 8.3 Laparoscopic Operations for Ectopic Pregnancy

### 8.3.1 Salpingectomy

This is the surgical removal of the fallopian tube along with the gestational sac and trophoblast (Figs. 17 and 18). The procedure is indicated in ruptured ectopic pregnancy when the contralateral tube is grossly normal. It is also preferred for isthmic ectopics and when haemostasis is difficult to maintain during salpingostomy/salpingotomy [19, 24, 25, 28].

#### Procedure

In Llyod's-Davis position under GA, with safe peritoneal cavity entry through a 10-mm trocar and cannula, the abdominal cavity is inspected, and ancillary ports are inserted under vision. The pelvis and abdominal cavities are inspected, and blood is sucked out from the peritoneum. The fal-

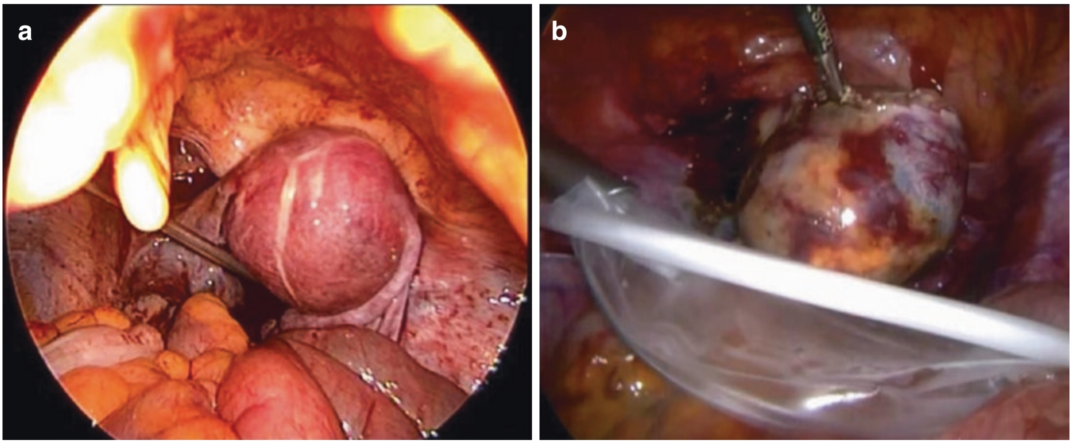



**Fig. 17** (**a**, **b**) Laparoscopic view of ruptured tubal ectopic pregnancy and specimen retrieval using an endobag. (Source: Authors)

lopian tubes are held with graspers after a decision for salpingectomy. Segmental resection of the fallopian tube is then performed using a combination of bipolar forceps and scissors or harmonic scalpel to cauterize and cut the mesosalpinx systematically from the proximal to the distal part of the tube or vice versa depending on the ease of performing the procedure (Fig. 18). Care is taken to avoid thermal injury to the arcuate branches of the uterine or ovarian vessel. Extracorporeal knotting may be necessary in some cases. The fallopian tube and the ectopic gestation can then be removed using an endobag (Fig. 17b) or through the 10-mm trocar sleeves. Copious peritoneal lavage is done to remove the blood and any other debris and product of conception.

### 8.3.2 Salpingotomy/Salpingostomy

This is the most common conservative surgical technique employed in treating ectopic gestation (Fig. 19). It entails removing the ectopic pregnancy after an incision is made on the fallopian tube's ante-mesenteric border [24, 25].

#### Procedure

Position and entry into the abdominal cavity are like that of the salpingectomy described above. The ante-mesenteric border over the portion of the fallopian tube containing the ectopic pregnancy is first injected with vasopressin solution to create an avascular area through which the incision is made, removing the ectopic pregnancy via suction/aspiration, hydrodissection or the use of forceps. Haemostasis is maintained using bipolar forceps, and copious lavage is done with normal saline. The tubal wound is left open to close on its own in salpingostomy, while fine sutures are used to appose the wound edges in salpingotomy.

### 8.3.3 Fimbrial Milking/Evacuation of Tubal Pregnancy

This is a conservative surgical approach for tubal gestation. It involves stepwise 'milking' of the fallopian tube proximal to the ectopic mass towards the fimbrial opening until the bulk of the tissues are expelled. Although several reports of milking of ectopic tubal pregnancy exist in the literature, it has not been generally recommended. This may likely be because of the perceived high rate of persistent trophoblastic disease following the procedure [28].

#### Procedure

Under general anaesthesia, with appropriate positioning and safe entry into the peritoneal cavity, the product of conception is located. The fallopian tube is gently grasped with two forceps. The forceps close to the proximal part of the tube is used to stabilize it; the distal forceps is used to gently push the product of conception out of the fimbrial opening. Haemostasis is maintained, and the specimen is retrieved with an endobag.

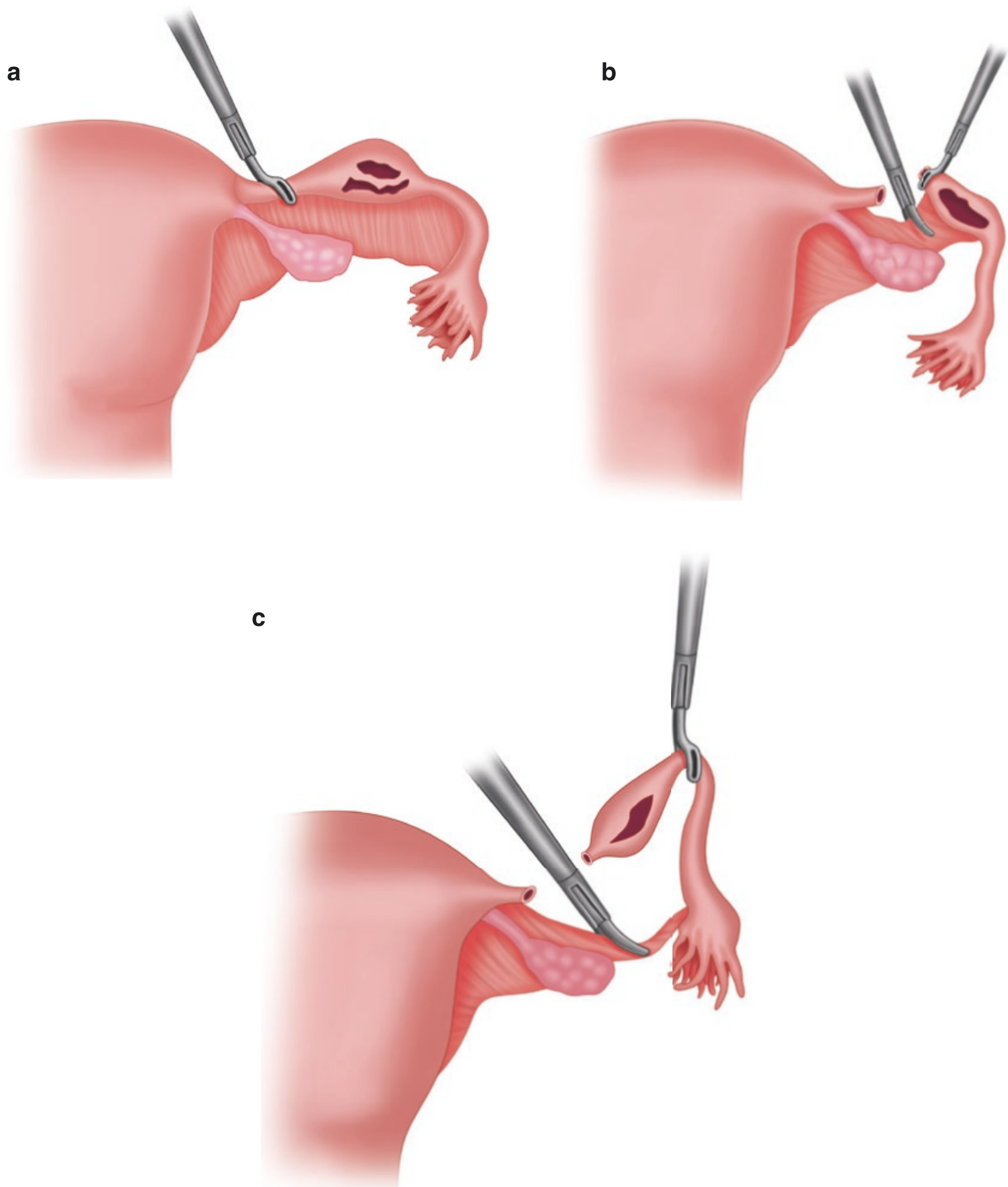



**Fig. 18** (**a**–**c**) Stepwise description of the procedure of salpingectomy

### 8.3.4 Cornual Excision/Cornuostomy

Treatment of cornual/interstitial ectopic pregnancy is challenging because of its location at the proximal part of the fallopian tube (Fig. 20). Wedge cornual resection and hysterectomy via laparotomy are the traditional treatment options. Single-dose prophylactic methotrexate may be given before laparoscopic surgery to reduce the incidence of persistent trophoblast. Physicians are often concerned about the possibility of uterine rupture in future pregnancy following resection of cornual ectopic pregnancy. Suturing of the incision site and elective caesarean section are often advocated to prevent uterine rupture. However, the antenatal uterine rupture has been reported [27, 30, 32].

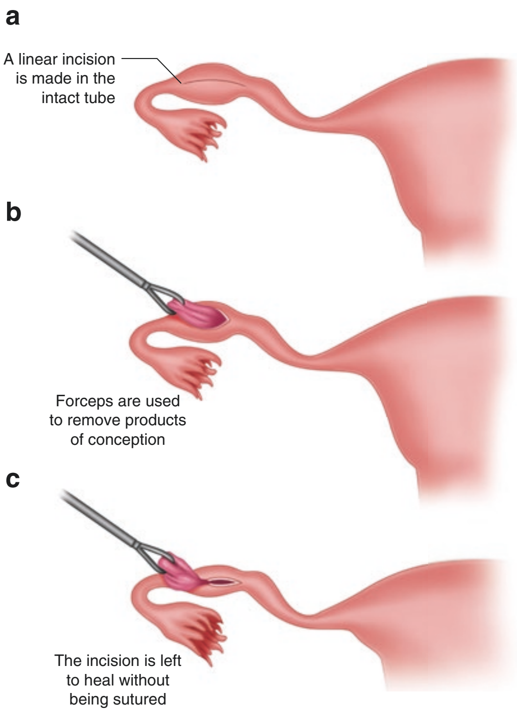



**Fig. 19** (**a**–**c**) Stepwise description of the procedure of salpingostomy

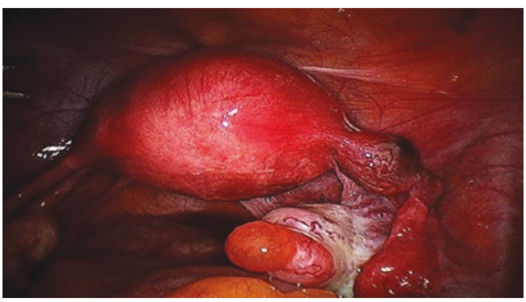


**Fig. 20** Laparoscopic view of right cornual pregnancy. (Permission to use image was given on 16 June 2022 by Dr. Nutan Jain of Vardhman Infertility and Endoscopic Clinic, Muzaffarnagar, India)

### The Procedure of Cornual Excision/Cornuostomy

With the safe entry into the peritoneal cavity using a 10-mm diameter trocar, pneumoperitoneum achieved with carbon dioxide insufflation and intra-abdominal pressure maintained at 15 mmHg maximum. Pelvic and abdominal cavities are inspected. Dilute vasopressin is injected directly over the cornual pregnancy using an aspiration needle. A linear incision is made with monopolar

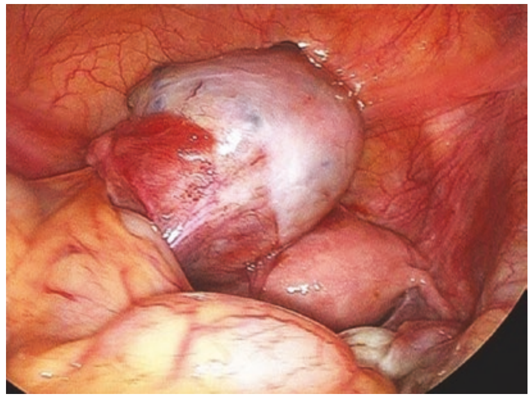


**Fig. 21** Laparoscopic view of left ovarian pregnancy. (Permission to use was image given on 16 June 2022 by Dr. Nutan Jain of Vardhman Infertility and Endoscopic Clinic, Muzaffarnagar, India)

cautery over the myometrial capsule and along the long axis of the cornual pregnancy. The gestational sac is removed using blunt, sharp and/or hydrodissection. Haemostasis is maintained using bipolar cautery. The incision is sutured with Vicryl 1 suture or left open to close primarily (cornuostomy). Copious peritoneal irrigation is done with normal saline, and the specimen is retrieved from the pelvis for histology using an endobag [32].

## 8.3.5 Hysteroscopic Removal Procedures Under Laparoscopic or Ultrasound Guidance

This is mostly done after methotrexate has been used either as a single dose or multiple doses. The patient is placed in a lithotomy position under anaesthesia, cleaned and draped. In-dwelling urethral catheter is passed. Sims speculum is inserted; the cervix is held with a Vulsellum and a resectoscope is introduced into the uterine cavity with the gestational tissue gradually removed from the cornual end using a loop electrode [33].

## 8.3.6 Enucleation of Ovarian Pregnancy/Ovarian Wedge Resection, or Ovariectomy

Ovarian pregnancy is treated laparoscopically with either enucleation of the pregnancy or ovariectomy. It is a rare form of ectopic pregnancy with criteria for diagnosis defined by Spiegelberg et al. (Fig. 21). They are intact ipsilateral tube, clearly separate from the ovary, gestational sac occupying the ovary, sac connected to the uterus by the ovarian ligament and histologically proven ovarian tissue located in the sac wall [26, 34, 35].

**Procedure**

With the safe entry into the peritoneal cavity using a 10-mm-diameter trocar, pneumoperitoneum is achieved with carbon dioxide insufflation and intra-abdominal pressure maintained at 15 mmHg. Pelvic and abdominal cavities are inspected. Enucleation/ovarian wedge resection is performed by grasping the ovarian surface with a Manhes forceps near the extrauterine pregnancy and stabilized by another pair of grasping forceps. Resection of trophoblastic tissue is then performed with monopolar scissors. Haemostasis is maintained with coagulation of the ovarian bed using fine bipolar forceps sparingly. The excised tissue is removed via one of the accessory ports after enlarging it to 10 or 12 mm, and peritoneal lavage is done using normal saline.

### 8.3.7 Removal of Abdominal Ectopic Pregnancy

Early abdominal ectopic pregnancy can be removed via laparoscopy (Fig. 22). One of the accessory 5-mm port site can be increased to 10 mm to accommodate the specimen's removal via an endobag. Haemostasis is maintained using bipolar forceps where necessary and peritoneal cavity irrigated copiously with normal saline [36].

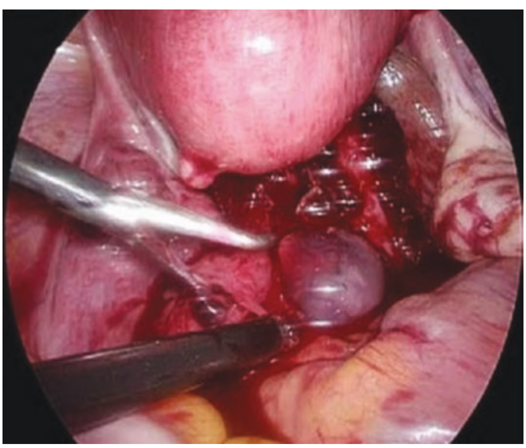


**Fig. 22** Laparoscopic view of gestational sac near Douglas cavum. (Permission to use image given on 13 June 2020 by Atsushi Yanaihara and Springer Nature Group [36])

## 8.4 Advances in the Management of Ectopic Pregnancy

### 8.4.1 Single-Incision Laparoscopic Surgery (SILS)

This is a rapidly developing field with the advantages of decreasing morbidities and improved cosmesis (Fig. 23). It can be used for various laparoscopic tubal procedures and treatment of ectopic pregnancy. Wheeless in 1969 used single incision for laparoscopic tubal sterilization. Yoon in the 1970s performed laparoscopic tubal ligation through a single umbilical incision. Pelosi and Pelosi performed a total hysterectomy and bilateral salpingo-oophorectomy using a single puncture technique in 1991. The SILS has recently gained momentum because of improving technological advancement relating to instrumentation, scopes/lighting and access ports.

Advantages over conventional laparoscopy include better cosmesis, less postoperative pain, rapid convalescence, decreased morbidity from

**Fig. 23** Single-incision laparoscopic surgery. (Source: Permission to use image given by Springer Nature [37])


**Fig. 24** Operating room set-up for robotic-assisted surgery. (Source: Cleveland Clinic website)

visceral and vascular injuries during trocar placement, risk reduction of postoperative wound infection and hernia formation and elimination of multiple trocar site closures [37].

### 8.4.2 Da Vinci Robotic Platform/System

This has the advantages of a three-dimensional view (Fig. 24), the robotic arm's wrist-like motion and an ergonomically comfortable position for the surgeon to perform a wide range of gynaecological surgeries conveniently. It also removes several limitations to traditional laparoscopy [38].

## 8.5 Conclusion

The high prevalence of tubal factor as a cause of infertility in Nigeria has left many patients who are unable to afford assisted reproductive techniques helpless. The growing population of skilled minimal access gynaecological surgeons bear the burden of providing succour and hope to patients with amenable tubal problems. Laparoscopic salpingectomy is a basic skill that should be readily available in all secondary health-care facilities; however, tubal reconstructive surgeries are more complex procedures requiring a lot of dexterity and skills like suturing techniques. Specialized regional units with acquired experience and competence in handling complex cases may serve as reference points for such cases apart from supporting capacity building in other centres.

**Learning Points**

- Tubal factor constitutes 42–63.6% of female factor infertility in Nigeria.
- Histologically, the tube is made up of an outer muscular wall and inner mucosa covered with columnar epithelium with specialized cells for motility and nutrition of fertilized ova.
- Laparoscopic tubal ligation can be achieved with Falope ring, Filshie clip, Hulka clip, and electrocautery.
- Laparoscopic tubal ligation reversal operations record better success in younger patients with clip or ring in a healthy tube without pelvic adhesion.
- Laparoscopic tubal reversal increases ectopic pregnancy rate up to 6.7%.
- Laparoscopic salpingostomy has poor outcome in a setting of severe tubal disease (stage 3), previous salpingectomy, repeated salpingectomy and positive chlamydia serology.
- Laparoscopic salpingectomy has better outcome in a setting of absence of rugae on HSG, presence of hydrosalpinges >15 mm, presence of significant pelvic adhesion and absence of fimbriae during laparoscopy.
- Laparoscopic-guided hysteroscopic tubal cannulation in carefully selected patients with proximal tubal occlusion shows a promising outcome.

- Laparoscopy remains the gold standard in surgical management of ectopic pregnancy.
- Laparoscopic salpingectomy is the treatment of choice in patients with a healthy contralateral tube.
- Laparoscopic salpingostomy carries the risk of persistent trophoblastic tissue and further interventions. Patient monitoring with β-hCG post-operation is mandatory.

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# Laparoscopy-Guided Hysteroscopic Proximal Tubal Cannulation (Endoscopic Tubal Cannulation)

Joseph Ifeanyichukwu Ikechebelu
and George Uchenna Eleje

## 1 Introduction

Infertility has a considerable psychosocial, medical and economic impact on the individuals, family and society. Tubal factor is the commonest cause of female infertility in Nigeria due to high prevalence of reproductive tract infections from sexually transmitted, post-abortion and puerperal infections.

Tubal pathology may involve the proximal, middle or distal portions of the fallopian tube. Hysterosalpingography (HSG) is the initial evaluation commonly used in Nigeria to diagnose tubal occlusion. However, proximal tubal occlusion (PTO) or cornual occlusion on HSG may be due to tubal spasm, mucus plugs, debris, or true blockage [1, 2]. This gives rise to a good degree of false-positive reports of tubal occlusion from HSG. The addition of diagnostic laparoscopy has further improved the accuracy of diagnosing tubal occlusion and other tubal pathologies like peritubal adhesions, hydrosalpinx, tubal congestion, etc. [1, 3, 4].

Available options for treatment of proximal tubal occlusion include tubal surgery, resection and anastomoses or re-implantation, hydrotubation or chromotubation and in vitro fertilization and embryo transfer (IVF). The choice of treatment option is usually based on the available expertise and technology and more importantly on funding. The high cost of these procedures added to lack of health insurance cover in low-income countries like Nigeria (patients pay out of their pocket), and the added low success rates particularly of the tubal surgeries is a significant consideration.

This has led to the introduction of endoscopic tubal cannulation (ETC) often called laparoscopy-guided hysteroscopic tubal cannulation procedure as a reasonable alternative to IVF and outright tubal surgery [1, 5]. ETC is a one-off treatment for PTO in selected cases which restores the tubal patency without adversely affecting the tubal anatomy. It has been shown to have a good treatment outcome for PTO with reduced risks, less costs and low morbidity compared to laparotomy tubal surgery [1, 5, 6]. Laparoscopy-guided hysteroscopic tubal cannulation procedure treatment option is gradually

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gaining acceptance in our low-income country settings [5].

This chapter discusses laparoscopy-guided hysteroscopic proximal tubal cannulation also called ETC under the following headings:

1. Preoperative considerations and requirements
2. Step-by-step procedure
3. Outcome of procedure
4. Complications and contraindications
5. Conclusion

## 2 Preoperative Considerations and Requirements

- The procedure requires a double set-up, one for laparoscopy and the other for hysteroscopy.
- A 7FG operating sheath is preferred though a 5FG sheath can also be used depending on the size of the cannulation set.
- Tubal cannulation device selected according to the hysteroscopy sheath.
- Personnel
  - Two competent gynaecological endoscopy surgeons required as they will work simultaneously with one performing the hysteroscopy and the other the laparoscopy.
  - Two endotrained perioperative nurses or theatre assistants required to assist on each procedure.
  - Endotrained anaesthesiologists to handle the anaesthesia.
- Properly selected patients with healthy looking tubes (no hydrosalpinx) with only proximal occlusion.

## 3 Step-by-Step Procedure for Endoscopic Tubal Cannulation

**Step 1**: Place the patient in supine position and administer general anaesthesia and reposition to a half-lithotomy position under GA. Note that regional anaesthesia (subarachnoid block) can also be used for this procedure.

**Step 2**: Prepare the abdomen, perineum and vagina for simultaneous hysteroscopy and laparoscopy (double set-up).

**Step 3**: Do a diagnostic hysteroscopy procedure, and assess the uterine cavity. Do also diagnostic laparoscopy with a probe or atraumatic grasper in the left lower lateral or suprapubic port for manipulation of the tube.

**Step 4**: Re-position patient to Trendelenburg (15° head down tilt). Focus the hysteroscope to one ostium (see Fig. 1), and pass the 50 cm long Teflon catheter guide (or silastic tube) via the operating channel into the tubal ostium (see Fig. 2).

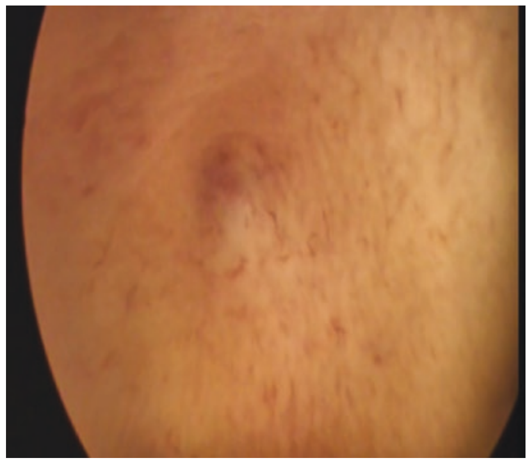

**Fig. 1** Hysteroscope focused on tubal ostium

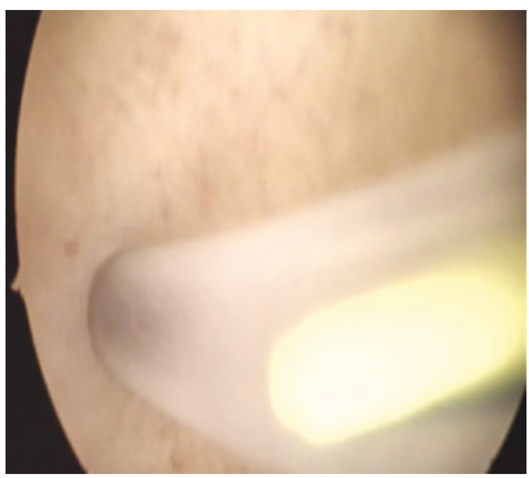

**Fig. 2** Teflon catheter (transparent tube) passed into the ostium. Steel wire (yellow) passed via the catheter

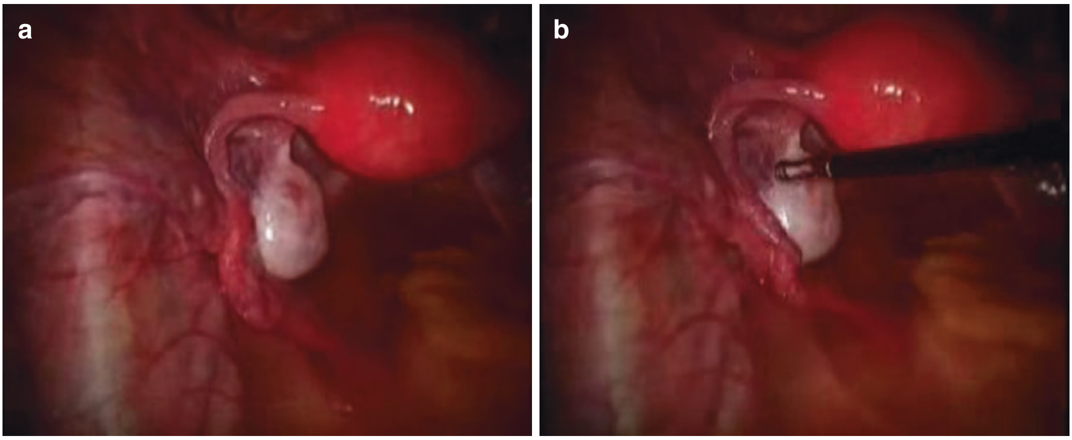


**Fig. 3** At laparoscopy, guide wire (**a**) entering proximal part of left fallopian tube; and (**b**) guided distally with atraumatic forceps

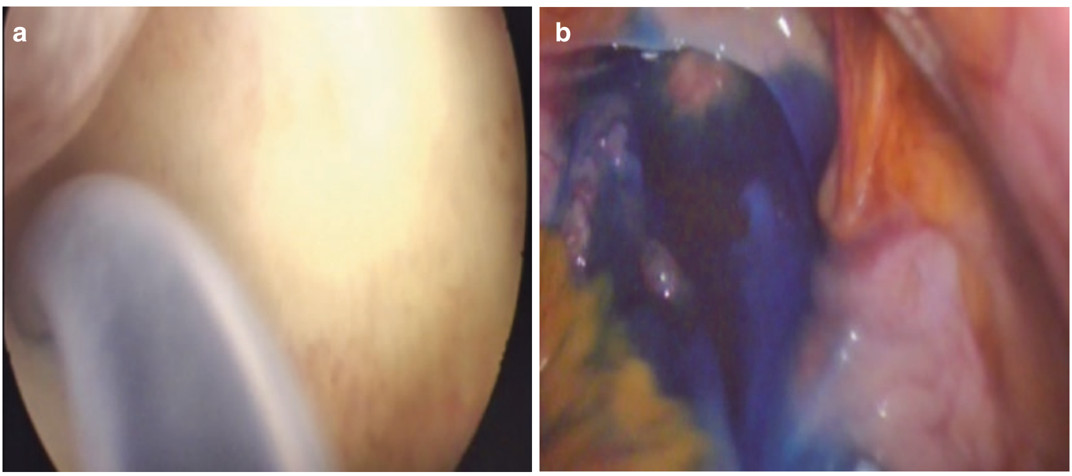


**Fig. 4** (**a**) Dye injection via the Teflon catheter seen at hysterectomy. (**b**) Dye spillage into peritoneum seen at laparoscopy

**Step 5**: Then pass the steel guide wire soft end (0.018 mm) via the Teflon catheter (or silastic tube) into the fallopian tube to overcome any resistance for a distance of about 1–2 cm (some may pass through the entire length of the tube).

**Step 6**: Through the laparoscope, the second surgeon will view and control the movement of the wire till the resistance is overcome (see Fig. 3a, b).

**Step 7**: The steel wire is withdrawn completely out of the Teflon catheter (or silastic tube).

**Step 8**: Fluid, like diluted methylene blue dye, sterile water or normal saline is injected via the Teflon catheter (or silastic tube) which is still in position, to check for patency of the tube (see Fig. 4a). Evidence of spillage of the dye or fluid into the peritoneal cavity is confirmed via the laparoscope immediately (see Fig. 4b).

**Step 9**: Once patency is confirmed, the Teflon catheter (or silastic tube) is withdrawn into the operating channel of the hysteroscope (see Fig. 5).

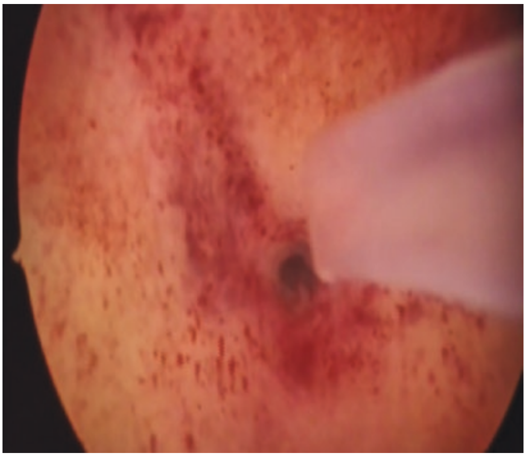

**Fig. 5** Teflon catheter withdrawn after dye test

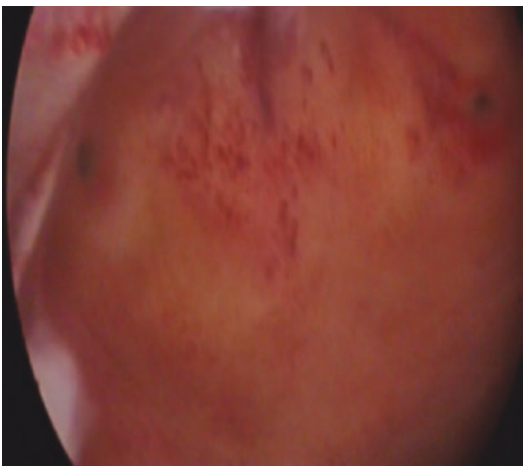

**Fig. 6** Panoramic view of cavity after bilateral cannulation

**Step 10**: The hysteroscope is rotated and focused on the other tube and above steps 4–9 are repeated for the other tube where bilateral cannulation is required (see Fig. 6).

**Step 11**: After the cannulation of the tube(s), the procedure is ended and the hysteroscope sheath is withdrawn from the uterine cavity. The vulsellum forceps are removed (if was used), and the vagina cleaned. Patient is returned to supine level position.

**Step 12**: On the laparoscopy section, remove the probe and cannula in the lateral port under vision. Then stop the gas flow.

**Step 13**: Remove the laparoscope and allow the gas used for pneumoperitoneum to escape. Then remove the primary port cannula.

**Step 14**: The port wound is closed with staples or absorbable suture material (preferable subcortical suturing for the skin) and sterile dressing applied.

**Step 15**: Anaesthesia is reversed (if general anaesthesia was used), and patient moved to the recovery room.

**Step 16**: Write a detailed operation note incorporating all the documented findings. Prescribe antibiotics and analgesics, and discharge home as appropriate after communicating the outcome of the procedure to the couple.

**Step 17**: Schedule her for a follow-up 4 weeks after the procedure via clinic appointment or telephone consultation.

## 4 Outcome of Tubal Cannulation

The outcome of tubal cannulation can be considered at different levels which will include:

- Successful opening of the tubes (Unilateral or Bilateral). In a preliminary study in Nigeria by Ikechebelu et al. [5], successful tubal cannulation rate was 90.2% per tube and 88.9% per patient. Other studies have revealed a success rate of 75–85% [2, 7, 8].
- Pregnancy rate following successful tubal cannulation. Ikechebelu et al. [5] reported a conception rate of 33.3%. Other authors reported intrauterine pregnancy rate of 20–55% [2, 7–10].

## 5 Complications

These include the following:

- All the complications of standard hysteroscopy procedure can occur here.
- All the complications of laparoscopy surgery related to access technique and pneumoperitoneum can occur here.
- Cannulation-related complications include:

  - Perforation of the tube and possible perforation of the uterus if the cannulation wire is wrongly directed.
  - Intra-luminal damage or tear where the wire creates a false passage in the tubal wall.
  - Infection.
  - Haemorrhage.
  - Failure of cannulation. This may be due to tissue fibrosis making passage of the steel wire extremely difficult, long segment occlusion, inappropriate technique and instrumentation and the presence of uterine fibroids or unidentified adenomyosis.

## 6 Contraindications

A few conditions could be considered as contraindications to this procedure. These include:

- Long segmental fibrosis of the fallopian tube
- Chronic salpingitis with distortion of the tubal anatomy
- Previous tubal surgery
- Pelvic tuberculosis with tubal involvement

## 7 Conclusion

Laparoscopy-guided hysteroscopic proximal tubal cannulation is assuming a more central role in the treatment of tubal infertility across the world, with minimal or no complication. There is need to develop the capacity for the procedure to improve management outcomes. It should be the first line treatment in selected women before referral for IVF and embryo transfer.

**Learning Points**

- There must be a valid indication for the laparoscopy-guided hysteroscopic proximal tubal cannulation procedure.
- Good patient selection is an optimal practice to improve outcomes and minimize complications.
- Meticulous preoperative considerations are very important to the success of the surgery.
- Always make sure the instruments are working, and take care of them after the procedure.
- Pay attention to basic cannulation safety principles. Ensure laparoscopic visualisation of the wire as it engages the fallopian tube to avoid perforation or intra-luminal damage.
- Proper documentation is very important.

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# Laparoscopy in Pregnancy

Michael E. Aziken, Michael C. Ezeanochie, and Kenneth C. Onumbu

## 1 Introduction

Laparoscopy has recently become popular, and indications for its use are expanding daily. Some of the reasons for its widespread use include its minimally invasive nature, reduced postoperative pain, and morbidity for the patient, earlier return of gastrointestinal function and earlier ambulation of the patient [1–3].

Traditionally, pregnancy was considered a contraindication for laparoscopic procedures. A major concern was the altered physiology of pregnancy which reduces maternal cardiopulmonary reserve [4]. Therefore, when pneumoperitoneum is induced with carbon dioxide ($CO_2$) in pregnant women for laparoscopy, it may rapidly equilibrate with the blood levels by diffusion from peritoneal surfaces leading to acid-base imbalance with hypercarbia and respiratory acidosis. Also, in the second and third trimester of pregnancy, the pneumoperitoneum along with the gravid uterus can exert substantial pressure on the inferior vena cava. This can impair venous return, consequently reduce cardiac output and increase the risk for venous thromboembolism. The enlarging uterus is also at risk of injury during entry at laparoscopy from either the Veress needle or the Trocar [5, 6].

Laparoscopy during pregnancy can potentially lead to adverse foetal outcomes [7]. Teratogenic effects from drug exposure when laparoscopy is performed in the first trimester, foetal acidosis from maternal acidosis, thermal effects of energy sources used in operative laparoscopy, $CO_2$ insufflation of the myometrium with the Veress needle and preterm delivery are some of the complications that have been associated with laparoscopy during pregnancy [8–10].

## 2 Current Perspectives on Laparoscopy in Pregnancy

Recently, there has been increasing evidence that diagnostic and operative laparoscopy can be safely performed during pregnancy. A recent sys-

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tematic review of published literature revealed that laparoscopy has been safely conducted in the first, second and third trimesters of pregnancy [11]. Some of the laparoscopic procedures that have been performed in pregnancy include adnexal surgery for adnexal torsion, ectopic pregnancy, accidental ovarian cysts, appendectomy and cholecystectomy. These conditions usually present with abdominal pain in pregnancy often as emergencies.

It is however noteworthy that majority of the published works on laparoscopy during pregnancy are retrospective case series with low-grade evidence. They, however, suggest that despite initial concerns, laparoscopic procedures can be successfully carried out in pregnancy with comparable risk as open surgery for the mother and foetus. Retrospective studies and case series may represent some selection bias as procedures that resulted in adverse outcomes may less likely be reported. There is a need for well-designed randomised clinical trials on the safety and feasibility of performing laparoscopic procedures during pregnancy as a routine.

The experience of the surgical team, clinical state of the patient and available equipment are still important factors to be considered when planning for a laparoscopic procedure for the pregnant patient in order to ensure god outcomes. Importantly, for resource-limited settings such as sub-Saharan Africa, the cost implications of laparoscopic procedures for the pregnant women need to be considered when making decision between open and laparoscopic procedures.

## 3 Indications for Laparoscopy During Pregnancy

- Sepsis (acute appendicitis, ovarian abscess)
- Biliary tract disease such as symptomatic gallstones
- Benign adnexal mass accidents such as torsion, large hydrosalpinx, rupture or haemorrhage into ovarian cysts
- Symptomatic fibroid (pedunculated, broad ligament)
- Heterotrophic pregnancy (tubal, rudimentary horn, ovarian)
- Suspected ovarian malignancy detected in pregnancy
- Laparoscopic abdominal cervical cerclage for history of repeatedly failed vaginal procedure

## 4 Some Contraindications for Laparoscopy During Pregnancy

- Lack of patient consent
- Lack of requisite skill and equipment
- Poor cardiopulmonary reserve
- Extensive abdominopelvic adhesions
- Shock
- Obesity

## 5 Relevant Investigations (Abdominal Pain in Pregnancy)

A blood work-up that includes a full blood count, electrolytes and urea with serum creatinine may be required. In addition, chest X-ray and electrocardiogram may be necessary before exposure to general anaesthesia required for laparoscopic procedures.

In terms of imaging, ultrasound imaging is most commonly used. It excludes differential diagnosis and helps in assessing foetal viability, well-being and pregnancy dating. MRI, where available, may also be a useful investigation. The CT scan has limitations for use in pregnancy because of radiation exposure and adverse effects of contrast that may be used.

- Haematological profile
- Chest X-ray
- Electrocardiogram
- Ultrasound scan
- MRI
- CT scan (rarely justified)

## 6 Valid Consent for Laparoscopy in Pregnancy

Consent may be considered not fully informed and therefore not valid if it did not include consequences to mother and child. After 20 weeks of cyesis, it is good practice to get an experienced neonatal doctor to talk to the patient about possible associated risks of severe prematurity and foetal demise.

## 7 Procedure for Laparoscopy in Pregnancy

To safely conduct laparoscopy during pregnancy, some precautionary measures and modifications from conventional techniques in laparoscopy for the non-pregnant woman have been described.

Lung maturity: If time allows, consideration should be given to improving foetal lung maturity with a course of two betamethasone or dexamethasone injections 12–24 h apart. It is also prudent to ensure neonatal ITU bed is available, in case preterm labour is triggered by surgery

Anaesthesia: General anaesthesia with endotracheal intubation remains the technique of choice for laparoscopy during pregnancy. In the first trimester of pregnancy, careful selection of drugs to avoid known teratogenic agents is important. In late pregnancy, impaired venous return from compression of the inferior vena cava arising from pressure of the gravid uterus and effects of pneumoperitoneum can be minimised by applying the lateral decubitus positioning of the patient and minimising the degree of reverse Trendelenburg tilt on the operating table.

The measurement of end-tidal $CO_2$ concentration in the endotracheal tubes by capnography to ensure it remains between the physiological ranges of 25–30 mm can help prevent hypercarbia and respiratory acidosis. If a rise in end-tidal $CO_2$ is detected, $CO_2$ elimination via the alveoli can be increased using controlled hyperventilation.

Surgical anatomy: In terms of technique for gaining access to the peritoneal cavity, an open Hasson technique appears safer than a closed percutaneous puncture using the Veress needle during the second and third trimesters of pregnancy. Insufflation using the sub-xiphoidal point and right or left mid-clavicular points 1–2 cm below the coastal margins have also been successfully described in pregnancy [1, 12].

The overall principle guiding placement of the primary port trocar placement is that it should be at least 6 cm above the palpated height of the uterine fundus. The placement of the secondary and other ancillary ports is determined by the planned surgical procedure and the stage of the pregnancy (Fig. 1).

Following insufflation, the intra-abdominal pressure should be maintained as low as possible, usually below 15 mmHg, while allowing adequate visualisation during the procedure. This helps reduce the pressure from pneumoperitoneum on the inferior vena cava and the gravid uterus.

Foetal consideration: Continuous monitoring of the foetus is recommended when laparoscopy

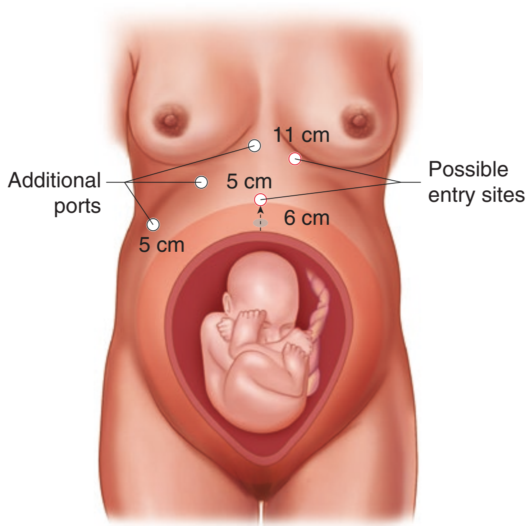


**Fig. 1** Sites for placement of trocar port during laparoscopy in pregnancy

is being performed during pregnancy for a viable foetus. This is to enable the early detection of significant foetal compromise during the procedure for appropriate intervention. The use of prophylactic tocolysis during the procedure has been suggested as a strategy to avoid preterm labour and delivery. The long-term effects of foetal acidosis arising from maternal respiratory acidosis during laparoscopic procedure in pregnancy have not yet been determined. Evidence suggests that preoperative and postoperative foetal monitoring suffices and does not support routine intraoperative tocolysis [13, 14].

## 8 Postoperative Considerations

Thromboprophylaxis is advised after laparoscopy in pregnancy especially where the surgical time was prolonged [15]. This could be done using pneumatic compression devices on the lower limbs of pregnant women undergoing laparoscopic procedures or pharmacologically with unfractionated or low-molecular-weight heparin. Other maternal complications that have been reported include wound infection, abdominal or pelvic abscess formation, intestinal ileus and haemorrhage [16].

Preterm delivery, foetal loss and injury to the gravid uterus have been documented [9, 17]. The monitoring of the foetal heart for abnormalities and the uterus for contractions should continue for at least 24 h after the procedure. Tocolysis should be administered when there is a high risk of, or evidence of, preterm labour [1, 13, 14].

## 9 Conclusion

Diagnostic and operative laparoscopy has increasingly become popular in contemporary surgical practice. Its advantages and benefits have made it an attractive option for performing surgical procedures during pregnancy. The physiological and anatomical changes associated with pregnancy present peculiar risks when laparoscopy is to be performed in pregnancy. An understanding of these changes is important in others to implement appropriate measures to prevent adverse outcomes and complications when laparoscopy is to be performed in pregnancy.

**Learning Points**

- Laparoscopic procedures are increasingly becoming more available and accessible.
- Previously, the anatomic and physiologic changes in pregnancy made pregnancy to be considered a contraindication for laparoscopic procedures.
- Recent advances in our understanding of the physiological changes in pregnancy, equipment for laparoscopy and surgical competence have made laparoscopy during pregnancy safer.
- Laparoscopic procedures such as adnexal surgery for adnexal torsion, ectopic pregnancy, accidental ovarian cysts, appendectomy and cholecystectomy have been safely performed in the first, second and third trimesters of pregnancy.
- Maternal complications from laparoscopy during pregnancy may include thromboembolic phenomenon, wound infection, intestinal ileus and haemorrhage.
- Foetal complications may include preterm delivery, foetal heart abnormalities and foetal loss.
- There is still a need for high-quality research evidence to explore the role, safety and efficacy of laparoscopic surgery during pregnancy compared to open surgery.

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# Laparoscopic Abdominal Cerclage

Christian Olajuwon Alabi, Anil Magdum, and Moses Fache

## 1 Introduction

Cervical insufficiency is an important cause of recurrent mid-trimester miscarriages and preterm births and is estimated to complicate up to 1% of pregnancies [1]. Cervical insufficiency leading to recurrent pregnancy loss is one of the most traumatic incidents women can go through during their obstetric career.

A cerclage, or purse-string suture around the cervix, can be used to treat cervical insufficiency and prevent mid-trimester loss and preterm birth. Traditionally, a cerclage is placed vaginally. However, a cerclage may instead be placed abdominally in more severe cases where a vaginal cerclage has failed or the cervix is extremely short for different reasons. An abdominal cerclage allows for placement of the suture at the internal Os, providing greater structural support to the cervix [2].

## 2 Historical Aspects

The first abdominal cerclage was reported by Benson and Durfee in 1965 as an alternative to vaginal cerclage for patients with extreme cervical shortening [3]. The indications were later expanded to include the most common present-day use for patients who have had second-trimester loss or preterm birth despite a vaginal cerclage, commonly termed a "failed" vaginal cerclage [4]. An abdominal cerclage is placed higher on the cervix and is felt to provide added integrity to the cervix in patients with cervical insufficiency. The laparoscopic approach was first performed by Lesser et al. [5] in 1998 and is increasingly used as the preferred method of abdominal cerclage placement with equitable outcome to the open procedure with lesser risk and quicker recovery.

## 3 Laparoscopic Approach

The obvious advantages of laparoscopic abdominal cerclage relate to the minimally invasive nature of the procedure. The laparoscopic

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approach is favoured due to reduced blood loss, fewer wound complications, a shorter length of stay and a faster return to normal activities compared with an open approach [6].

Laparoscopy lends improved visualization of the pelvic anatomy, aiding in avoidance of uterine vessel injury. Many patients with cervical insufficiency may have also had one or more caesarean deliveries, resulting in uterine adhesions that may be more carefully lysed with the laparoscopic method.

## 4 Indications for Laparoscopic Abdominal Cerclage

1. Previous failed vaginal cerclages (McDonald's or Shirodkar's).
2. Cerclage procedure not possible due to cervical changes (previous trachelectomy, birth trauma, cone biopsy or deep loop biopsy).
3. Laparoscopic abdominal cerclage as first-line management of cervical incompetence: Laparoscopic abdominal cerclage as first-line management of cervical incompetence is controversial. This is a relative indication. Many clinicians believe the success rate of abdominal cerclage is better than vaginal cerclage procedure, and hence they prefer abdominal cerclage over vaginal cerclage as a first-line treatment for the incompetent cervix. There is not enough evidence to support this as a general rule.

## 5 Timing of the Procedure: Prenatal or Antenatal

### 5.1 Laparoscopic Abdominal Cerclage on a Non-pregnant Uterus

Whenever indicated, abdominal cerclage is easier to perform on a non-gravid uterus. Uterine manipulation is easy, and the risk of bleeding is less. Uterine and other pelvic vessels are not as congested as during pregnancy. This reduces the risk of haemorrhage during placement of the Mersilene tape or suture material used. It is easier to place the tape medial to uterine vessels in a non-gravid uterus compared to gravid uterus. There is no risk of procedure-related miscarriage. The main disadvantage of prenatal laparoscopic abdominal cerclage is lack of opportunity to screen the foetus for foetal malformations.

### 5.2 Laparoscopic Abdominal Cerclage During Pregnancy

The biggest advantage of performing the surgery during pregnancy is the confirmation of viability of pregnancy. The most ideal time for placement of antenatal cerclage is immediately after results of screening for common chromosomal abnormalities, and most clinicians aim for between 12 and 14 weeks of pregnancy. Laparoscopic abdominal cerclage should be placed immediately after the results.

Overall, the level of difficulty while performing the procedure increases with advancing gestational age. One cannot use any intrauterine manipulator for uterine manipulation. Surgeons have to rely completely on extra-uterine manipulation. The risk of haemorrhage during surgery increases due to engorged pelvic vessels. With advancing gestational age, available space within the pelvis decreases especially medial to the uterine vessels. There is a risk of miscarriage and preterm labour.

## 6 Preoperative Counseling of Patients

This should ideally start after a miscarriage. The following points should be discussed during counseling:

- Options of interval cerclage (non-gravid uterus) or antenatal cerclage (cerclage during pregnancy).
- The procedure is performed under general anaesthesia with intubation.

- The procedure involves dissection of the urinary bladder and placement of Mersilene tape or other sutures around the cervix.
- There is risk of injury to surrounding structures like urinary bladder, uterine and other pelvic vessels and perforation of the uterus during manipulation.
- They can plan for a pregnancy anytime 8 weeks after the procedure to allow healing (if performed in the non-pregnant woman).
- Caesarean section is the only way of delivery after laparoscopic abdominal cerclage.
- First trimester miscarriage can be managed effectively without disturbing the cerclage stitch.
- The Mersilene tape can be cut either by open, laparoscopic or posterior culdotomy method in case of intrauterine foetal death or second trimester miscarriage. Hysterotomy is another option if required to keep the Mersilene tape intact.
- After caesarean section, the cervical cerclage tape is left in situ for the next pregnancy or can remain in the body even if further pregnancies are not desired. Very rarely, the tape causes any untoward effects and warrants removal.

## 7 Instruments and Sutures Needed

- Mersilene tape or another non-absorbable suture of surgeon's choice
- Polyglactin (910) suture size 2-0 (or 3-0)
- 10 mm trocar × 1
- 5 mm trocars × 3 or 4 (additional 10 and 5 mm trocars may be needed if cerclage is to be performed on gravid uterus). Size and number of ports are left to surgeon's discretion
- Monopolar hook or spatula or ultrasonic device
- Needle holders
- Uterine manipulator
- Scissors
- 5 mm graspers: Maryland, Babcock
- 3 and 5 flanged liver retractors (in case of cerclage on a gravid uterus) (Fig. 1)

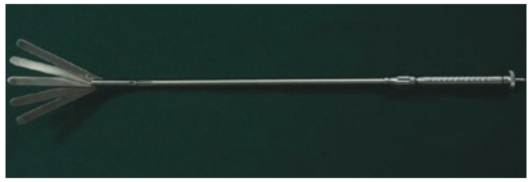

**Fig. 1** Laparoscopic liver retractor

### 7.1 Stepwise Procedure in Non-pregnant Uterus

- Trans-cervical uterine manipulator is inserted.
- Ports are inserted.
- Uterovesical fold of the peritoneum is opened, and the bladder pushed down.
- Bilateral uterine vessels exposed.
- Needle with suture material (Mersilene tape or other suture of surgeon's choice) inserted through the port. Straightening of the needle helps some surgeons.
- Uterus is kept in a retroverted position.

The first side where the needle is inserted at the cervico-isthmus junction medial to the uterine vessels can either be started on right or left side due based on surgeon's preference.

- Needle is held with a needle holder with its concavity facing toward the lateral pelvic wall.
- Needle is passed from anterior to posterior on the left side medial to the uterine vessels.
- Uterus is slowly anteverted while piercing the needle from anterior to posterior aspects.
- The exit point of the needle on the posterior surface should be 1–2 cm above the attachment of uterosacral ligament.
- The tape is pulled sufficiently.
- Uterus is then kept anteverted to allow a better view of the pouch of Douglas.
- The same needle is pulled toward the right side in the pouch of Douglas (Fig. 2).

**For the Right Side**

- Needle is held in the needle holder with concavity facing toward right lateral pelvic wall.

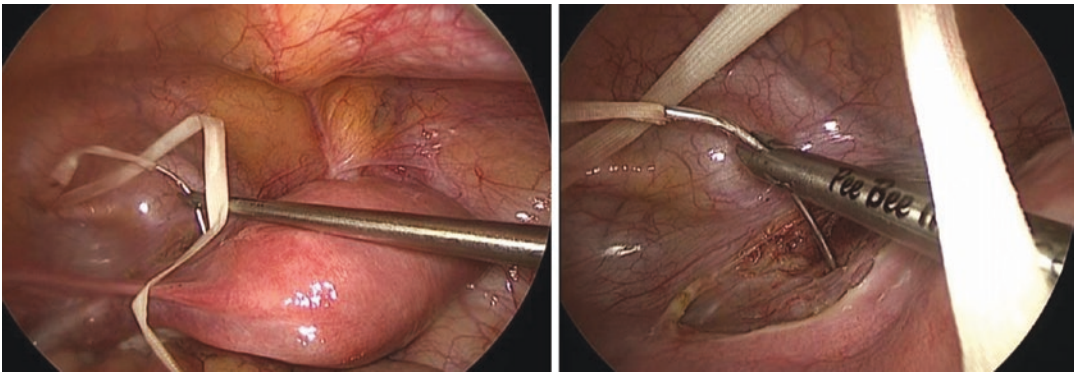


**Fig. 2** Placement of cerclage on left side with concavity of partially straightened needle facing toward lateral pelvic wall

**Fig. 3** Position of tape above attachment of uterosacral ligaments

**Fig. 4** Tying the anterior knot

- The needle is passed from posterior to anterior aspect medial to the uterine vessels around 1 to 2 cm above the attachment of the right uterosacral ligament with the uterus.
- Uterus is slowly retroverted.
- Needle is pulled from anterior surface of the uterus.
- Needle is cut, and both free ends of the tape are pulled, and the knot is tied. Single throw of the tape gives better tightening. Uterine manipulator is kept inside the uterus while tightening the Mersilene tape. The knot is placed anterior to the uterus. Uterovesical fold of the peritoneum is closed with polyglactin suture 2-0 or 3-0.
- Uterine manipulator is then removed (Figs. 3 and 4).

### 7.2 The Following Modifications Can Be Done to the Above Procedure

- Few surgeons use other needles of the Mersilene tape. In this, the needle is passed from anterior to posterior just like on the left side, and the knot is tied posterior.
- A long suture passer needle (also called a port closure needle) can be used to pick up the Mersilene tape. The needle is passed from anterior to posterior while anteverting the uterus. The free end of the tape is caught in the needle and pulled up while retroverting the uterus. Similar procedures can be done on the other side (Fig. 5).

**Fig. 5** Suture passer needle or port closure needle

## 8 Laparoscopic Abdominal Cerclage During Pregnancy

All the steps are similar to procedure in non-pregnant uterus. It needs the following modifications:

- The optic trocar is placed higher depending upon the gestational age (uterine size).
- $CO_2$ pneumoperitoneum pressures are kept higher while placing trocars to avoid accidental injury to the uterus.
- Round ligaments are used to manipulate the uterus.
- Window is created in broad ligament on both sides. This helps to manipulate the needle of Mersilene tape in such a way that the tape traverses medial to the uterine vessels.
- Liver retractor can be used to retract the gravid uterus.
- Manipulation of the uterus is possible by holding the round ligament with atraumatic grasper (Figs. 6 and 7).

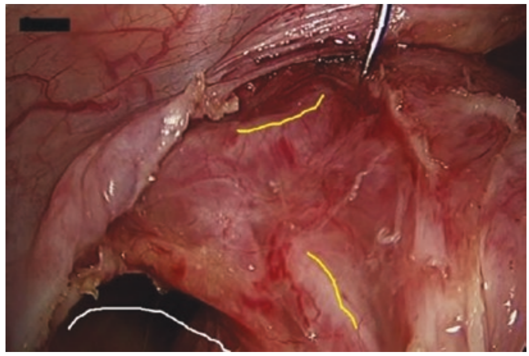

**Fig. 6** Window in broad ligament (white circle) on left side to facilitate smooth passage of Mersilene tape needle medial to the uterine vessels (yellow lines)

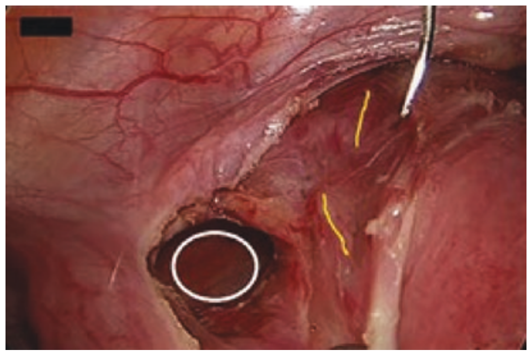

**Fig. 7** Window in the broad ligament lateral to uterine vessels helps visualization of the needle tip

## 9 Special Precautions with Advanced Gestational Age

- Tocolysis in the form of progesterone and/or nifedipine during perioperative period.
- Palmer's point and Hasson technique are probably safer for primary port insertion.
- Trocars should be placed sufficiently high to have proper access to the enlarged uterus.
- Additional accessory trocars will be needed for the liver retractor to retract the gravid uterus.
- All the movements of the instruments should be under vision (both inward and outward movement of the graspers and other instruments) to reduce the risk of injury to the gravid uterus.

– Uterovesical fold of the peritoneum is opened from one round ligament to the other round ligament completely. This helps for safer placement of the tape.
– Urinary bladder is pushed down very gently so as to avoid injury to engorged blood vessels. This can be achieved with traction and counter-traction with two graspers.
– Ultrasonic energy or bipolar cut energy can be used safely for opening the peritoneal fold.

## 10 Placement of Suture Lateral to Uterine Vessels

Placement of the tape medial to the uterine vessels may be difficult in few of the cases of cerclage during pregnancy. In such cases, tape can be placed lateral to the uterine vessels. Mersilene tape can be placed lateral to the uterine vessels in broad ligament on both sides. This will occlude both the uterine vessels once the knot is tied. The collateral circulation will take care of the blood supply to the uterus, and foetus outcome is unaffected. Incidence of miscarriage or intrauterine growth restriction is not increased in such cases. So, placement of Mersilene tape lateral to uterine vessels on both sides is an acceptable option.

## 11 Postoperative Care After Laparoscopic Abdominal Cerclage

### 11.1 Non-pregnant Uterus Cerclage

Routine postoperative care is sufficient. Preconception prophylactic folic acid supplementation can be prescribed as per the institutional policy, and pregnancy can be planned 8–12 weeks after cerclage.

### 11.2 Cerclage During Pregnancy

Tocolysis can be considered as per institutional policy. Patient is warned about signs and symptoms of preterm pre-labour rupture of membranes and preterm labour and advised to contact the hospital if any contraction or leaking of fluid after the procedure.

## 12 Complications of the Procedure

### 12.1 Non-pregnant Cerclage

– Injury to uterine vessels or iliac vessels or urinary bladder
– Passage of needle and tape through the vagina/fornix

### 12.2 Cerclage During Pregnancy

– Injury to engorged pelvic blood vessels, rectum, and urinary bladder
– Injury to the gravid uterus
– Miscarriage
– Preterm labour (if cerclage procedure done beyond 20 weeks of gestation)

## 13 Laparoscopic Abdominal Cerclage in Challenging Conditions

### 13.1 Previous Lower Segment Caesarean Section (LSCS)

Few of the patients might have undergone preterm LSCS during previous pregnancy in view of recurrent pregnancy losses. In such cases, bladder dissection will be challenging. It needs careful dissection with gentle traction and counter-traction with a grasper and ultrasonic energy probe.

### 13.2 Laparoscopic Abdominal Cerclage for Bicornuate Uterus

Laparoscopic abdominal cerclage can be placed in the bicornuate uterus similar to a normal uterus. The steps are similar. The risk of preterm delivery is very high in these women.

### 13.3 Removal of the Cerclage Stitch

Generally, the stitch is left in situ during the caesarean section. It need not be removed, if the patient is planning for subsequent pregnancy. In a case report where the patient suffered from chronic pelvic pain with no other identifiable causative factor, the stitch was removed. She was relieved of the pelvic pain after stitch removal [7].

In case of second trimester miscarriage after laparoscopic abdominal cerclage, stitch can be removed, and the patient is allowed to deliver vaginally. This can be done via open, laparoscopic way or through culdotomy depending on the availability of expertise. James et al. described one such case where the stitch was cut laparoscopically for second trimester miscarriage [8].

Cho et al. mentioned about successful removal of Mersilene tape in five patients during caesarean section without complication [9].

Option of hysterotomy without removal of cervical cerclage tape should be discussed with the patient in second trimester miscarriages.

## 14 Caesarean Section After Laparoscopic Abdominal Cerclage

The patient should undergo a planned caesarean section after 37 completed weeks. Emergency caesarean section is done for those women who present in labour earlier.

The tape does not interfere with the usual steps of lower segment caesarean section as observed by the authors and also reported by Cho et al. [9].

**Learning Points**

- Laparoscopic abdominal cerclage is a safe procedure and good alternative to open abdominal cerclage.
- It is an effective treatment of cervical incompetence where vaginal cerclage has failed earlier.
- Laparoscopic abdominal cerclage is feasible in pregnant women with advanced gestational age.
- Procedure of laparoscopic abdominal cerclage is technically challenging in pregnancies with advanced gestational age.
- Laparoscopic abdominal cerclage procedure should be offered to all those women with cervical incompetence where vaginal cerclage has failed on one or more occasions.

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# Minimal Access Urogynaecology

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## 1 Introduction

The urogynaecology and pelvic floor subspecialty is one of the fields of gynaecology most significantly impacted by the minimal access gynaecology revolution. Some of the most common problems seen in the subspecialty include urinary incontinence and pelvic organ prolapse. For both these conditions, the traditional open surgical approach to management is increasingly being replaced by minimal access techniques, ostensibly because of the numerous advantages of the latter. Some of these advantages include less bleeding, less postoperative pain, and reduced need for analgesia. Others are faster recovery, shorter hospital stay, as well as less infection and wound morbidity [1].

The urogynaecology and pelvic floor subspecialty boasts a wide range of endoscopic procedures, including some of the most advanced minimal access gynaecological surgeries known. Surgical procedures such as laparoscopic Burch colposuspension for treatment of stress urinary incontinence and laparoscopic sacrocolpopexy for treatment of vault prolapse are ready examples. These procedures require an in-depth understanding of retroperitoneal anatomy because of the substantial retroperitoneal dissection involved, and advanced laparoscopic suturing skills—including both intracorporeal and extracorporeal suturing. Furthermore, procedures such as injection of urethral submucosa bulking agents for treatment of stress urinary incontinence call for urethroscopy skills, while injection of the bladder wall with Botox (Botulinum toxin) for treatment of detrusor overactivity demands cystoscopy skills [2–7].

The intricate pelvic floor reconstruction and vaginal surgery skills of the urogynaecologist and pelvic floor surgeon, meanwhile, must not be dispensed with, even in the advent of minimal access urogynaecology. This is not only for the sake of certain pelvic floor procedures which cannot be performed endoscopically, but also for the fact that there are some mandatorily vaginal steps in the performance of some laparoscopic urogynaecological procedures (such as vaginally assisted laparoscopic sacrohysteropexy for treatment of pelvic organ prolapse), and thirdly, because urgent conversion to a vaginal approach still remains a valuable escape route in the event of some problems that may be encountered during a minimal access procedure.

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Pelvic organ prolapse and stress urinary incontinence have a common underlying aetiology, which is weakness of the pelvic support [8]. The pelvic support is principally made up of the pelvic floor muscles (levator ani) and their surrounding fascia (pelvic fascia) [9]. The pelvic fascia in turn is condensed in specific areas to form pelvic ligaments which include the uterosacral, cardinal, and pubocervical ligaments. These ligaments together with the pelvic floor muscles constitute the true supports of the uterus [9]. This true support however sometimes fails due to a loss of connective tissue integrity, or weakness of the pelvic floor muscles, or a combination of both factors. While the former is most often due to postmenopausal hypoestrogenism, the latter is usually the long-term result of pregnancy and childbirth [9].

The evaluation of the pelvic organ prolapse patient to determine the type and severity of prolapse needs to be very thorough and accurate. Of equal importance is the need for the evaluation to be performed and documented using a universally accepted format which enables pre- and post-treatment comparisons for objective measurement of the anatomical treatment outcomes. This would also make comparison with other populations across the globe possible. The Pelvic Organ Prolapse Quantification (POP-Q) system ticks all these boxes [10]. It should therefore be used for all assessment and reporting of pelvic organ prolapse. A detailed description of the POP-Q system is beyond the scope of this chapter.

The management of stress urinary incontinence similarly requires careful and detailed pretreatment evaluation. In this regard, urodynamics are a mandatory requirement for cases being considered for surgical treatment [11–15]. In some developed countries, the decision to offer surgery and the specific surgery to be offered patients with stress urinary incontinence is mandatorily a urogynaecology and pelvic floor multidisciplinary team (MDT) decision [15]. Improvements in symptoms and quality of life are also further ways of measuring treatment outcomes in stress urinary incontinence and pelvic organ prolapse patients. Again, these must be measured using validated international consensus instruments, which at present are the ICIQ-UI (International Consultation on Incontinence Questionnaire—Urinary Incontinence) for urinary incontinence, ICIQ-VS (Vaginal Symptoms) for prolapse, and ICIQ-AI (Anal Incontinence) for anal incontinence [16–18]. A detailed description of these is also beyond the scope of this chapter. However, long-term outcome assessment is of great importance in prolapse and incontinence patients, as future recurrence even after surgery for these conditions is not uncommon [19].

When it comes to the treatment of pelvic floor disorders, a couple of non-surgical options are of well proven efficacy and should therefore be considered first, especially in mild to moderate cases. These options include supervised pelvic floor muscle training with biofeedback, and the use of pessaries. While pelvic floor muscle training is most effective for early treatment of stress urinary incontinence and to a lesser degree for urge and mixed urinary incontinence, pessaries are of great value in the treatment of various stages of prolapse [20–23]. Of note, pessaries are especially helpful in situations where surgery may be contraindicated, such as during pregnancy or in poor surgical risk women. Indeed, pessaries have been known to help avoid surgery altogether in many women for whom they were originally inserted as a temporary measure while awaiting definitive surgery for prolapse [24].

Generally, pelvic floor surgeries are aimed at the restoration and reinforcement of the weakened pelvic support. This aim is usually achieved with the use of native tissue, autograft, or synthetic mesh. Originally, the use of native tissue was the only available option. This later advanced to the use of fascia autografts such as those from the sheath of the rectus abdominis muscle or from the tensor fascia latae on the thigh, for sacrocolpopexy. However, by late 1990s the use of synthetic mesh got introduced into urogynaecology, from its hugely successful use in abdominal hernia repair by the general surgeons. It quickly gained popularity for treatment of both stress urinary incontinence and pelvic organ prolapse [25–27].

Urinary incontinence affects 15–17% of women worldwide, while pelvic organ prolapse affects 3–6%, and over 20% of women worldwide will need surgical treatment for either condition [28, 29]. This amounted to 28 million women as of 2014 [30]. It therefore did not take long for big pharma to discover the enormous market potential for proprietary synthetic mesh products. This literally generated a goldrush which resulted in the creation of the billion-dollar global urogynaecological mesh industry [31]. Based on a clause called article 510(k), some US-based pharmaceutical companies were able to obtain FDA approval for synthetic mesh products without going through the rigorous clinical trials that such products are normally subjected to before approval [32, 33].

The use of synthetic mesh inserted through the vaginal or abdominal route soon became almost customary for surgical management of pelvic organ prolapse and stress urinary incontinence in developed countries [34]. In the management of stress urinary incontinence, for instance, various mesh procedures were employed including the retropubic sling operation, the mid-urethral sling, or tension-free vaginal tape procedure via an outside-in TOT (Trans-Obturator Tape) or an inside-out TVT-O (Trans-Vaginal Tape Inside-Out) approach [35]. For treatment of pelvic organ prolapse, many women had mesh repairs of the anterior or posterior wall prolapse, while synthetic mesh sacrocolpopexy became the gold standard treatment of vault prolapse, and mesh sacrohysteropexy also developed as a uterus conserving option [36–38]. These abdominal mesh procedures also started to be performed laparoscopically with the advances in minimal access gynaecology [1].

After almost a decade of pelvic mesh surgeries, the FDA issued a public warning in 2008 and another in 2011 about the safety of vaginal mesh kits [39, 40]. Studies had started revealed a disturbing (up to 3%) rate of severe and sometimes even debilitating long-term complications of pelvic floor mesh [42]. These complications included mesh exposure and bleeding, mesh infection, mesh erosion, nerve entrapment as well as nerve irritation and chronic pelvic pain. Many women suffered severe dyspareunia to the point of becoming apareunic [39–43]. These complications were the subject of class action lawsuits against some leading manufacturers of urogynaecological mesh like Johnson and Johnson (Ethicon) and Mentor Corp, ending in huge settlement payments and discontinuation of their mesh products [44, 45].

Current guidelines regarding the management of patients suffering from pelvic mesh complications recommend that these women should be managed in a dedicated specialist unit with a sufficient case load for the specialists to be able to maintain privileges. This would usually require the creation of regional centres for the care of these patients [11, 13–15]. The surgeries often entail partial or total mesh excisions, although minor procedures like mesh re-epithelization may occasionally be all that is required [46]. The major procedures often involve extensive dissection to free the mesh from vital structures that it may sometimes have eroded into such as major vessels, nerves, bladder, and bowel. These surgeries are usually multidisciplinary, involving the urologist, colorectal, and vascular surgeons. The surgical approaches should preferably be laparoscopic but may also be abdominal or vaginal. Rarely, a transrectal approach may be required [46].

The current place of synthetic mesh in urogynaecology is still somewhat controversial [47, 48]. While for instance, it is almost universally agreed that there should no longer be vaginal use of synthetic mesh for treatment of pelvic organ prolapse, there is much less consensus regarding its use in treatment of stress urinary incontinence [48]. Many countries currently differ in their guidelines and recommendations regarding the continued use of mid-urethral sling as first-line treatment for stress urinary incontinence [13–15, 48]. While the American Urology Association (AUA) argues that any restriction to the use of synthetic mesh is a disservice to women choosing surgical management of stress urinary incontinence, the Canadian Urology Association (CUA) and the National Institute for Health and Care Excellence (NICE) maintain that there is insufficient evidence to support the safety of unrestricted use of urogynaecological mesh products [48]. Clinical trials are therefore urgently needed to determine the future of these products. In the meantime, injection of urethral submucosa bulking agents and laparoscopic or abdominal Burch colposuspension are available alternatives for stress urinary incontinence management [2, 4–6].

With respect to the intra-abdominal use of synthetic mesh for sacrocolpopexy or sacrohysteropexy however, it is generally agreed that the remarkably high success rate and reasonably low mesh complication rate justify its continued use for these procedures [31]. Moreover, the alternatives such as native tissue repair are associated with a relatively high recurrence rate, while autografts impose additional morbidity at the donor site and have a higher recurrence rate than synthetic mesh [25]. Other techniques have also been tried, including the use of partly degradable synthetic mesh, and the mesh-less techniques which involve suture darning. None of these has however proven superior to non-degradable synthetic mesh [25].

Minimal access urogynaecological procedures can generally be grouped into two categories:

1. Prolapse procedures
   (a) Laparoscopic sacrohysteropexy
   (b) Laparoscopic sacrocolpopexy
   (c) Laparoscopic uterosacral suture hysteropexy
   (d) Sacrospinous fixation
2. Incontinence procedures
   (a) Laparoscopic Burch colposuspension
   (b) Urethroscopic Bulkamid injection
   (c) Cystoscopic Botox injection
   (d) Laparoscopic vesicovaginal fistula repair

## 2 Preoperative Management

All the above listed procedures are laparoscopic, except Bulkamid® injection which is urethroscopic, Botox injection which is cystoscopic, and sacrospinous ligament fixation which is usually vaginal. The urethroscopic and cystoscopic procedures can be done under local anaesthetic, although procedural analgesia, or even general anaesthesia is sometimes used. The 5% risk of urinary retention should be explained to these patients preoperatively and they should be taught clean intermittent self-catheterization [4–6]. Sacrospinous ligament fixation can be done under spinal or general anaesthesia. Preoperative bowel preparation is advisable.

For the laparoscopic procedures, the preoperative preparation and operating room set-up are quite similar.

### 2.1 Bowel Preparation

- Liquid diet for 24 h prior to surgery
- Polyethylene glycol is given orally in the evening before the day of the operation to empty the bowel

### 2.2 Operating Room Set-Up

- Patient under general anaesthesia with or without regional anaesthesia
- Perioperative antibiotics are administered.
- Patient is placed in modified lithotomy position using Allen's stirrups with thighs and legs apart and a slight flexion at both the hip and knee joints
- Compression stockings are applied to prevent deep vein thrombosis.
- Both arms are positioned along the side of the body.
- Shoulder support should be used to prevent patient from sliding 'up' the table.
- Gastric tube and bladder catheter to be placed
- Warming device may be used.
- Surgeon stands to the left of the patient (see Fig. 1)
- First assistant to the right of the patient (see Fig. 1)

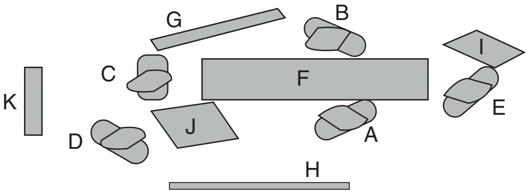


**Fig. 1** Operating room set-up for laparoscopy. A, surgeon; B, first assistant; C, second assistant; D, scrub nurse; E, anaesthetist; F, patient; G, surgeon's monitor and equipment stack; H, assistant's monitor; I, anaesthetic machine; J, Mayo trolley; K, accessory screen

- Second assistant seated between legs of the patient (see Fig. 1)
- Laparoscopic trolley placed at the leg end of the patient (see Fig. 1)

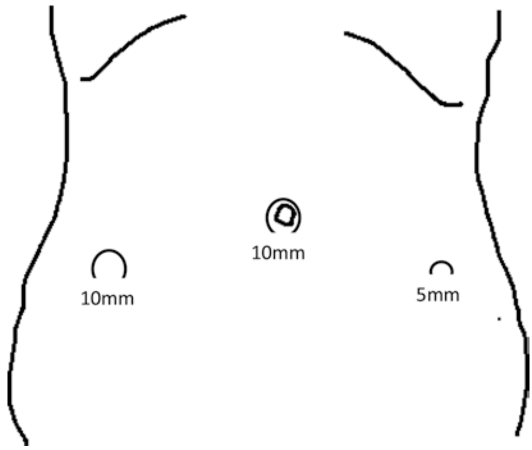


**Fig. 2** Suggested port placement and sizes for laparoscopic prolapse and incontinence surgeries

### 2.3 Trocar Placement (Using the Ipsilateral Port Placement)

- 10 mm camera port placed at the umbilicus (see Fig. 2)
- Secondary ports are placed under vision. These will include:
  – One 5 mm port in each iliac fossa, placed 2 finger-breadths above and medial to the anterior superior iliac spine (see Fig. 2)
  – One midline 5 mm port between umbilicus and pubic symphysis can be placed depending upon the procedure (see Fig. 2)
- Patient is subsequently placed in Trendelenburg position

### 2.4 Uterine Manipulation

An intrauterine manipulator is inserted for effective uterine manipulation.

### 2.5 Energy Sources

Harmonic® because of its excellent performance in tissue dissection is most favoured [49]. In its absence however, monopolar diathermy on laparoscopic scissors can be used for the required peritoneal incisions.

## 3 Surgical Procedures

### 3.1 Laparoscopic Y-Mesh Sacrohysteropexy

This procedure commences with a transverse incision on the vesicouterine peritoneum to open the uterovesical space and reflect the bladder away caudally. This incision is extended on each side to create an avascular window through both layers of the broad ligament on either side (please see Image 1a). The uterus is then maintained in constant anteversion by the second assistant using a uterine manipulator. Caution must however be exercised in order not to perforate the uterus. The right ureter is identified as it enters the pelvis lateral to the sacrum, and a longitudinal incision is made on the peritoneum medial to it. This incision is extended down to the pouch of Douglas. Blunt dissection is then performed to free both sides of this peritoneal incision and the rectovaginal space.

A single Y-shaped macroporous polypropylene mesh is introduced into the pouch of Douglas and aligned lengthwise along the posterior surface of the uterus. The two arms of the Y are

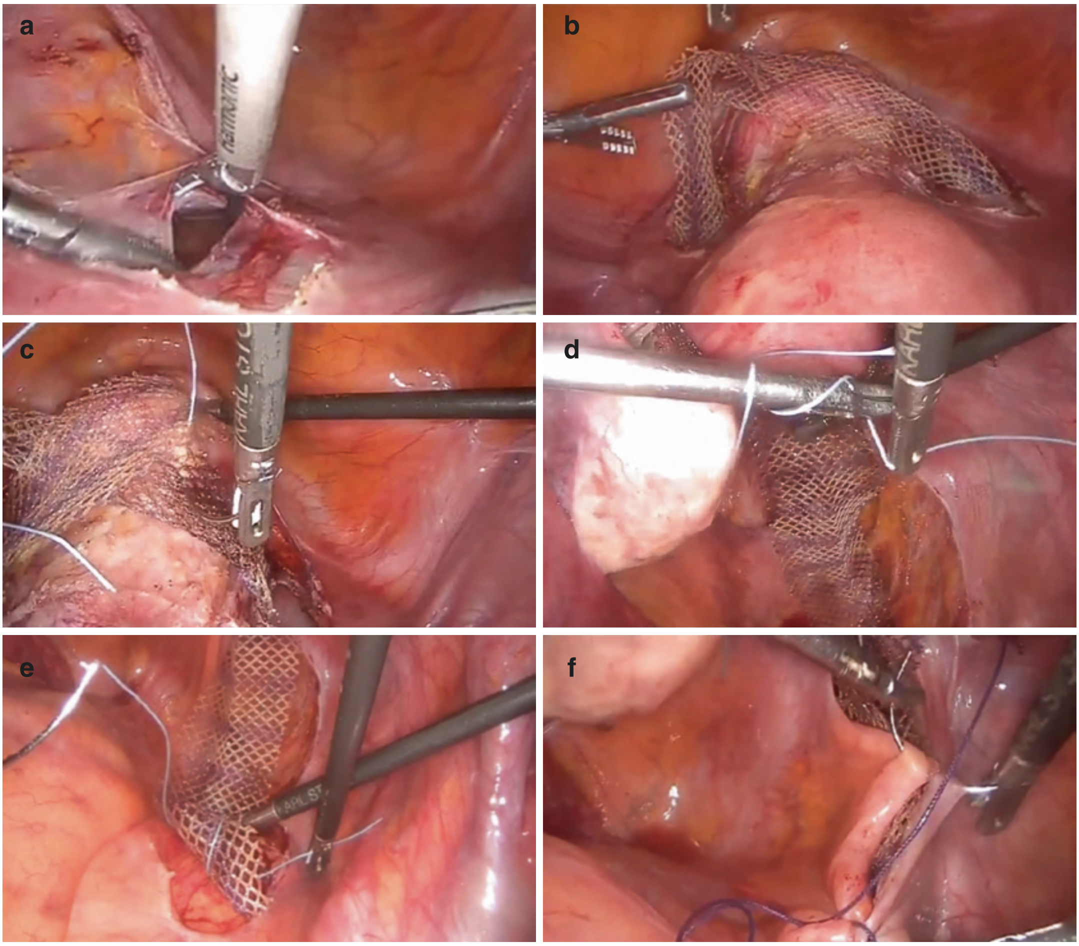


**Image 1** (**a**) Creation of avascular window in right broad ligament after dividing the uterovesical peritoneum. (**b**) Both limbs of Y-mesh brought anteriorly through broad ligament windows. (**c**) Suturing both limbs of the Y-mesh to the cervix anteriorly. (**d**) Suturing the stem of the Y-mesh to the cervix posteriorly. (**e**) Anchoring the tail of the Y-mesh to the anterior longitudinal ligament of the sacrum by laparoscopic suturing. (**f**) Closure of the peritoneum by simple continuous laparoscopic suturing to completely cover the mesh. (Adapted from Salunke V, Pande S. Laparoscopic Hysteropexy for Prolapse Uterus. Accessed at: https://www.youtube.com/watch?v=9nGbHbvuGqE)

passed anteriorly (one on each side) through the earlier created windows in the broad ligament. Both arms are then brought together in the midline on the uterine cervix and isthmus (see Image 1b). Interrupted stitches of a nonabsorbable suture such as No. 1 Ethibond or Prolene are used to anchor the mesh to the cervix (see Image 1c). Posteriorly, the mesh is anchored with similar sutures to the posterior surface of the uterus at a level below the uterosacral ligaments (see Image 1d). Subsequently, stitches are placed to anchor the mesh to the uterine attachment of each uterosacral ligament. The stem of the Y is further anchored to the cervix in the midline posteriorly. Its free end is then anchored to the anterior longitudinal ligament of the first piece of the sacrum using nonabsorbable stitches, while the posterior vaginal fornix is elevated from below to achieve the depth of correction that approximates the total vaginal length (see Image 1e). Tackers can be used as an alternative to sutures at this point. Any excess mesh is trimmed off. Finally, using

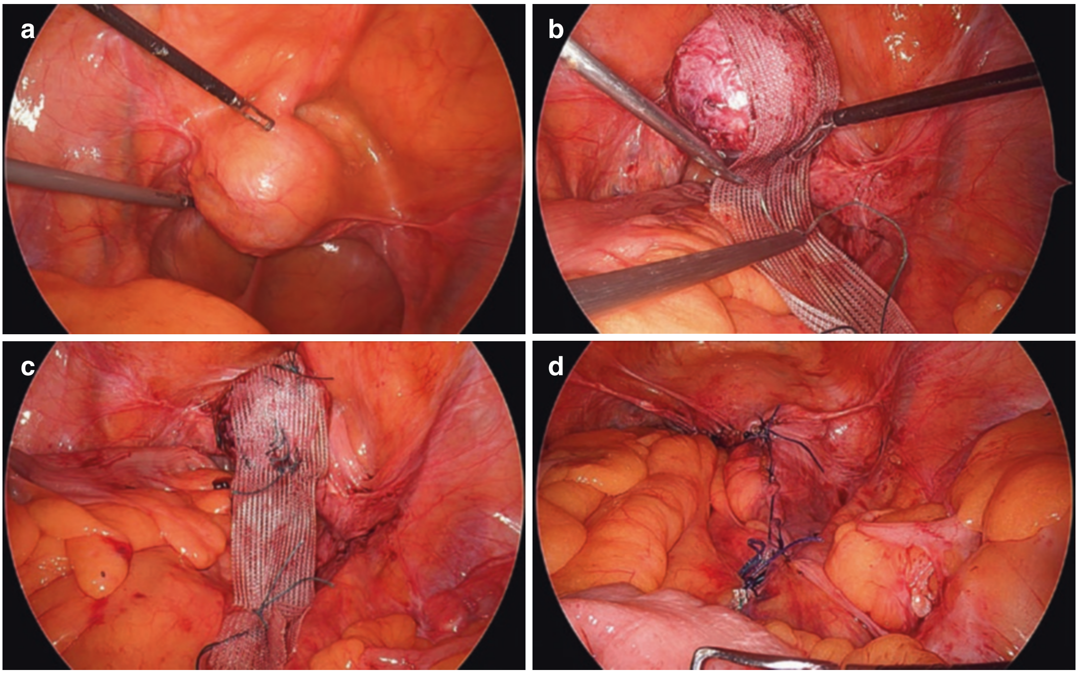


**Image 2** (**a**) Placing a transverse incision on the peritoneal covering of the vaginal vault. (**b**) Anchoring the mesh to the vaginal vault with the aid of laparoscopic suturing. (**c**) Mesh fully anchored to vaginal vault and sacrum with the aid of laparoscopic suturing. (**d**) Re-peritonealization of the sacrocolpopexy mesh completed. (Images used with the kind permission of Dr. Nutan Jain)

continuous 2/0 vicryl suturing, the vesicouterine and rectovaginal peritoneal incisions are closed in such a way as to completely bury the mesh (see Image 1f). Overall, laparoscopic sacrohysteropexy has a 95% cure rate [50].

### 3.2 Laparoscopic Sacrocolpopexy

This procedure bears great similarity to sacrohysteropexy, except for the absence of the uterus. In this case, the second assistant inserts a swab-on-a-stick into the vagina to aid the laparoscopic delineation of the vaginal vault. A transverse incision is made into the peritoneum covering the vaginal vault. Through this incision, blunt dissection is performed to separate the bladder and displace it caudally (see Image 2b). A longitudinal peritoneal incision is placed medial to the right ureter as earlier described for sacrohysteropexy. A Y-shaped piece of macroporous polypropylene mesh is draped over the vaginal vault such that one arm apiece is on the anterior and posterior vaginal walls, while its tail end is extended to the sacral promontory.

The anterior arm of the mesh is sutured to the anterior wall of the vagina. The mesh is progressively anchored at the vaginal apex and the posterior vaginal wall. The proximal end of the mesh is then fixed to the anterior longitudinal ligament of the first sacral piece using either sutures or tackers. Finally, the peritoneum is closed to completely bury the mesh as described for sacrohysteropexy (see Image 2a–d). This procedure has similar success rates to sacrohysteropexy [49].

### 3.3 Laparoscopic Uterosacral Suture Sacrohysteropexy

This procedure is also referred to as the meshless sacrohysteropexy [51]. It is essentially the laparoscopic plication of the uterosacral ligaments using a nonabsorbable suture such as No. 1 Ethibond or prolene. The procedure has a good success rate, but recurrence rates may be high [52].

### 3.4 Sacrospinous Ligament Fixation

Sacrospinous ligament fixation is a vaginal procedure which provides an alternative to sacrohysteropexy or sacrocolpopexy. The procedure starts with injection of fluid into the subcutaneous tissue of the posterior vaginal wall for hydro-dissection of the rectovaginal space. A midline vertical incision is thereafter placed on the posterior vaginal wall and this is bluntly dissected postero-laterally with a finger to reach the sacrospinous ligament. The sacrospinous ligament runs between the ischial spine laterally and the sacrum postero-medially.

With three Langdon retractors carefully placed to retract the vaginal walls, each sacrospinous ligament can be sufficiently exposed in succession A No. 1 Ethibond or prolene suture on a Capio needle [53] is then passed through the ligament at least 2 cm medial to the ischial spine to avoid damaging the pudendal vessels and sciatic nerve which pass behind the ligament [54]. Two to three such sutures are laid at least 5 mm apart. The same procedure may be repeated on the opposite side. As an alternative to the Capio needle, a long needle holder may be used to drive the suture needle through the ligament and the needle retrieved with a laparoscopic needle holder [55]. The already laid sacrospinous ligament sutures are anchored to the cervix if the uterus is present, or the vaginal vault if the uterus had been removed.

Repair of the vaginal incision is commenced from the apex with 2/0 vicryl. The sacrospinous ligament sutures are then tied firmly, thereby pulling up the vaginal apex to the level of the sacrospinous ligaments. The prolene sutures are then cut and the posterior vaginal wall closure completed. Sacrospinous ligament fixation has a success rate of 85%. It is however associated with a high rate of postoperative gluteal pain [56].

### 3.5 Laparoscopic Burch Colposuspension

Burch colposuspension is the reference standard against which every other treatment of stress urinary incontinence is compared. The procedure starts with fluid distension of the bladder to delineate it. A transverse incision is then made on the anterior abdominal wall peritoneum, above the level of the distended bladder (see Image 3a), and bluntly dissected caudally into the space of Retzius (see Image 3b, c). The space of Retzius is bounded anteriorly by the transversalis fascia, the pubic symphysis medially, the superior pubic rami and Cooper's ligaments laterally, and the obturator fascia inferiorly [57]. This space is dissected until the Cooper's ligaments are well exposed laterally, and the urethrovesical junction and proximal urethra are seen resting on the vagina posteriorly (see Image 3d).

A swab-on-a-stick inserted in the vagina by the second assistant will help delineate the vaginal wall and therefore the paravaginal fascia. Using a nonabsorbable suture such as No. 1 Ethibond or prolene, bites are taken of the paravaginal fascia beside the urethra at the level of the midurethra and tied to the Cooper's ligament (see Image 3e, f). A second bite is taken at the level of the urethrovesical junction and also tied to the Cooper's ligament. Two similar stitches are placed on the contralateral side and all the stitches are tied securely, resulting in elevation of the bladder neck and proximal urethra. The peritoneal incision is subsequently closed with simple continuous vicryl 2/0 suturing. Thereafter, a cystoscopy is performed to rule out any urethral or bladder injury.

### 3.6 Transurethroscopic Bulkamid® Injection

Transurethroscopic injection of a urethral submucosa bulking agent such as polyacrylamide

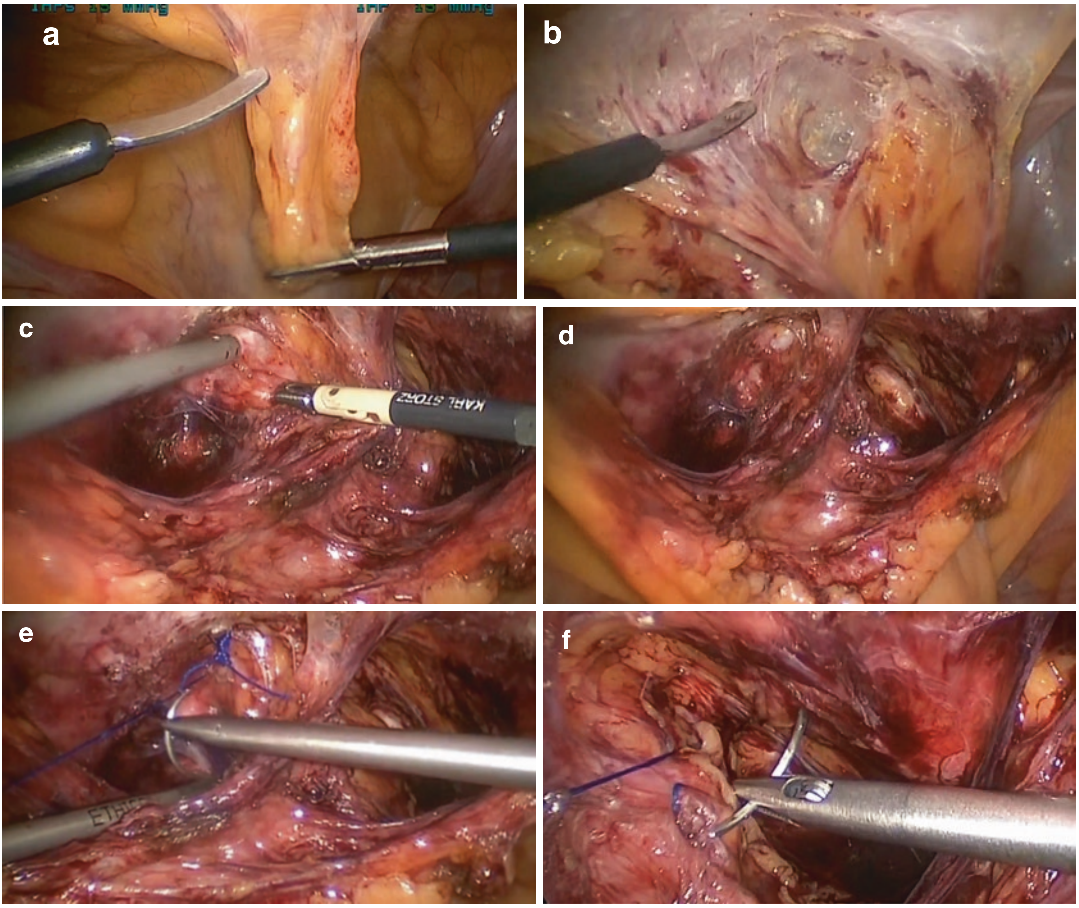


**Image 3** (**a**) Transverse incision of the anterior abdominal wall peritoneum above the distended bladder to access the space of Retzius. (**b**) Blunt dissection of the space of Retzius facilitated by the pneumoperitoneum. (**c**) Dissection of the left retropubic space. (**d**) Completed dissection of the retropubic space bilaterally. (**e**) Stitch placement in the paravaginal left fascia. (**f**) Taking a bite of the Cooper's ligament to complete the colposuspension stitch. (Adapted from Salunke V, Pande S. Burch Colposuspension. Accessed at: https://www.youtube.com/watch?v=Vl_ji1Gh2vM)

hydrogel (Bulkamid®) is currently a first-line treatment option for stress urinary incontinence [4–6]. The procedure starts with mounting the supplied needle on the preloaded gel syringe and charging the needle to expel air. The urethroscope is coupled with its sheath and the charged needle, and syringe is inserted into the working channel of the sheath. The needle is held back within the sheath, and urethroscopy is performed. After visualizing the entire urethra up to the internal meatus, the assembly is withdrawn slightly to about the midurethra and aligned to be in contact with and parallel to the 6 O'clock. The needle is then advanced into the urethral submucosa up to the first calibration mark (1 cm), and the gel is injected until the resulting cushion occludes the internal urethral meatus halfway. The same procedure is then repeated at the 3 and 9 O'clock positions, to achieve optimal coaptation of the urethra. An indwelling catheter must not be inserted, as the gel can model around it, resulting in loss of the intended coaptation. Bulkamid is usually effective for more than 5 years, and repeat injections can be administered when the effect wears off. Success rate with Bulkamid is up to 95% [4–6].

### 3.7 Cystoscopic Botox Injection

Direct injection of Botox (Onabotulinum toxin A) into the detrusor muscle of the bladder is a valuable treatment modality for urge incontinence due to detrusor overactivity when pharmacological treatment has failed [7]. The procedure entails performing a diagnostic cystoscopy to first visualize the inter-trigonal ridge and the trigone of the bladder. The ureteric orifices are visualized, and spontaneous jets of urine observed. The supra-trigonal walls of the bladder are then inspected. Afterwards, a cystoscopic needle mounted with a syringe containing the intended dose of Botox (100–200 IU) is inserted through the working channel of the cystoscope. The needle is advanced at an angle and inserted 2–3 mm into the bladder wall, and the Botox is injected in 0.5–1 cc aliquots at different points at least 1 cm apart distributed all over the bladder wall excluding the trigone. The procedure has a success rate of 73% and is effective for 6–9 months [7]. It can therefore be repeated every 6–9 months.

### 3.8 Laparoscopic Vesicovaginal Fistula Repair

There are two different techniques commonly applied in laparoscopic vesicovaginal fistula repair. The first is the transvesical approach which is similar to the open transabdominal O'Conor technique in that it involves intentional laparoscopic vesicostomy to gain access to the fistula through the bivalved bladder [58–62]. The fistula is then dissected to separate the bladder and vaginal walls sufficiently for adequate tissue mobilization and tension-free repair. The vaginal and bladder defects are then sutured separately using single layer interrupted intracorporeal or extracorporeal surgeon's knots carefully placed to ensure a water-tight seal. The vesicostomy is similarly sutured, and a pedicled omental flap may then be interposed between the vaginal and vesical suture lines.

The second method is the extravesical approach which as the name implies avoids vesicostomy [63, 64]. In this technique, a cystoscopy is first performed during which both ureteric orifices are catheterized with double-J stents. One end of a different coloured ureteric catheter is then inserted per urethra and guided cystoscopically into the vagina through the vesicovaginal fistula, and then brought out at the vaginal introitus, thus straddling the fistula. This catheter will serve as an important landmark during the laparoscopic dissection and mobilization of the bladder and vaginal walls surrounding the fistula.

The uterovesical peritoneum is incised laparoscopically, and dissection is carried on caudally to expose the ureteric catheter straddling the fistula, which is then cut and pulled out by its tails through the vagina and urethra. The dissection and tissue mobilization around the fistula are then completed, and the bladder and vaginal defects are closed separately, without tension. A pedicled omental flap can also be interposed between the bladder and vaginal suture lines thereafter.

## 4 Conclusion

Minimal access gynaecology has undoubtedly altered the practice of the urogynaecology and pelvic floor medicine subspecialty. The resulting combination which may be termed minimal access urogynaecology is indeed a very dynamic field, demanding constant attention to be able to keep abreast with new advances. The recent synthetic surgical mesh controversy is a prime example of the need to follow developments closely by every pelvic floor surgeon in order to be well guided concerning the directions of future practice in the subspecialty.

**Learning Points**

- Urogynaecological disorders such as urinary incontinence and pelvic organ prolapse are very common worldwide, and their treatment is quite often surgical.
- With the advent of minimal access gynaecology, some of the more traditional approaches to the surgical management of urogynaecological disorders have begun to give way to

the laparoscopic, urethroscopic, and cystoscopic approaches to surgical treatment.

- Minimal access procedures such as laparoscopic sacrocolpopexy or sacrohysteropexy, laparoscopic Burch colposuspension, and laparoscopic vesicovaginal fistula repair, transcystoscopic Botox injection for detrusor overactivity and transurethroscopic injection of bulking agents for treatment of stress urinary incontinence are now standard.
- The controversy surrounding the use of synthetic mesh in the pelvis is still ongoing and every pelvic floor surgeon must keep abreast with the current evidence-based guidelines, to guide their practice.

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# Laparoscopic Myomectomy

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## 1 Introduction

Uterine fibroids are benign monoclonal tumours of the smooth muscle cells of the uterus. Fibroids typically develop in any area with smooth muscle cells derived from the Mullerian duct. For this reason, fibroids can be found in the uterine body, cervix, and fallopian tubes. Within the uterus, they can be subserous, intramural, or submucous.

Fibroids are common in women of African descent, compared with their Caucasian counterparts, with an 80% and 70% chance, respectively, of developing fibroids by the age of 50 years [1]. Most women with uterine fibroids are asymptomatic, but sometimes symptoms such as abnormal uterine bleeding, urinary frequency, pelvic pressure and pain, infertility, and rarely constipation might arise, necessitating treatment. Treatment can be in the form of a myomectomy, especially in women still desirous of conception. Some postmenopausal women might occasionally desire a myomectomy rather than a hysterectomy for some psychosocial and cultural reasons.

The precise impact of fibroids on fertility is unknown. While submucous fibroids have been demonstrated to impair fertility, the subserous components do not seem to have any effect on fertility [2, 3]. The evidence for the removal of intramural fibroids is weak, and if intramural fibroids do have an impact on fertility, it appears to be very small, especially if the endometrium is not breached [4]. In cases where no other cause can be adduced for infertility, it might be prudent to consider a myomectomy [5].

Fibroids can be surgically removed via a laparotomy (open myomectomy), laparoscopy, and hysteroscopy.

Laparoscopic myomectomy was described for the first time in 1979, exclusively for subserous fibroids [6]. About a decade later, laparoscopic myomectomy for intramural fibroids was performed [7]. Presently, the surgical expertise of laparoscopic myomectomy has grown in leaps and bounds.

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## 2 Advantages of Laparoscopic Myomectomy Over Open Abdominal Myomectomy

- Fewer scars
- Less tissue handling
- Less blood loss
- Less risk of adhesion formation
- Less post-operative pain
- Early recovery and discharge

Cost and prolonged operating time are disadvantages of laparoscopic myomectomy.

## 3 Patient Selection for Laparoscopic Myomectomy

Not all patients with uterine fibroids are candidates for laparoscopic myomectomy. Proper patient selection is key to an effective and safe surgery. Laparoscopic myomectomy is primarily for the removal of intramural and subserous fibroids. The size and number of fibroid seedlings are also of immense importance. In the largest prospective multicentre study of 2050 women undergoing laparoscopic myomectomy, certain fibroid characteristics were observed to be significantly associated with major complications such as bleeding requiring blood transfusion, visceral injury, and procedural failure. These characteristics included the size of the fibroid greater than 5 cm, more than three fibroid seedlings removed, and intraligamentous location [8]. While significantly larger fibroids have been removed laparoscopically, it is generally recommended that fibroids with sizes not more than 8–10 cm and a maximum number of 4 should be managed laparoscopically [9]. Also, most surgeons have over time developed their own individual criteria, and the choice in terms of size and number of fibroids is often determined by the pathological findings and surgical skills [10].

While hysteroscopic myomectomy is advocated in the management of submucous fibroids, a laparoscopic approach has more advantages in type 2 submucous fibroids (more than 50% of the fibroids lie within the uterine muscle) measuring more than 4 cm in diameter [11].

## 4 Preoperative Considerations

Following a clear-cut indication for myomectomy, it is important that the patient should be properly evaluated preoperatively to ensure she is the right candidate for the laparoscopic approach. This would involve a detailed history with an emphasis on the symptom profile, menstrual and reproductive histories, including assessing the patient's goals. A proper physical examination is mandatory.

General investigations including a full blood count particularly packed cell volume estimation to rule out anaemia; infection screening for the human immunodeficiency virus, hepatitis B and C viruses; blood sugar profile; electrolyte, urea, and creatinine; and liver function test and urinalysis are performed. Blood is equally grouped and cross-matched before surgery.

Imaging techniques play a vital role in determining the patient's suitability or otherwise for laparoscopic myomectomy. A pelvic ultrasound scan gives important information about the type, size, and location of the fibroids. In a recent prospective cohort study, a preoperative pelvic ultrasound scan was able to correctly identify the number of fibroids in 72.3% of the patients studied. While 94.7% of the 208 fibroids identified by ultrasound scan were removed, 11 or 5.3% (all intramural) were not visualized during LM and therefore could not be removed [12].

Saline infusion sonography and hysteroscopy are particularly helpful in ruling out any endometrial cavity involvement of the fibroid and therefore have a role in determining the suitability or otherwise of laparoscopic myomectomy.

Magnetic resonance imaging (MRI) is superior to pelvic ultrasound scans in terms of determining the number of fibroids, their location, and nature. It can also effectively rule out adenomyosis and is of benefit in cases with large broad ligament fibroids with possible ureteric obstruction (which can also be diagnosed with an intravenous urogram).

Preoperative considerations should also include ruling out occult malignancy. For this reason, an endometrial biopsy and cervical cytology should be performed. Power morcellation is contraindicated if a malignancy is diagnosed or suspected.

Above all, proper counselling of the patients about the risk of laparoscopic myomectomy, conversion to laparotomy or even hysterectomy, route of subsequent deliveries, as well as the risk of uterine rupture should be discussed and documented.

The use of GnRH agonist prior to surgery makes it more difficult to identify and dissect the cleavage plane between the fibroid and its pseudocapsule, thereby increasing operating time and the risk of conversion [13, 14].

## 5 Instruments Required

Apart from the general instruments required for laparoscopy, the following should be available:

1. Trocars: 5 mm × 3; 10 mm × 2
2. Unipolar/bipolar electrodes
3. Myoma screw
4. Laparoscopic tenaculum
5. Vasopressin
6. Newer sealing devices if available (Harmonic scalpel, thunderbeat, etc.)
7. Uterine manipulator
8. Morcellator

## 6 Technique

### 6.1 Patient Positioning

The patient is usually placed (under anaesthesia) in the dorsal half-lithotomy position with both arms tucked by her side in a military-style position and adequately padded with foam. To prevent excessive pressure on the legs, these can be supported with stirrups such as Allen's stirrups.

### 6.2 Preparation of the Operating Field

The abdominal wall and perineum, including the vagina, are cleaned with antiseptics and draped. An indwelling Foley catheter may be left behind. Intravenous prophylactic antibiotics are administered.

### 6.3 Port Position

A number of port configurations exist for laparoscopic myomectomy. Generally, port placement is based on the position and size of the fibroids to be removed and also on what is comfortable for the surgeon. While single, 2-port, 3-port, and 4-port approaches have been described for laparoscopic myomectomy, the authors use the 4-port technique. The primary port for the laparoscope should ideally be placed higher than the fundus of the uterus, or for fibroids, this might mean above the umbilicus (Fig. 1) or Palmer's point. While some surgeons prefer contra-lateral ports for suturing, the authors use ipsilateral ports. Two ancillary ports are placed about 3 cm medial and superior to the anterior superior iliac spines. For ipsilateral suturing, a fourth port is placed laterally, slightly caudal to the umbilicus. All three ancillary ports can be 5 mm ports, with the ipsilateral lower port later converted to 10–12 mm or

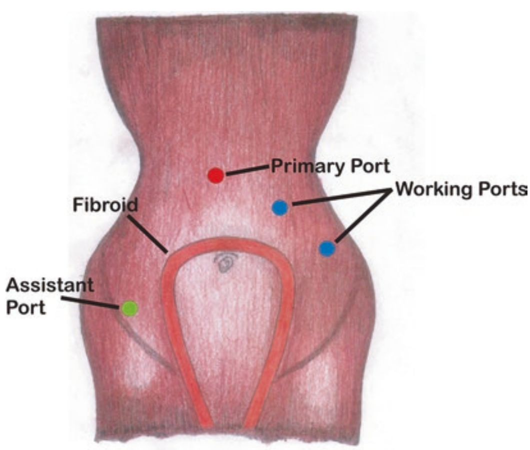


**Fig. 1** Port positions

higher (depending on the size of the morcellator) for morcellation. Occasionally, some surgeons introduce a suprapubic port to help with uterine manipulation and/or suturing. Proper inspection of the pelvic cavity is undertaken (Fig. 2).

## 6.4 Vasopressin Injection

Myomectomy can be associated with significant bleeding because of the increased number of arterioles and venules to the fibroids. Vasopressin, which is a vasoconstrictor, decreases blood loss during myomectomy and has the added advantage of assisting with aquadissection (Fig. 3a, b). Before injecting the vasopressin, it is usually diluted with normal saline. Because of the several complications associated with vasopressin injection such as bradycardia, cardiovascular collapse, and even death, it should be used with caution [15]. While no agreed optimal dose exists, most reported complications occurred when high doses were administered. Friedman et al. [16] proposed an upper limit of 4–6 units as being safe. Between 0.05 and 0.3 IU/L [17] of vasopressin is injected with either a 20-gauge spinal needle percutaneously or a laparoscopic needle attached to a hypodermic syringe that contains the drug, passed through the port closest to the fibroid. The pseudocapsule of the fibroid is injected until blanching occurs. As an example, 20 IU of vasopressin in 100 mL of normal saline gives a dilution of 0.2 IU/L. If 25 mL of the solution is used, it translates to a dose of 5 IU. Since vasopressin has a half-life of 45–60 min, it is safe to repeat the dose thereafter. It is good practice to confirm the needle is not in a blood vessel, and informing the anaesthetist before injecting. Alternatives to vasopressin include 0.25% bupivacaine with epinephrine injected in exactly the same way. The use of laparoscopic uterine artery occlusion for the reduction of blood loss has also been described [18].

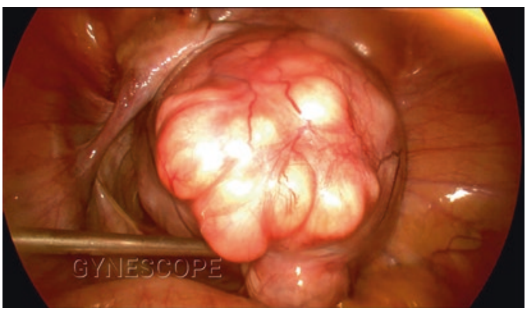


**Fig. 2** Inspection of the pelvic cavity

## 6.5 Making the Uterine Incision

Following the injection of vasopressin (or the other alternatives), an incision is next made on the serosa overlying the fibroid. This is commonly made with a monopolar hook or with more advanced devices like the harmonic scalpel (Fig. 4). The type of incision whether vertical or transverse will depend on the choice of the surgeon as well as port placement. While some surgeons prefer vertical incisions, others prefer a

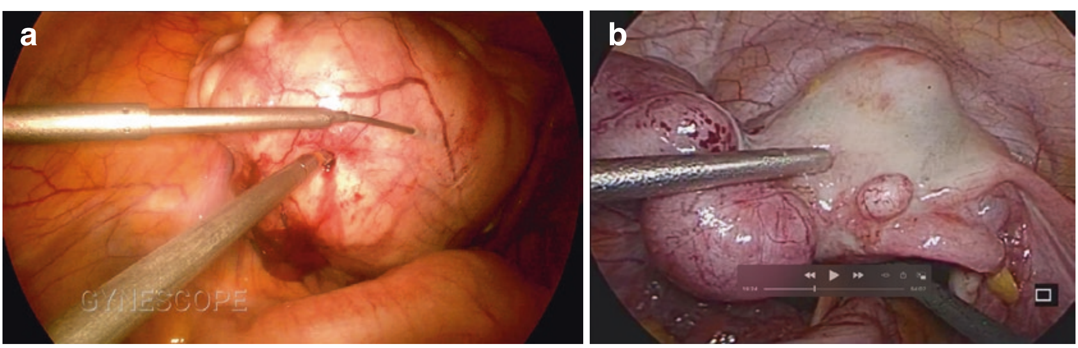


**Fig. 3** (**a**, **b**) Vasopressin injection. (Image b courtesy of Dr. Joseph Njagi)

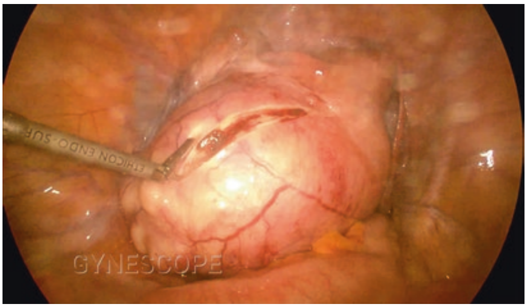


**Fig. 4** Making an incision with a harmonic scalpel

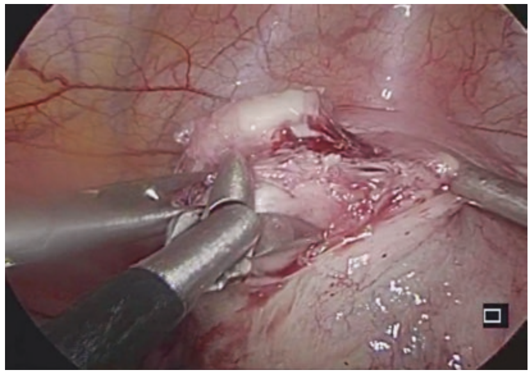

**Fig. 5** Enucleation of the fibroid seedlings. (Image courtesy of Dr. Joseph Njagi)

transverse incision. It would be extremely difficult repairing a vertical incision via ipsilateral ports just as it would be difficult repairing a transverse incision using contra-lateral ports. The incision is continued until it reaches the fibroid capsule; usually, the glistening white capsule can be visualized, and the fibroid bulges out.

## 6.6 Enucleation of the Fibroid

Commence enucleation by grasping the fibroid with either a laparoscopic tenaculum or a myoma screw and apply traction while holding the edge of the myometrium with traumatic grasping forceps such as an Alice forceps (Fig. 5). A suction irrigation tubing, Maryland dissector, or the harmonic scalpel can then be used to shell out the fibroid. The uterine defect is irrigated, and any visible bleeder coagulated with bipolar forceps.

## 6.7 Suturing the Defect

This is a crucial aspect of laparoscopic myomectomy. Whether re-approximating the myometrium via laparoscopic suturing gives the uterine wall the same strength as multilayer closure at laparotomy is still debatable [13, 19]. While there seems to be no agreement in terms of the number of layers of suturing that could prevent future uterine rupture, it is essential however to close dead spaces to prevent haematoma formation, which can potentially lead to wound breakdown or future rupture of the uterus. First start by suturing any endometrial defect with vicryl 3-0 or monocryl 3-0 in a single layer, either by continuous or interrupted stitches. Next, repair the myometrium ensuring symmetry of both sides of the myometrium. The authors commonly use vicryl 1 or 2-0 sutures in a continuous fashion taking bites about 1 cm apart. One or two layers of closure are applied depending on the depth of the uterine wound. Finally, the serosa layer is closed, typically in a continuous manner, preferably using monocryl 3-0 sutures (Fig. 6a–c). Suturing is generally performed using intracorporal suturing techniques, albeit, some surgeons prefer extracorporal suturing

The introduction of the barbed suture, V-loc, and Quill sutures has made suturing much easier as they obviate the need for tying knots. The quill (Stratafix) suture is bidirectional. Suturing therefore begins from the middle of the wound, and each half is run in the opposite direction until they reach the edge of the defect.

## 6.8 Removal of Fibroids

This is achieved with the use of a morcellator preferably via the left lower quadrant port (Fig. 7a, b), or via a posterior colpotomy. In using a morcellator, the risk of an occult malignancy and risk of spread should be borne in mind and steps taken toward preventing this. Morcellation within a retrieval bag helps reduce the dissemination of fibroid tissues within the abdominal cavity. Proper irrigation is mandatory thereafter.

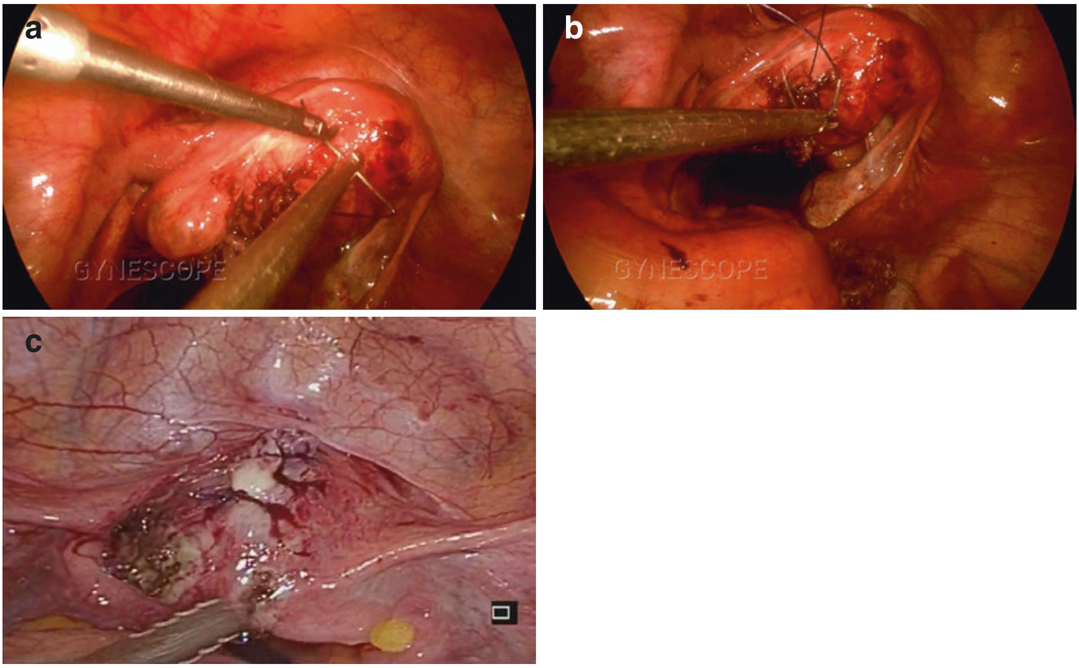


**Fig. 6** (**a**, **b**) Suturing. (**c**) Suturing of the fibroid cavities

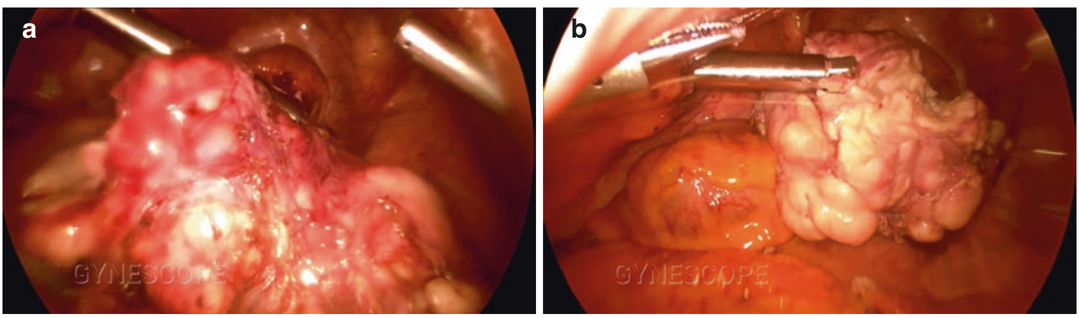


**Fig. 7** (**a**, **b**) Morcellation

## 7 Special Situations

### 7.1 Hand-Assisted Laparoscopic Myomectomy (HALM)

This helps to overcome some of the limitations of laparoscopic surgery, such as multiple or massive fibroids, as well as diverse pelvic adhesions. It takes advantage of the benefits of laparoscopy as well as that of a tactile feel. In the year 2000, Pelosi reported hand-assisted laparoscopic surgery (HALS) with the evacuation of a fibroid mass that reached the level of the liver and weighed 3120 g [20].

Typically, an incision is made in the patient's abdomen, and the size of the incision is based on the surgeon's hand and the size of the tumour. A special appliance is introduced into the abdomen via the incision. This prevents leakage of gas. The surgeon introduces his hands via this device and takes advantage of the feedback of tactile sensation which seems to make HALS safer and more accurate [11, 21].

## 8 Postoperative Considerations

We usually would discharge the patient the following day on non-steroidal anti-inflammatory drugs. She is seen 2 weeks postoperatively and counselled against conception for at least 3 months.

Uterine rupture during subsequent pregnancies is one of the feared complications of laparoscopic myomectomy. The risk of uterine rupture has been reported to be 0.6–1% [22]. Parker et al. [23] reviewed 19 cases of reported uterine rupture following laparoscopic myomectomy and found that the excessive use of electrocautery and single-layer closure were risk factors for subsequent uterine rupture, albeit, it was also suggested that individual wound healing characteristics might predispose to uterine rupture.

**Learning Points**

- While submucous fibroids might impair fertility, the effect of intramural fibroids on fertility remains controversial.
- Patient selection is key to an effective laparoscopic myomectomy.
- As a rule, ensure that the primary port is above the uterine fundus.
- Use vasopressin to control bleeding with care.
- Ensure adequate suturing of the defect with the appropriate suture.
- Do not use a morcellator in suspected malignancies.

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# Laparoscopic Management of Endometriosis

Uche A. Menakaya and Vaduneme Kingsley Oriji

## 1 Definition

Endometriosis is a clinical condition characterized by the presence of endometrial glands and stroma in sites other than the endometrial cavity [1, 2]. Endometriosis principally involves the structures within the female pelvis, but it can also affect tissues beyond the pelvis, resulting in endometriosis of gastrointestinal tract, the thoracic cavity and cutaneous endometriosis. Although endometriosis is a benign disease, it has the capacity to cause significant pelvic pain, patient suffering and reduced quality of life for women living with endometriosis.

## 2 Prevalence

The reported overall prevalence of endometriosis varies between 10% and 15% of reproductive age women [3]. Globally, there are nearly 176 million women living with endometriosis [4]. The disease affects up to 50% of women with infertility and up to 5% of fertile women [3, 5, 6]. Studies have suggested ethnic variations in the prevalence of endometriosis with the disease being more prevalent among Oriental women and least in African American women [7, 8].

Epidemiological data on the prevalence of endometriosis among African indigenous women are meagre [9]. In some of the few published studies, endometriosis constituted the third most common finding at laparoscopies and was reported in 15.7% of laparoscopies performed for infertility assessment [10]. In South Africa, Wiswedel et al. (1989) [11] reported a prevalence of 2% among African indigenous women presenting to an infertility clinic compared to a prevalence of 4–6% among South Africans of mixed and white race. In Nigeria, a prevalence of 4–8% has been reported among women also presenting for assisted reproductive programmes [10, 12, 13].

The low prevalence of endometriosis reported among indigenous African women has been attributed to different cultural and lifestyle factors [14]. In particular, early age at first pregnancy, shorter inter pregnancy intervals with large size families, taboos around menstruation and pain, increased risk of pelvic inflammatory disease and blocked fallopian tube [14–16]. These factors contribute to delays in expression of symptoms and limit the cumulative number of menstrual cycles with retrograde menstruation

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[14–16]. Others have attributed the lower prevalence of endometriosis among indigenous African women to the low awareness of the disease in sub-Saharan Africa, the poor access to diagnostic and therapeutic facilities and the limited training available for the management of endometriosis in the region [12, 17, 18].

## 3 Pathogenesis

A number of theories have been proposed for the pathogenesis of endometriosis [19–22]. A common theory for the pathogenesis of ectopic endometrium is the retrograde menstruation theory where blood from menstruation flows through the fallopian tubes into the pelvis, the viable endometrial tissues in the reflux gets implanted into the pelvic peritoneum and is with under the influence of the cyclical hormonal interplay of the female reproductive system and bleed just like the eutopic endometrium during menstruation [23] (see Fig. 1). This bleeding results in inflammation, adhesions, cysts and other changes within the pelvis that manifest the symptoms and signs of endometriosis [19].

Other theories include the metaplasia of coelomic epithelium, seeding of endometrial cells through the lymphatic channels and blood to ectopic sites [24]. A genetic predisposition with possible polygenic inheritance, hormonal as well as immunologic theories has all been advocated to explain the pathogenesis of endometriosis [20, 25, 26]. Iatrogenic endometrial tissue seedling during caesarean sections, episiotomy scars and during myomectomies is also possible [27].

The biologic mechanisms that link endometriosis and infertility include altered peritoneal, hormonal and cell mediated function, endocrine and ovulatory abnormalities, distorted pelvic anatomy, impaired implantation, poor oocyte and embryo quality and abnormal uterotubal transport [28].

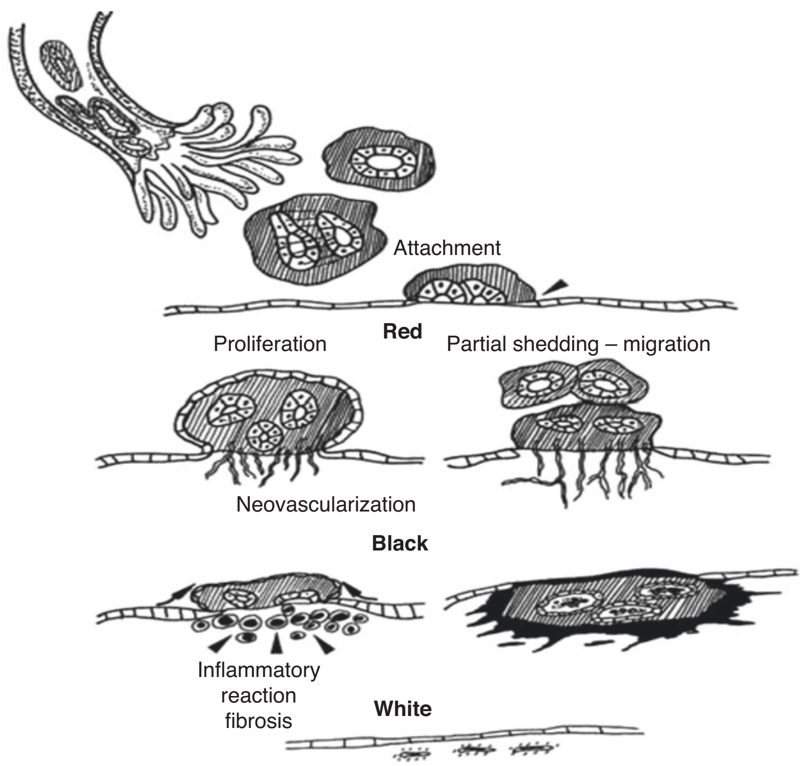



**Fig. 1** Deposition of endometrial tissue through retrograde menstruation and the different forms of peritoneal endometriosis. (Image from Atlas of operative hysteroscopy and laparoscopy, 3rd edition by Jacques Donnez)

## 4 Clinical Features

Pelvic endometriosis is a known cause of chronic pelvic pain and infertility. The disease may be asymptomatic or present as cyclical spasmodic dysmenorrhea, dyspareunia, dyschezia, dysuria and/or infertility. Other symptoms include non-cyclical lower abdominal pain, chronic pelvic pain, low back pain, menorrhagia and irregular menses. Cyclical nonspecific symptoms like insomnia, fatigue, malaise, nausea and vomiting have been described in patients with endometriosis [29, 30].

Additionally, cyclical pain or tender swelling and bloody discharge from the umbilicus and surgical scars as in laparotomy or episiotomy scars may relate to cutaneous endometriosis. The severity and chronicity of the pain induced by endometriosis impact negatively on the general quality of life of women with endometriosis affecting their sexual life, efficiency and productivity at work [7, 8, 31].

Risk factors for endometriosis include early menarche, reduced cycle length, prolonged inter pregnancy interval, nulliparity, family history of endometriosis and exposure to diethylstilbesterol in utero [32]. Conversely, the use of oral contraceptive pills and parity reduce the risk of endometriosis [33, 34].

Physical examination may not be helpful in making diagnosis as vast majority of patients with endometriosis have no significant physical findings. However, a pelvic examination could reveal discrete tender nodules in the adnexa or pouch of Douglas. Cervical motion tenderness may be present as well, and the uterus may be immobile from adhesions. This may suggest the presence of deep infiltrating endometriosis in the pouch of Douglas. A pelvic examination is mandatory to rule out other possible causes of symptoms including pelvic inflammatory disease.

The European Society of Human Reproduction and Embryology (ESHRE) recommends a diagnosis of endometriosis in the presence of gynaecological symptoms such as dysmenorrhoea, non-cyclical pelvic pain, deep dyspareunia, infertility and non-gynaecological cyclical symptoms like dyschezia, dysuria, haematuria and rectal bleeding, shoulder tip pain and fatigue in women of reproductive age [35].

## 5 Histological Phenotypes of Endometriosis

Endometriosis is a heterogenous, multiforme disease. Three principal histological phenotypes of endometriosis are recognized. These include the superficial (peritoneal) disease, deep infiltrating endometriosis (DE) and ovarian endometrioma [36, 37]. These subtypes can occur alone or in combination presenting additional phenotypes of endometriosis that include ovarian adhesions and/or pouch of Douglas obliteration. The severity of symptoms, best treatment option and recurrence rates vary significantly among these various phenotypes of endometriosis [29, 30].

## 6 Diagnosis

Delays in the diagnosis of endometriosis are a significant challenge in the management of endometriosis worldwide. For example, diagnostic delays of up to 10 years have been reported in a number of European countries [38, 39]. In Nigeria, diagnostic delays of 5–7 years have been reported [38].

These delays mainly occur at the primary level of care with women reporting an average of seven visits before specialist referral [38]. The "discrediting" nature of menstrual irregularities and associated risk of stigmatization may also delay women from seeking help [40, 41]. These delays contribute to unnecessary patient sufferings, reduced quality of life and significant personal and societal costs associated with endometriosis [38].

Laparoscopic visualization of endometriotic lesions is considered the current gold standard in the diagnosis of endometriosis, and limited access to expensive laparoscopic services in resource-restricted countries is another contributor to the delay in the diagnosis of endometriosis in these countries.

## 6.1 Preoperative Diagnosis

A number of preoperative strategies are now utilized in clinical practice to reduce the delays in the diagnosis of women with endometriosis. For example, some symptom-based models have demonstrated good accuracy with predicting moderate to severe endometriosis [42]. Predictive tools based on these symptoms-based models could help prioritize women for surgical investigation and treatment in clinical practice [42].

Pelvic ultrasound is another strategy for improving the preoperative diagnosis of endometriosis. There is evidence in support of the performance of transvaginal pelvic ultrasound in the diagnosis of ovarian and extra-ovarian endometriosis as well as their markers of local invasiveness when compared to gold standard laparoscopy [43]. A major advantage of pelvic ultrasound is its ease of use, availability and accessibility to women in resource-restricted countries [44].

## 6.2 Intraoperative Diagnosis

Intraoperative diagnosis of endometriosis can be made with laparotomy or laparoscopy. Laparoscopy is a preferred modality for diagnosing endometriosis because it is usually associated with better intraoperative magnification, less pain, less postop adhesions, shorter hospital stay, quicker recovery and better cosmetics. Irrespective of the modality of surgery, intraoperative recognition of the three principal phenotypes of endometriotic lesions and their markers of local invasiveness are critical to the diagnosis of endometriosis.

Ovarian endometriomas are the most recognized form of endometriosis (see Fig. 2g, h). They are typically described as chocolate cysts and occur in 17–44% of women with endometriosis [45]. DE are endometriosis implants that extend deeper than 5 mm under the peritoneum surface or those involving or distorting bowel, bladder, ureter or vagina [46] (see Fig. 2i, m–p). They occur in 1–5% of women with endometriosis and are commonly found on the uterosacral ligaments [47]. They can also be found on other pelvic organs like the bowel, appendix, bladder and pelvic sidewall and less commonly on the diaphragm and upper abdomen (see Fig. 2q, r).

**Table 1** Types of peritoneal endometriosis [49]

| Colour | Appearance |
|---|---|
| Black | Typical puckered black lesions |
| Red | Red flame-like lesions |
| | Glandular excrescences |
| | Petechial peritoneum |
| | Areas of hyper-vascularization |
| White | White opacifications |
| | Sub-ovarian adhesions |
| | Yellow brown peritoneal patches |
| | Circular peritoneal defects |

Peritoneal endometriosis refers to lesions that involve only the peritoneum and do not invade the underlying tissue. It is the most common type of endometriosis occurring in up to 66% of women undergoing laparoscopy for endometriosis [48]. Peritoneal endometriosis is multiforme and can appear as black, red, white, yellow brown peritoneal lesions or circular peritoneal defects [49] (see Table 1 and Fig. 2a–d). The red lesions are highly vascular, bleed into the peritoneal cavity during menstruation and are associated with early neoangiogenesis, adhesion formation and inflammation (see Fig. 2c, e). Dark or white lesions are correlated with higher amounts of fibrosis, decreased vascularity and decreased bleeding [50] (see Fig. 2a, b, d and f). Peritoneal endometriotic implants can change appearance and even regress with medical treatment but often reappear after cessation of treatment and return of the menstrual cycle [50].

## 6.3 Visual vs. Histological Diagnosis of Endometriosis

Laparoscopy with or without histological verification is widely used to diagnose and rule out the presence of endometriosis. Without histological verification, the experience, skill and knowledge of the surgeon are critical to a diagnosis of endometriosis at laparoscopy [35].

Current evidence recommends that clinicians confirm a positive laparoscopy by histology since positive histology confirms the diagnosis of endometriosis and rules out rare forms of malignancy [35]. The combination of laparoscopy and the histological verification of endometrial glands and/or stroma are considered to be the gold standard for the diagnosis of the disease [35].

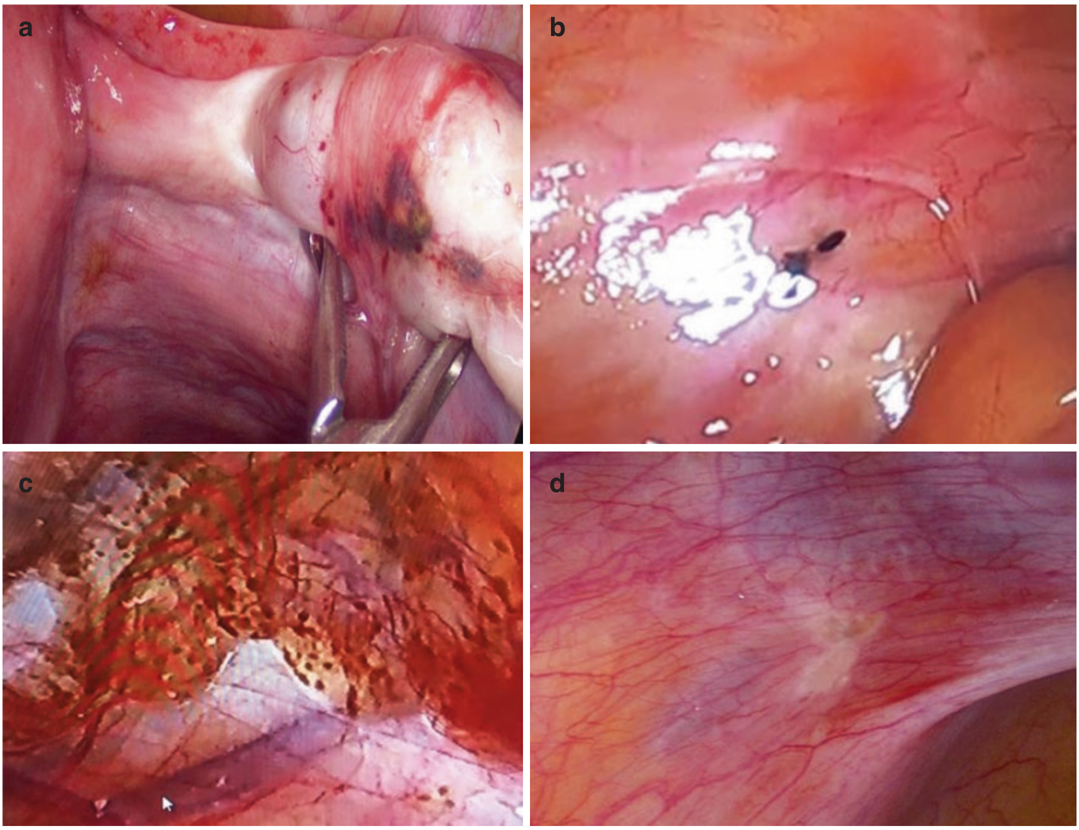



**Fig. 2** Laparoscopic images of different types of endometriosis. (**a**) Superficial ovarian endometriosis (black). (**b**) Peritoneal endometriosis at left pelvic brim (black). (**c**) Widespread peritoneal endometriosis endometriosis in utero vesical space (red). (**d**) Another form of peritoneal endometriosis (yellow brown). (**e**) Another form of peritoneal endometriosis (red). (**f**) Another form of peritoneal endometriosis (white). (**g**) Left endometrioma. (**h**) Right endometrioma with spillage of content. (**i**) Uterovesical endometrioma. (**j**) Rectal endometriosis adherent to left USL DIE. (**k**) Endometriosis with POD obliteration. (**l**) Bowel involvement in POD obliteration. (**m**) Bladder endometriosis. (**n**) Isolated left uterosacral DE. (**o**) Large sigmoid nodular endometriosis. (**p**) Rectal endometriosis in POD. (**q**) Diaphragmatic DE endometriosis. (**r**) Peritoneal endometriosis on diaphragm. (Images courtesy of Junic Laparoscopy Australia)

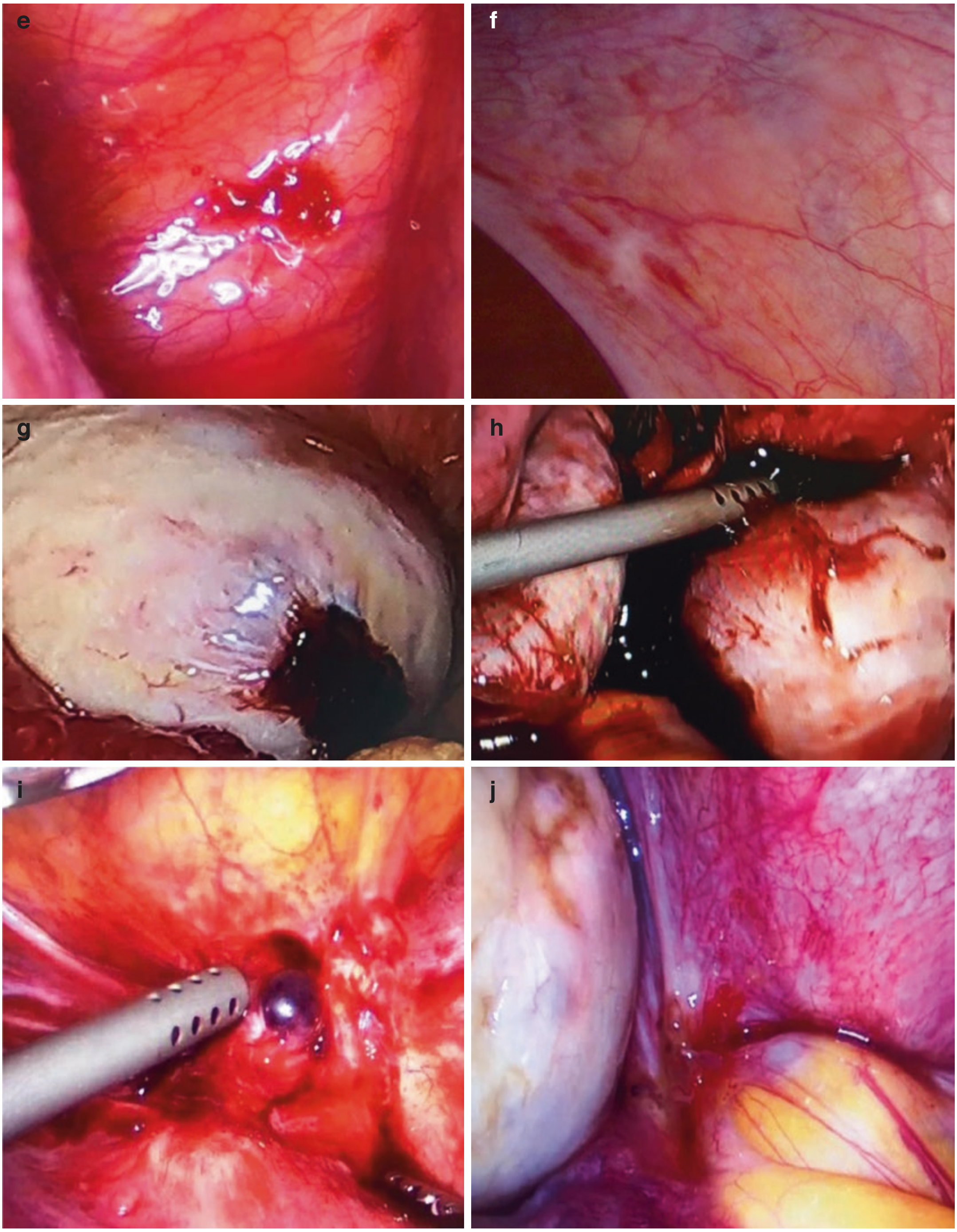



**Fig. 2** (continued)

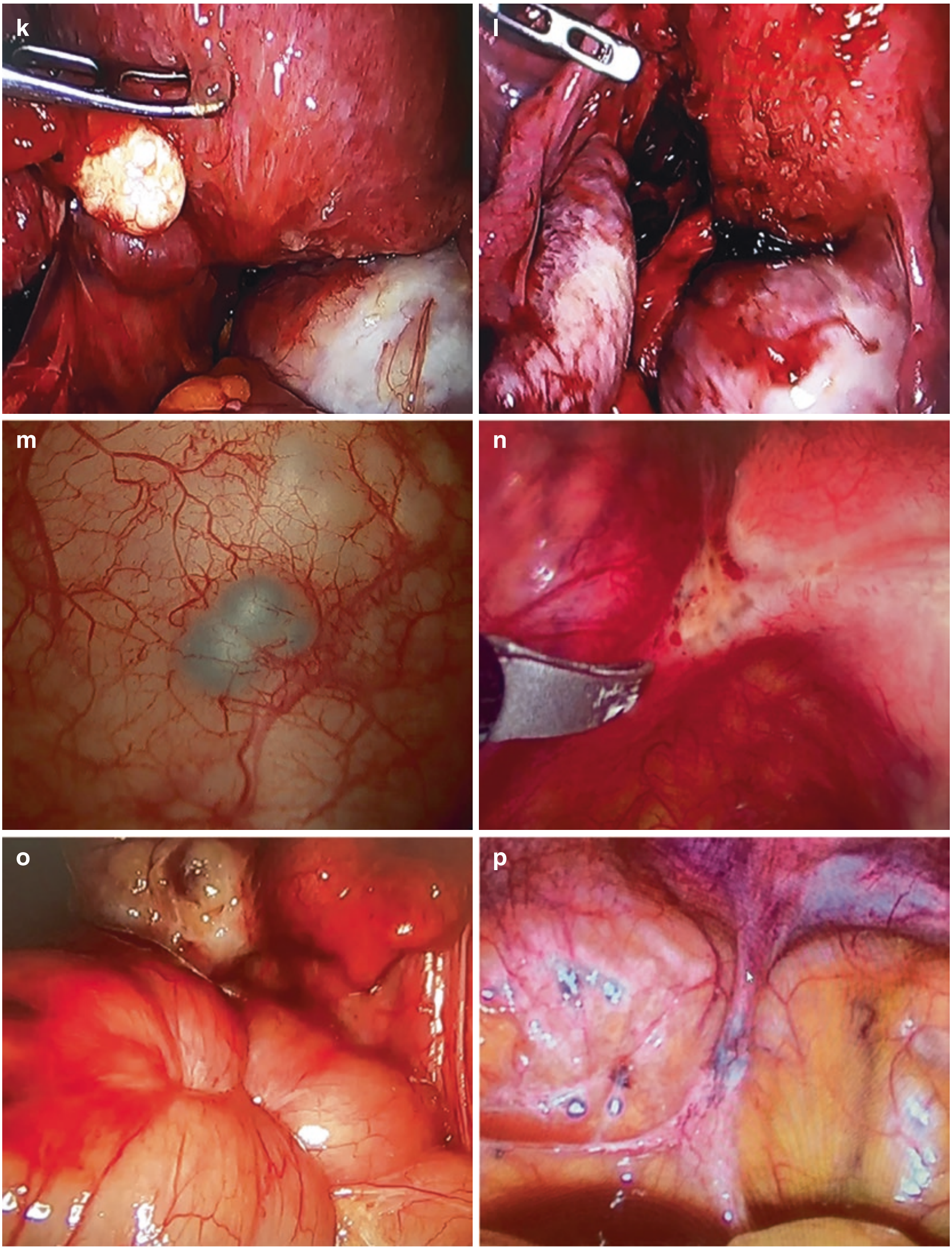



**Fig. 2** (continued)

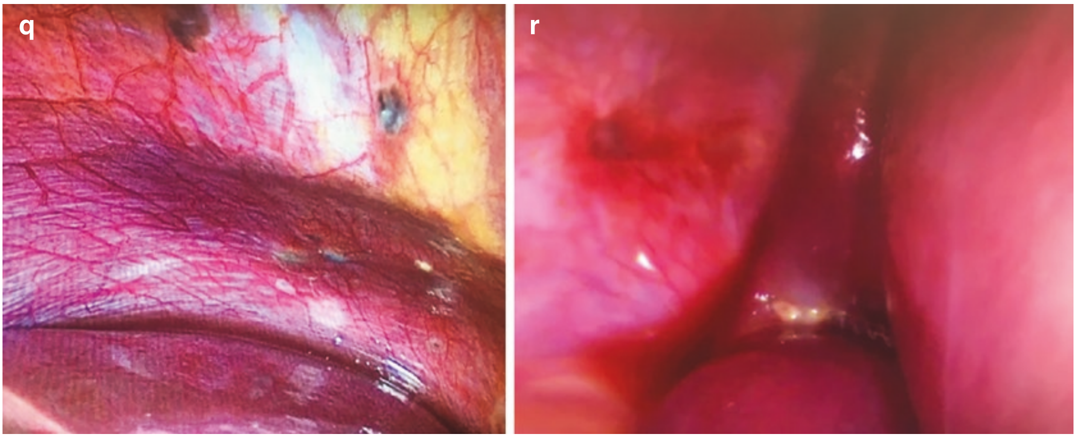



**Fig. 2** (continued)

## 7 Classification of Endometriosis

The classification of endometriosis is another challenge in the management of endometriosis due to the multiple clinical and anatomical manifestations of the disease [36]. Efforts to develop a classification system for endometriosis have struggled to yield a suitable system that enhances endometriosis-related symptom management, prognosis for response to therapies, prediction of recurrence, association with other disorders, quality of life and other key elements of concern (surgeon expertise) to women with endometriosis [36].

A good classification system should be one that benefits women with endometriosis. It should be simple to explain and easy to perform and allow a simple description of the disease. It should also correlate well with the principal symptoms of endometriosis and have the capacity to give prognostic information, predict response to treatment and recurrence of symptoms after treatment. It must be empirically and scientifically based and should have general consensus [51]. A number of pre- and intraoperative classification systems that address some of the key concerns of women living with endometriosis are currently in clinical use.

### 7.1 Preoperative Classification

Preoperative classification of endometriosis is important because it can improve the comprehension of disease severity and enable appropriate preoperative counseling and the triage of women to different forms of treatment [43]. It can also assist with theatre list planning and reduce the need for multiple laparoscopic surgeries [52, 53].

#### 7.1.1 Ultrasound-Based Endometriosis Staging System (UBESS)

An UBESS can be utilized preoperatively to predict the level of complexity of laparoscopic surgery expected for endometriosis [54]. UBESS is a three-stage preoperative staging system that predicts the severity of pelvic endometriosis and is based on the histological phenotypes of endometriosis, the anatomical locations of deep infiltrating endometriosis and their sonographic markers of local invasiveness. The three stages of UBESS (I–III) correlate well with the three levels of complexity of laparoscopic surgery for endometriosis as described by the Royal College of Obstetricians and Gynaecologists (Levels 1–3) (see Table 2).

**Table 2** An ultrasound-based endometriosis staging system to predict complexity of laparoscopic surgery [54]

| UBESS stages | Features assessed on transvaginal ultrasound | Interpretation | Complexity level of surgery |
|---|---|---|---|
| Stage I | Positive SST in PC<br>Mobile ovaries, no endometrioma<br>POD: Positive sliding sign<br>DE nodules: Absent | No hard markers for endometriosis | Level 1<br>Negative laparoscopy or mild stage disease |
| Stage II | Positive SST in PC<br>+ Endometrioma present ± mobile ovaries<br>POD: ± positive sliding sign<br>± Non-bowel DE nodules<br>Bowel DE nodules | Endometrioma<br>± Non-bowel DE<br>Normal POD | Level 2<br>Moderate-stage disease |
| Stage III | Positive SST in PC<br>± Endometrioma ± mobile ovaries<br>POD: Positive or negative sliding sign<br>± Non-bowel DE nodules<br>+ Bowel DE nodules | + Bowel DE<br>± Abnormal POD | Level 3<br>Higher-stage disease |

*SST* site-specific tenderness, *PC* posterior pelvic compartment, *POD* pouch of Douglas, *DE* deep endometriosis
Adapted from Menakaya et al. [54]

### 7.2 Intraoperative Classification

A number of intraoperative classification system for endometriosis are in current clinical use. The most commonly used classification system is the rAFS classification system [55] (see Table 3). In the rAFS classification system, minimal to mild disease describes superficial peritoneal endometriosis and possible presence of small deep lesions and mild filmy adhesions with no endometrioma. Moderate to severe disease describes the presence of superficial peritoneal endometriosis, deeply invasive endometriosis with moderate to extensive adhesions between the uterus and bowels and/or endometrioma cysts with moderate to extensive adhesions involving the ovaries and tubes. The template for recording findings at laparoscopy is shown in Fig. 3. The rAFS classification has limited predictive ability for persistent pelvic pain and pregnancy after surgery.

Another intraoperative classification system in current use is the endometriosis fertility index (EFI) [56]. The EFI provides a simple clinical tool that incorporates the rAFS to predict pregnancy rates for patients after surgical treatment of endometriosis [56]. Unlike the rAFS classification system, the EFI is a useful prognostic tool for developing treatment plans in infertile patients with endometriosis (see Fig. 4) [56].

**Table 3** The revised AFS intraoperative staging for endometriosis

| rAFS stages | Points assigned | Description |
|---|---|---|
| Stage 1 (minimal) | 1–5 | • Few superficial implants |
| Stage 2 (mild) | 6–15 | • More and deeper implants |
| Stage 3 (moderate) | 16–40 | • Many deep implants<br>• Small cysts on one or both ovaries<br>• Presence of filmy adhesions |
| Stage 4 (severe) | >40 | • Many deep implants<br>• Large cysts on one or both ovaries<br>• Many dense adhesions |

(a) REVISED AMERICAN SOCIETY FOR REPRODUCTIVE MEDICINE CLASSIFICATION OF ENDOMETRIOSIS 1985

Patient's Name ____________________ Date: ________________

Stage I (Minimal) 1-5 Laparoscopy______Laparotomy______Photography________
Stage II (Mild) 6-15 Recommended Treatment ____________________________
Stage III (Moderate) 16-40 ____________________________________________
Stage IV (Severe) >40
Total ____________ Prognosis ________________________

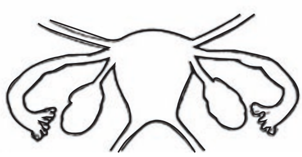
| | ENDOMETRIOSIS | < 1 cm | 1 – 3 cm | > 3 cm |
|---|---|---|---|---|
| Peritoneum | Superficial | 1 | 2 | 4 |
| | Deep | 2 | 4 | 6 |
| Ovary | R Superficial | 1 | 2 | 4 |
| | Deep | 4 | 16 | 20 |
| | L Superficial | 1 | 2 | 4 |
| | Deep | 4 | 16 | 20 |
| | POSTERIOR CULDESAC OBLITERATION | Partial | Complete | |
| | | 4 | 40 | |
| | ADHESIONS | < 1/3 Enclosure | 1/3-2/3 Enclosure | > 2/3 Enclosure |
| Ovary | R Filmy | 1 | 2 | 4 |
| | Dense | 4 | 8 | 16 |
| | L Filmy | 1 | 2 | 4 |
| | Dense | 4 | 8 | 16 |
| Tube | R Filmy | 1 | 2 | 4 |
| | Dense | 4 | 8 | 16 |
| | L Filmy | 1 | 2 | 4 |
| | Dense | 4* | 8* | 16 |

*If the fimbriated end of the fallopian tube is completely enclosed, change the point assignment to 16.

Additional Endometriosis: ________________ Associated Pathology: ________________

To Be Used with Normal Tubes and Ovaries

L R



To Be Used with Abnormal Tubes and/or Ovaries

L R

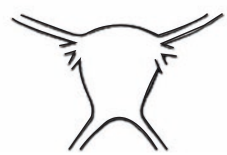


**Fig. 3** RAFS template for recording and scoring findings at laparoscopy. (Revised American Society for Reproductive Medicine scoring system for all women with endometriosis. Reprinted with permission from Elsevier from Fertil Steril 1997;67:817–821)

### LEAST FUNCTION (LF) SCORE AT CONCLUSION OF SURGERY

| Score | | Description | | Left | Right | |
|---|---|---|---|---|---|---|
| 4 | = | Normal | Fallopian Tube | | | |
| 3 | = | Mild Dysfunction | | | | |
| 2 | = | Moderate Dysfunction | Fimbria | | | |
| 1 | = | Severe Dysfunction | | | | |
| 0 | = | Absent or Nonfunctional | Ovary | | | |

To calculate the LF score, add together the lowest score for the left side and the lowest score for the right side. If an ovary is absent on one side, the LF score is obtained by doubling the lowest score on the side with the ovary.

Lowest Score: [ ] Left + [ ] Right = [ ] LF Score

### ENDOMETRIOSIS FERTILITY INDEX (EFI)

| Historical Factors | | | Surgical Factors | | |
|---|---|---|---|---|---|
| **Factor** | **Description** | **Points** | **Factor** | **Description** | **Points** |
| Age | | | LF Score | | |
| | If age is ≤ 35 years | 2 | | If LF Score = 7 to 8 (high score) | 3 |
| | If age is 36 to 39 years | 1 | | If LF Score = 4 to 6 (moderate score) | 2 |
| | If age is ≥ 40 years | 0 | | If LF Score = 1 to 3 (low score) | 0 |
| Years Infertile | | | AFS Endometriosis Score | | |
| | If years infertile is ≤ 3 | 2 | | If AFS Endometriosis Lesion Score is < 16 | 1 |
| | If years infertile is > 3 | 0 | | If AFS Endometriosis Lesion Score is ≥ 16 | 0 |
| Prior Pregnancy | | | AFS Total Score | | |
| | If there is a history of a prior pregnancy | 1 | | If AFS total score is < 71 | 1 |
| | If there is no history of prior pregnancy | 0 | | If AFS total score is ≥ 71 | 0 |
| **Total Historical Factors** | | | **Total Surgical Factors** | | |

**EFI = TOTAL HISTORICAL FACTORS + TOTAL SURGICAL FACTORS:** [ ] Historical + [ ] Surgical = [ ] **EFI Score**

### ESTIMATED PERCENT PREGNANT BY EFI SCORE

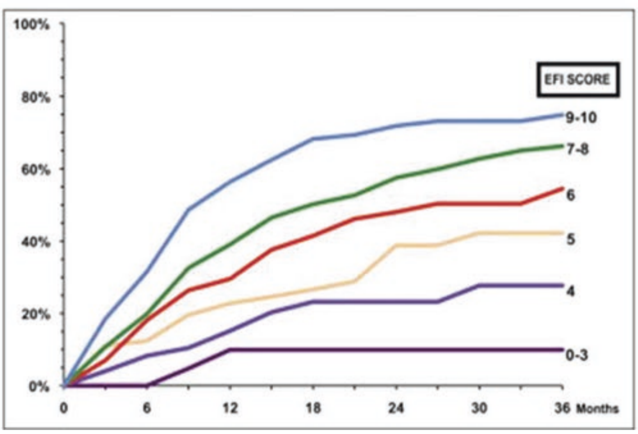



**Fig. 4** Endometriosis fertility index surgery form

## 8 Surgical Treatment

The treatment of endometriosis is aimed at achieving three primary objectives. These include a reduction in pelvic pain symptoms, improvements in pregnancy rates and delays in recurrence of disease. The prerequisites for successful treatment outcomes should include a guideline-oriented approach, a multidisciplinary team care approach and experience of surgical techniques [57].

The knowledge and skill required for treating endometriosis at laparoscopy are increasingly becoming an area of sub-specialization [58]. This is because the laparoscopic technique, the planning of the surgical intervention, the extent of information provided to patients and the interdisciplinary coordination make surgical treatment of endometriosis a challenging intervention.

Surgical treatment should begin with a detailed historical evaluation of patient symptoms and the utilization of appropriate and adequate diagnostic tools. These diagnostic tools are important for preoperative planning, allocation of theatre time and appropriate counselling of patients on the expected outcomes and potential risks associated with surgical intervention.

At laparoscopy, the abdominal entry techniques for endometriosis are similar to that utilized for other gynaecological surgeries. This includes a standard primary visual port usually via the umbilicus or the palmer's point and additional two to three working ports located in the supra public and/or iliac fossae. During surgery, the complete resection of all visible foci of disease offers the best control of symptoms. However, the surgeon must first identify all foci of endometriosis through a systematic evaluation of the pelvis and abdomen prior to their resection.

### 8.1 Systematic Evaluation of the Pelvis at Laparoscopy for the Diagnosis of Endometriosis

A standardized approach to the evaluation of the pelvis at laparoscopy for endometriosis has been recommended. This should incorporate a systematic assessment of the uterus and its adnexa like the anterior and posterior broad ligament and ovaries, the peritoneum of ovarian fossae, the utero-vesical fold, the pouch of Douglas and pararectal spaces including underneath the utero-sacral ligaments. It should also evaluate the rectum and sigmoid for isolated deep endometriosis nodules, the appendix and caecum as well as the upper abdomen including the diaphragm and liver. A pelvic examination under anesthesia is also recommended to assess for deep endometriosis nodules in the laparoscopic basement, i.e. rectovaginal septum, vagina or cervix [53].

Such a comprehensive evaluation of the pelvis would require the patient in Trendelenburg position with at least one secondary port for a suitable laparoscopic grasper. The laparoscopic grasper will assist with clearing bowel loops from the pelvis, fluid suctioning and manipulating the ovaries to examine the ovarian fossae (see Fig. 5).

### 8.2 Conservative, Semi-conservative and Radical Surgical Treatment for Endometriosis

Conservative surgery for endometriosis refers to the resection of visible endometriosis lesions with preservation of the woman's reproductive potential. Semi-conservative surgery includes a hysterectomy with the resection of visible endometriosis lesions but with ovarian conservation. Semi-conservative surgery may be indicated for women with debilitating symptoms who have completed childbearing but are too young to undergo surgical menopause. Radical surgical treatment for endometriosis refers to the inclusion of bilateral oophorectomy together with hysterectomy and resection of visible endometriosis lesions. Patients who undergo hysterectomy with ovarian conservation have a sixfold higher rate of recurrence compared to women who undergo oophorectomy [59].

### 8.3 Ablation vs. Excision

Excision of lesions is preferred as it includes the possibility of retrieving samples for histological diagnosis. Furthermore, ablative techniques are

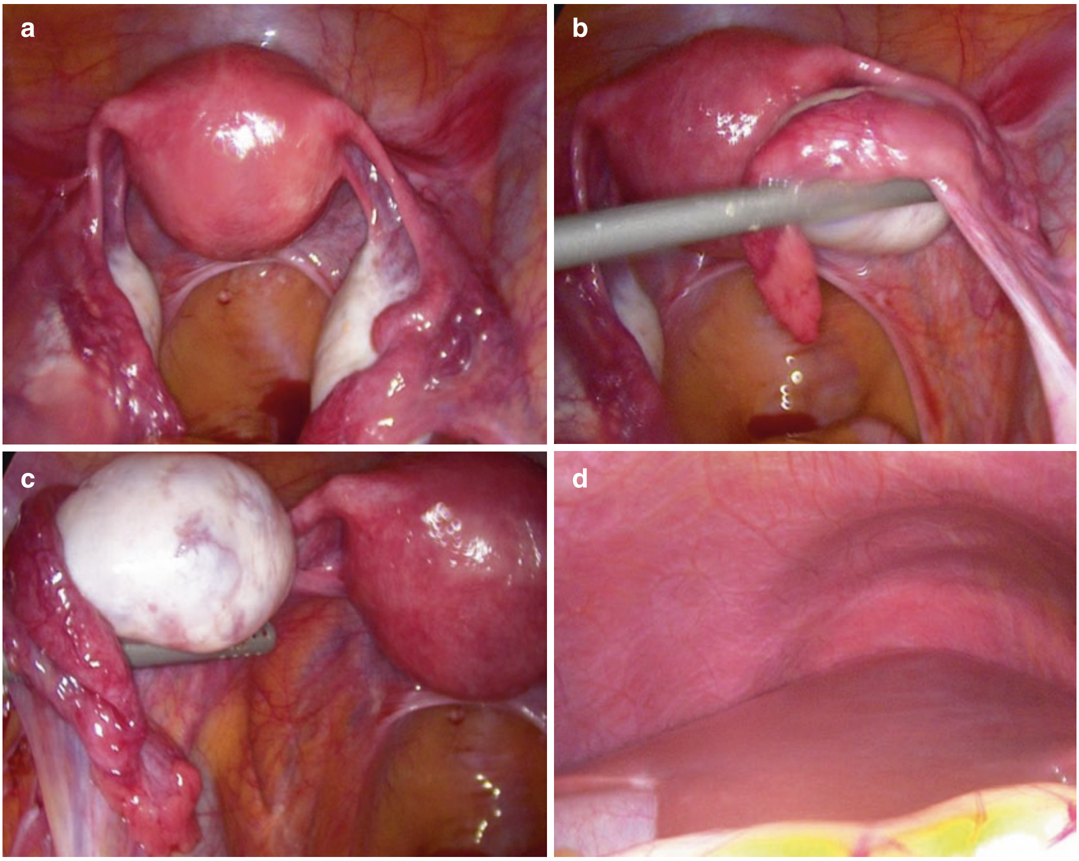



**Fig. 5** Systematic evaluation of the pelvis for endometriosis with patient in Trendelenburg position using an appropriate laparoscopic instrument. (**a**) Image of the POD with bowel displaced. (**b**) Inspection of the right ovarian fossae. (**c**) Inspection of the left ovarian fossa. (**d**) Inspection of the right upper abdomen. (Images courtesy of JUNIC Laparoscopy Australia)

unlikely to be suitable for managing deep infiltrating endometriosis lesions [35]. Ablative techniques could involve the use of $CO_2$ laser or energy instruments (unipolar or bipolar) to destroy visible peritoneal endometriosis lesions.

## 8.4 See and Treat vs. Two-Stage Approach

Where endometriosis is identified at laparoscopy, it is recommended that these lesions are treated as this is effective for reducing endometriosis-associated pain, i.e. 'see and treat' approach [60]. The see-and-treat approach is cost-effective and limits patients' exposure to multiple surgical interventions. It can be useful for treating minimal, mild and/or moderate endometriosis and depends on the skill and expertise of the laparoscopic surgeon. Where the disease at the time of initial laparoscopy is more surgically complex and extensive than originally anticipated (stage 4 endometriosis), a two-stage treatment process can be considered to ensure complete resection of visible lesions and normalization of pelvic anatomy.

The finding of more extensive and surgically complex disease at initial (diagnostic) laparoscopy presents considerable challenge as regards the preoperative consent and information provided to the patient as well as the surgical logistics like allocated theatre time [61]. Such scenario may necessitate a second laparoscopy at an appropriate unit with requisite expertise for definitive surgical treatment after appropriate patient counselling and adequate theatre time allocation.

A two-stage treatment process may be better suited for resource-restricted countries where the ability to predict the complexity of laparoscopic surgery for endometriosis with transvaginal ultrasound preoperatively is not yet available [53].

## 9 Outcomes from Surgical Treatment

The surgical treatment of endometriosis should be designed in line with the patients' individual needs. The surgeon should discuss with the patient whether the primary reason for treatment is acute or chronic endometriosis-related pain or a desire for fertility [62].

Surgical intervention for endometriosis-related pelvic pain significantly decreases postoperative pain when compared to diagnostic laparoscopy alone [63–65]. The post-operative pain scores and quality of life assessments are significantly improved in regards to dysmenorrhea, non-menstrual pelvic pain, dyspareunia and dyschezia for a period of up to 5 years post-operatively [65, 66].

Recurrence of endometriosis or exacerbation of pelvic pain can also occur after successful endometriosis surgery [67]. Up to 36% of women would require further surgical intervention within 5 years of primary surgery [67]. Women who had more severe disease are more likely to require repeat procedures [65]. The risk of re-operation was also increased with the presence of endometriosis on ovary, adhesions in the pouch of Douglas, bowel, fallopian tubes or ovaries [65, 68].

Repeat procedures were lowest among women greater than 44 years of age, while women who presented for surgery at an age less than 30 were significantly more likely to have a repeat procedure [66]. Furthermore, 38% of women would continue to experience pelvic pain despite no histologic evidence of endometriosis suggesting that chronic pelvic pain can be present without recurrence of disease [65, 69].

The outcomes following laparoscopic surgery to improve fertility outcomes are now better predicted using the endometriosis fertility index (EFI). The EFI is a simple, robust, and validated clinical tool that predicts pregnancy rates after laparoscopic surgery for endometriosis. It provides reassurance to those patients with good prognoses and avoids wasted time and treatment for those with poor prognoses [56] (see Fig. 4).

## 10 Complications from Laparoscopic Surgery for Endometriosis

Injuries are fairly common during laparoscopic surgery for endometriosis especially with treating deep infiltrating endometriosis affecting the bowel [35, 61]. The injuries could occur at the time of laparoscopic primary and secondary port entry and during excision of endometriosis lesions. It can also occur during the use of laparoscopic energy instruments resulting in delayed presentation of diathermy injury to abdominal viscus. The reported total intraoperative complication rate in laparoscopic surgery for endometriosis is 2.1%, and total post-operative complication rate is reported as 13.9% with 9.5% representing minor complications and 4.6% major complications [70].

For women undergoing extensive laparoscopic surgery for endometriosis, the excision of ovarian endometrioma can result in a significant impairment of ovarian function, while damage to nerve structures during resection of the uterosacral ligaments, the parametrium, the rectovaginal septum or the vaginal cuff to treat deep infiltrating endometriosis can lead to serious functional impairments such as voiding disorders. Therefore a detailed risk-benefit analysis and shared decision-making are necessary, and patients must be treated using an individualized approach that focuses on the primary reason for treatment.

## 11 Medical Treatment of Endometriosis

Medical treatment of endometriosis is focused on hormonal suppressive therapy and/or pain therapy for chronic pelvic pain. Other complimentary therapies useful for endometriosis management include psychotherapy and pain education, pelvic

**Table 4** Summary of treatment modalities available for managing endometriosis

| Modality of treatment | | Treatment objectives |
|---|---|---|
| Surgical treatment | Peritoneal endometriosis | Complete removal or ablation of visible endometriosis lesions |
| | Ovarian endometriosis | Careful cystectomy with complete removal of cyst. The surrounding healthy tissue must be preserved. Seeding of viable endometriosis cells through iatrogenic cyst rupture must be avoided. Preferably to suture the ovary rather than use diathermy to achieve haemostasis |
| | Deep infiltrating endometriosis | Complete excisional biopsy recommended. This can be achieved via laparoscopy or laparotomy |
| | Uterine adenomyosis | Vaginal hysterectomy (VH) is not recommended because of the lack of opportunity to remove any additional foci of endometriosis that might be present<br>Abdominal hysterectomy (AH) and total laparoscopic hysterectomy (TLH) preferred<br>Organ-preserving techniques for treating adenomyosis:<br>– Surgical removal of adenomyoma via laparoscopy or hysteroscopy<br>– Endocrine: therapeutic induction of amenorrhea—nonstop oral contraceptives, progestogens, GnRH analogues |
| | Fertility | Surgical removal of implanted endometriosis tissue improves the chances for spontaneous conception<br>Assessment of tubal patency is also recommended<br>If extensive endometriosis is present with tubal damage, assisted reproduction should be considered after removal of damaged tubes<br>The use of the EFI can be useful in post-op patient counselling |
| Pharmacotherapy | Hormonal suppression therapy | Therapeutic induction of amenorrhea: continuous combined oral contraceptives, progestogens, GnRH analogues |
| | Pain therapy—involvement of pain specialist may be necessary | Nonsteroidal anti-inflammatory drugs (NSAID), COX inhibitors, mild opioids, antidepressants, combinations of the above |
| Complimentary therapies | Psychotherapy and pain education | Positive thinking, relaxation techniques, imagery, understanding pain origins |
| | Physiotherapy | Diagnosis and treatment of functional disturbances of the body |
| | Nutrition | Balanced diet with adequate vitamins and minerals, reduction of alcohol, sugar and caffeine intake, exclusion of fructose or lactose intolerance. |

Adapted from Beilecke K, Ebert AD: Urogenitale Endometriose. In: Tunn R, Hanzal E, Perucchini D. (Eds.): Urogynäkologie in Praxis und Klinik. Berlin-New York 2010: 353–73

floor physiotherapy and nutrition [71] (see Table 4). Hormonal suppressive therapy is usually over a long period of time, and their side effects may limit their usefulness.

Recurrence of endometriosis has been reported in 13–36% of those with medical treatment [26].

## 12 Multidisciplinary Team Care Approach

The complete resolution of symptoms of endometriosis is still not possible; however, there is evidence that the best way to treat symptomatic patients with endometriosis is with an individualized combination of surgery and hormonal pharmacotherapy, supported by complementary treatment approaches that include pelvic floor physiotherapy, pain psychology and pain specialist. It is however acknowledged that the outcomes of this comprehensive approach to endometriosis treatment may still fall short of achieving its objective of addressing the chronification of the patient's symptoms. As such, patient management should focus on outcomes that address improvements in their most troublesome symptom, their quality of life parameters and their satisfaction with treatment.

## 13 Challenges of Managing Endometriosis in Resource-Restricted Countries

The challenges of managing endometriosis in resource-restricted countries are gigantic. For example, options for medical management and access to complimentary therapy are limited. MRI services are not available in many centres, and the expertise required for diagnosing certain phenotypes of endometriosis with transvaginal ultrasonography is lacking in these countries. Physicians diagnose endometriosis based on historical variables and the exclusion of other differential diagnosis like pelvic inflammatory disease.

Laparoscopy is an invaluable tool in the management of endometriosis. Although the development of laparoscopy in resource-restricted countries is still at an infantile stage, there are significant challenges to its widespread use. These include the high cost of purchase and maintenance of laparoscopic equipments, the limited number of endoscopic companies in these countries and the lack of integrated endoscopic training in gynaecology residency programmes. Furthermore, physicians with skills in endoscopic surgery need access to continuing education programmes to improve their recognition of the disease and develop their expertise in treating mild, moderate or severe disease.

The treatment of endometriosis is lifelong, expensive and time-consuming. In resource-restricted countries, there is significant lack of awareness of the disease among physicians and patients. These countries also have limited healthcare insurance programmes and widespread consumer payer systems such that affordability of treatment services is virtually impossible for the women living with endometriosis.

## 14 Conclusion

Laparoscopy has been a major tool for the surgical management of women with endometriosis for more than four decades in developed countries. The current evolution of endoscopic surgery in low-resource countries stands to benefit from this experience and must include strategic efforts that integrate endoscopy training in gynaecology residency programmes. It should also develop programmes that build the capacity of surgeons to recognize and treat endometriosis in ways that improve patient outcomes.

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# Laparoscopic Hysterectomy

Okechukwu Ibeanu and Dama Ziworitin

## 1 Introduction

Since the initial use of laparoscopy for assessment of abdominal organs, described by Jacobeus in 1911 [1], progressive modifications and technological advancements have led to enormous expansion of small incision, minimally invasive surgeries for diagnosis and treatment of numerous abdominal and pelvic disorders. The first laparoscopic hysterectomy was performed in 1988 [2]. Today, laparoscopy is part of the standard of care for many gynecologic conditions which previously were only amenable to laparotomy incisions for surgical treatment. Gynecologic surgeons now routinely use the laparoscopic approach for performance of the hysterectomy operation for various indications, with satisfactory patient outcomes. This chapter will discuss the laparoscopic hysterectomy operation, with an emphasis on perioperative considerations, technique, and intraoperative measures to reduce the incidence of surgical complications.

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## 2 Advantages of Laparoscopic Approach to Hysterectomy

Multiple studies have demonstrated several benefits of laparoscopy compared to laparotomy in the use of hysterectomy for the treatment of benign and malignant uterine disease. Decreased blood loss, reduced need for blood transfusions, shorter patient hospitalization postoperatively, reduced postoperative pain scores, earlier time to ambulation, reduced dependence on pain medications, fewer abdominal wall infections, and lower cost are several of the benefits to patients [3, 4]. Patients also have cosmetically acceptable incisions.

The American College of Obstetricians and Gynecologists and the American Association of Gynecologic Laparoscopists recommend consideration of the vaginal or laparoscopic route as the initial choice for patients needing hysterectomy [5, 6]; however, certain issues such as prior intra-abdominal surgeries, large uterine size, and surgeon experience may limit the use of these options. When feasible, laparoscopic hysterectomy should be considered for patients, in lieu of laparotomy, at least for benign disease. Laparoscopy is also a standard-of-care treatment option for primary resection of malignant uterine disease. The Gynecologic Oncology Group study LAP2 randomized clinical trial on patients with stage I and II uterine cancer, reported in 2009 [7],


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demonstrated advantages of laparoscopy over laparotomy, similarly reported in prior studies of laparoscopic hysterectomy for benign disease. The laparoscopic approach for endometrial cancer was also noted to result in equivalent lymph node yield, with feasibility of completing surgical staging even in patients with morbid obesity.

Drawbacks to laparoscopy include operating time, especially among surgeons who are in the steep part of the learning curve for laparoscopy [3]. Other limitations are the use of two-dimensional camera vision, surgeon fatigue, elbow fulcrum for instrument movement, and the use of Trendelenburg position which may not be tolerated by morbidly obese patients [8].

In resource-challenged environments where laparoscopy is in early stages of adoption or implementation, laparoscopic surgery provides an opportunity to overcome several of the challenges associated with laparotomies. Specifically, less blood loss, fewer blood transfusions, earlier time to ambulation, less pain and medication requirement, and shorter postoperative hospitalization may cumulatively result in less burden on limited individual and health system resources. As such, it is ever so important now to develop and sustain laparoscopic surgery in these environments.

## 3 Perioperative Considerations

### 3.1 Indications for Laparoscopic Surgery: Patient Selection

In principle, the most important considerations hinge on patient safety and accomplishment of the surgical goal in question, which is to remove the uterus. These considerations are dependent on several factors:

- Ability of the patient to undergo a major surgical operation

  Laparoscopic hysterectomy is a major intra-abdominal operation, albeit performed through small-sized incisions. There should be evaluation of the patient's preexisting medical status that may impact the feasibility of the operation. Preoperative medical evaluation to assess cardiorespiratory status, performance status, thromboembolism risk, perioperative anticoagulation management, and other perioperative recommendations is an important part of patient preparation for surgery.

  The Trendelenburg position is essential for pelvic visualization during laparoscopic hysterectomy and involves 30–40° of downward tilt from the supine position [9]. This patient position may be associated with physiologic alterations related to increased cardiac, cerebral, and retinal venous blood return. There is the risk of cerebral and ocular edema. Effects on cardiac output are debatable, but exacerbation of cardiac congestion may occur. Lung ventilation may be difficult in patients with diminished lung compliance, such as with chronic heavy tobacco smoking, emphysema, and other obstructive pulmonary diseases. Morbid obesity presents a challenge with regard to safe positioning, lung ventilation, intraoperative visibility, bleeding, safe endotracheal intubation, and extubation.

  The assessment of the anticipated impact of preexisting medical disease is crucial in patient selection for laparoscopic hysterectomy to reduce the risk of life-altering intraoperative complications or death.

- Prior major abdominal surgery

  Prior laparotomy may be associated with intra-abdominal adhesion formation, which may make subsequent laparoscopic hysterectomy challenging. Adhesions may require extensive resection around pelvic viscera, and vascular, bowel, or urinary tract injury risk may be increased [6]. Unfortunately, no thresholds have been established for laparoscopy patients, with regard to a number of prior surgeries; however, preoperative assessment should include a thorough evaluation of past surgical history, with attention to the exact nature and chronology of prior surgeries. Upper abdominal surgeries can result in abdominal wall adhesions which could impact on choice of laparoscopic trocar positioning or could necessitate the use of left upper quadrant (Palmer's point; mid-axillary line, below the costal margin) for abdominal entry and insufflation [8]. Endometriosis, acute or chronic pelvic visceral inflammation, and pelvic radiation are other factors that can alter pelvic anatomic relationships. Assessment of the abdomen and pelvis should be made upon abdominal entry, prior to commencing any resections; high risk or unsafe procedures can be safely aborted at such uncommitted stage of the operation.

- The current disease status for which hysterectomy is being considered as treatment option
  Safe removal of the uterus may be impacted by intraoperative factors related to the patient's disease process. Extensive pelvic adhesions, severe anatomic derangements, inability to develop safe dissection planes, and frozen pelvis may make laparoscopic approach less appropriate to use. It is important to note that surgical approach should depend on the feasibility of the chosen laparoscopic approach to accomplish the specific goal of the operation.
- The size of the uterus and ovaries
  A major factor in the choice of laparoscopic technique for hysterectomy is the size of the uterus and the adnexae. Classic gynecologic surgical teaching has dictated uterine size as a potential limitation to using laparoscopic hysterectomy. Interestingly, there is no established cutoff size in the surgical literature. Extra-pelvic enlargement of the uterus may present intraoperative challenges; however, recent reports have challenged this thinking [10].
  - The problems with significantly enlarged uteri include:
  - Intraoperative visibility may be compromised.
  - Ability to extract the uterus through the vagina may not be feasible.
  - Ability to extract the uterus intact may not be possible, leading to the use of morcellation. Morcellation of the uterus is a controversial technique which has been criticized for the risk of intra-abdominal dissemination of undiagnosed uterine cancer [11].

  The surgeon's assessment of his or her own skill and ability matched against the anticipated level of difficulty and extent of the operation.
  It is essential to develop contingency plans to address anticipated problems during the laparoscopic operation.

## 4 Laparoscopic Hysterectomy and Modifications

As with open abdominal operations to remove the uterus, various iterations of hysterectomy can be performed laparoscopically. The choice of procedure may be predetermined preoperatively or may be dictated by intraoperative events, such as bleeding, the presence of adhesions, unacceptable risk of visceral injury, cardiorespiratory difficulties, emergency operation, among many issues.

Laparoscopic total hysterectomy refers to complete removal of the uterus, including the cervix, with all dissection and colpotomy performed endoscopically prior to removal of the uterus from the abdominal cavity. The vaginal cuff may be closed endoscopically or transvaginally.

Laparoscopic supracervical (subtotal) hysterectomy refers to removal of the uterine fundus, with all dissection performed endoscopically prior to removal of the specimen from the abdominal cavity.

Laparoscopic-assisted vaginal hysterectomy refers to removal of the uterus using transvaginal technique, after laparoscopic resection of utero-ovarian ligament and round ligament; the colpotomy and uterine artery control are performed through the vagina, prior to removal of the uterus. Some surgeons prefer to control the uterine artery endoscopically prior to the vaginal part of the procedure.

Laparoscopic radical hysterectomy refers to removal of the uterus with a resection margin that includes the parametria and wider cuff of vaginal tissue around the cervix. In addition, the uterine arteries are ligated at their origins off the internal iliac arteries, and the uterosacral ligaments are skeletonized and transected, prior to colpotomy.

## 5 Operative Setup

Successful surgery is dependent on multiple factors working in harmony. Ergonomics during laparoscopic surgery cannot be overstated. The appropriate positioning of personnel and operative instrumentation is important in ensuring safe performance of a laparoscopic hysterectomy (Table 1).

Basic considerations are:

- Patient positioning
  The preferred position of the patient is lithotomy, with Trendelenburg tilt. Steep Trendelenburg position involves a greater degree of tilt. Important areas that need to be protected with padding include the patient airway, the arms, hands and fingers (the authors prefer the arms tucked to the patient's sides), the flexures of the knees, and ankles. The operating field includes the entire abdomen, perineum, and vagina. The vagina and rectum should be accessible externally during the entire procedure; therefore, the thighs should be spaced apart enough to facilitate this. Over-abduction of the shoulders and hips and hyperflexion of the hips and knees should be avoided. At the conclusion of patient positioning, the operating room table should be placed in Trendelenburg's position for several minutes, while cardiorespiratory vital signs are observed, and any signs of patient sliding are noted. Slip-resistant table padding is usually used to counter patient sliding from gravity forces, especially in obese patients (Figs. 1 and 2).
- Circulating staff
  Essential staff need to be able to transit the operating room without distracting the surgeon. Because laparoscopic surgery involves the use of several disposable devices, sometimes in quick sequence, it is important that the flow of the operation is sustained through easy accessibility of surgical supplies.

**Table 1** Key points

| Surgical tips for laparoscopic hysterectomy | |
|---|---|
| Thorough preoperative assessment<br>Correct patient positioning<br>Surgical measures to reduce complications:<br>– Detailed anatomic knowledge<br>– Dissection using pedicle creation prior to cautery and ligation<br>– Use of natural tissue planes for dissection<br>– Adequate dissection of the bladder inferiorly, below the level of the vaginal cuff, to avoid bladder injury<br>– Control of uterine artery vascular supply; initial cautery burn should be high up against the lateral aspect of the uterine body; at the level of the bladder peritoneal incision<br>– Cauterization of the uterine artery pedicle working from a medial aspect to avoid ureteral injury<br>– Confirm hemostasis, integrity of bladder/ureters/bowel before abdominal closure | Problems with steep Trendelenburg's position:<br>– Consider decreasing intra-abdominal insufflation pressure, reducing the degree of tilt angle, alteration in ventilation rate<br>– Decision to terminate laparoscopic approach should be made as early as possible if there are problems with Trendelenburg position<br>Distorted pelvic anatomy:<br>– Consider beginning the dissection from the easier aspects of the anatomy; identify landmarks such as the round ligament, infundibulopelvic ligament, and vesicouterine peritoneum<br>– Keep the surgical field as dry as feasible; bleeding reduces visual contrast and blurs anatomic detail, increasing the risk of visceral injury<br>– When faced with insurmountable intraoperative challenges, get help if available and be decisive about converting to laparotomy. Earlier conversion to laparotomy reduces unnecessary anesthesia exposure, reduces operative comorbidity |


**Fig. 1** Laparoscopic hysterectomy setup: the instrument tower is on the right of the operating table. The video screens are placed across from the surgeon and assistant

**Fig. 2** Patient position for laparoscopic hysterectomy: The entire abdominal field is exposed, and the chest strap is latched above the xiphisternum. The pink padding is anti-slip and extends down to backside of the patient. Together with the chest strapping, sliding is prevented when the patient is placed in Trendelenburg's position. The arms are protected with a padded sleeve, and the legs are padded within the stirrups, to prevent neuropathy, and injury to bony prominences. In the correct position, the legs should point toward the opposite shoulder and should rest upright in the stirrup boots. The sacrum should rest above the edge of the operating table to avoid back injury

- Equipment arrangement
  The operating room hardware should be positioned for clear lines of visibility of the video screens, each opposite the surgeon and assistant. Alternatively, a single video screen can be positioned above the foot of the table.
- The laparoscopic auxiliary tower is usually positioned off to either side of the operating table, allowing enough space for the surgeon or assistant to maneuver during the operation. Other equipments that may have variable position around the room include cautery machine, suction canister, sequential compression boot pump, intravenous bag poles, and the instrument table.
- Laparoscopy trocar placement

Typical trocar placement utilizes triangulation for optimal spacing of instruments to avoid dueling during manipulation. Any number of trocars can be placed, depending on the challenges involved during dissection. Usually, the laparoscopic camera port is inserted in the midline [12], at or above the umbilicus, while additional ports are placed in the right and left lower quadrants, 4–5 cm lateral to and inferior to the umbilicus to avoid the inferior epigastric artery. Trocar placement below the level of the anterior superior iliac spines may lead to iliohypogastric or genitofemoral nerve injury during suture closure of those ports. Additional assistant ports can be placed in the right or left upper quadrants or epigastric region. Five- to twelve-millimeter diameter ports are generally used in laparoscopy. Port incisions greater than 8 mm are usually approximated with suture to include the muscle fascia. Extension of port incisions to mini-laparotomy may be necessary to retrieve large specimens that cannot traverse the vaginal orifice.

## 6 Surgical Anatomy

A brief overview of relevant surgical anatomy will be discussed in this section. The value of detailed anatomic knowledge in the performance of laparoscopic hysterectomy cannot be overemphasized.

The laparoscopic view of the pelvis actually involves an appreciation of structures above the pelvic brim, in continuity with the bird's eye view of the true pelvis, that is necessary to safely perform the hysterectomy operation [13, 14] (Fig. 3).

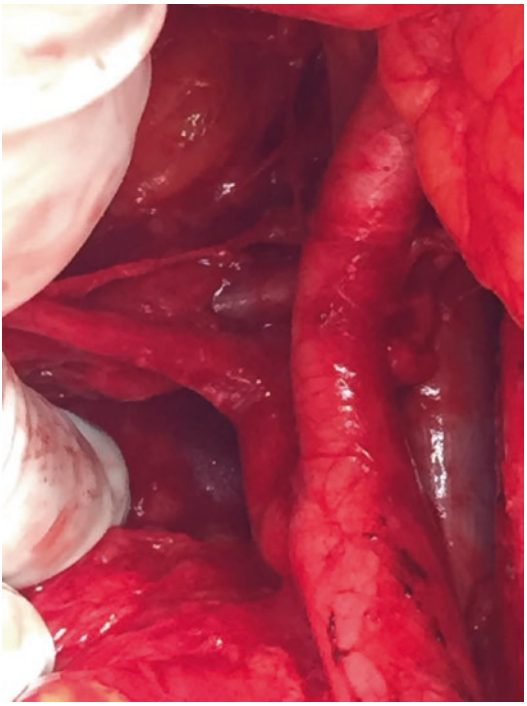

**Fig. 3** Anatomic view of right pelvis showing the common iliac artery bifurcating to external iliac artery with external iliac vein visible inferolaterally. The internal iliac artery is seen descending inferomedially and giving off the uterine artery. The uterine vein is seen below the artery and lying over the cardinal ligament which is not visible in this photograph. The ureter is under the surgeon's finger, medial to the vessels. The para-rectal space is seen adjacent to the surgeon finger below the uterine artery. The paravesical space is seen superior to the uterine artery. The psoas muscle lies to the right, lateral to the external iliac vessels

## 6.1 Abdomen and Pelvis

The cecum and ascending colon and their peritoneal attachments are found at the right abdominal wall, above the pelvic brim, and may be closely related to the right adnexa, specifically, the infundibulopelvic ligament. The appendix arises from the base of the cecum, at the junction of the cecal tenia. The peritoneum covering of the right abdominal sidewall continues inferiorly toward the pelvis, covering the uterus, round ligament, bladder, and vasculature of the deep pelvis. The descending colon is tethered to the left abdominal sidewall and transitions to become the rectosigmoid colon in the pelvis. The rectosigmoid colon may be encountered close to the left adnexa, bound by adhesions. The peritoneal covering of the rectosigmoid colon extends to the pouch of Douglas (cul-de-sac), before sweeping over the posterior uterus and fundus to continue over the urinary bladder and retropubic space. Similar to the right side, the peritoneum also extends over the left round ligament and vesicouterine space. The uterosacral ligaments appear as trouser pant legs arising from the posterior aspect of the uterus and extending to the anterior aspect of the rectum. The uterosacral ligaments are usually closely related to the ureters which pass just lateral to the ligaments. The uterosacral ligaments straddle the rectovaginal space which is accessed by incising the peritoneum between the ligaments. The rectovaginal space can be dissected down to the perineum [13–15].

### 6.1.1 Pelvic Viscera and Blood Supply

*Ureter*: The ureter arises from the renal pelvis and travels lateral to the respective colon on each side, medial to the ovarian vessels which arise below from the ventral aspect of the aorta. At the pelvic brim on each side, the ureter enters the pelvis, crossing diagonally from lateral to medial over the bifurcation of the common iliac artery. This is a critical landmark during pelvic dissection. The ureter deviates medially, along the medial leaf of the broad ligament, and continues to the vesicoureteral junction, passing lateral to the uterosacral ligament, then under the distal uterine artery before turning further medial and entering the bladder trigone. The ureter is also found lateral to the rectosigmoid colon mesentery at the level of the pelvic brim. The ureter is covered by a loose network of capillaries on its surface and usually tunnels within a rich vascular sheath of adventitial tissue as it passes under the uterine artery. Small plexi of blood vessels may be encountered in the vesicouterine bands that cover the most distal portion of the ureter. These tissue bands run from the lateral aspect of the uterine-vaginal junctions to the respective lateral aspect of the bladder base. In the abdominal portion of its course, the blood supply to the ureter arises medially, off of small twigs from the gonadal artery, and the aorta. The pelvic portion of the ureter is supplied laterally from anastomotic branches arising off the internal iliac artery. Below the pelvic brim, the ureter is attached to the medial peritoneal leaf of the broad ligament with fine capillaries in the adventitium along the entire length of the ureter. It is important to preserve this adventitial layer as much as possible during ureterolysis.

*Blood vessels*: The bifurcation of the aorta rests just above the sacral promontory, at about the level of the fourth lumbar vertebral space. The common iliac arteries branch off diagonally, medial to the psoas major muscle, and each continues as a larger external iliac artery, and smaller internal iliac artery which dives inferomedially in keeping with the drop off of the sacral promontory. The internal iliac artery supplies the pelvic viscera, directly or indirectly, and is the source vessel for a rich pelvic anastomotic blood supply. The internal iliac artery gives off a posterior branch about 2 cm from its origin, before continuing as the anterior division which ends as a solid cord, known as the obliterated internal iliac or hypogastric artery. The internal iliac artery can be safely sacrificed through ligation or resection if necessary.

Posterior branches of the internal iliac artery:
- Lateral sacral artery
- Iliolumbar artery
- Superior gluteal artery

Anterior branches of the internal iliac artery:
- Middle rectal artery
- Uterine artery
- Obturator artery
- Superior vesical artery
- Pudendal artery
- Umbilical artery

The pelvic veins usually follow the course of their corresponding arteries. The uterine artery occasionally has a deep branch which is usually encountered along the inferior aspect of the cardinal ligament. A more superficial uterine vein is seen above the cardinal ligament entering the internal iliac vein. A deep uterine vein is found at the inferior aspect of the cardinal ligament in the parametrial region. The most medial large pelvic vessel is the **left** common iliac vein which **crosses** directly below the sacral promontory as it joins the right common iliac vein, to form the vena cava, which ascends along the right aspect of the abdominal aorta, into the abdomen.

## 6.2 Important Anatomic Relationships

The gonadal vessels, namely, ovarian artery and vein, are wrapped in peritoneum covering and descend into the pelvis as the infundibulopelvic or suspensory ligament. The infundibulopelvic ligament maintains a close relationship to the course of the ureter above the pelvic brim. Below the pelvic brim, on the medial peritoneal leaf of the broad ligament, the ureter deviates inferomedially, while the gonadal vessels course superomedially to the ovarian hilum. The close proximity of the ureter and gonadal vessels at the pelvic brim poses a potential risk of ureteral injury during hysterectomy dissections, if the ovaries are to be removed with the uterus. The right ovarian vein drains into the inferior vena cava, while the left ovarian vein drains **directly** into the left renal vein.

The uterine artery arises from the internal iliac artery, passing medially across to the lateral aspect of the cervical-vaginal junction, and up against the lateral aspect of the uterine body. The ureter consistently passes under the uterine artery, as this blood vessel ascends upward at the cervical-vaginal junction. This junction of the uterine artery and the ureter is the commonest site of ureteral injury during hysterectomy [13–16].

### 6.2.1 Internal Iliac Artery Ligation

Ligation of the internal iliac artery is a technique used to prevent or control heavy bleeding during hysterectomy. Ligation or stapling off the internal iliac artery should be performed beyond the origin of the posterior branch, usually at least 5 cm **distal to** the origin of the internal iliac artery. This precaution helps to avoid ischemic sequela from accidental ligation of the posterior branch of the internal artery which is given off about 2–3 cm distal from the origin of the internal iliac vessel.

During radical hysterectomy [14], the ureter is typically "unroofed" by dissecting it free of the overlying adventitial sheath and vesicouterine bands. This is a maneuver that can be associated with bleeding, if the vascular connections in the sheath are not efficiently clamped off and ligated safely. Prior proximal ligation of the uterine artery at the pelvic sidewall origin from the internal iliac artery helps to diminish he incidence of problematic bleeding when dissecting out the ureter.

The ureter has a close relationship to the cervical-vaginal junction as it courses into the bladder. The average distance of the ureter from the vaginal cuff angles may be as short as 0.5 cm laterally, and superomedially, just before the ureter enters the bladder trigone. Insufficient mobilization of the bladder off the anterior vagina could lead to ureteral kinking or ligation during clamping of the uterine artery, vaginal cuff closure, or during efforts to control bleeding in the deep pelvis. When necessary, the use of rubber ties around one or both ureters can help with locating them easily during challenging dissections. Care must be taken to avoid forceful pulling on the ties to avoid avulsion of the ureters.

### 6.3 The Avascular Spaces of the Pelvic Retroperitoneum [13, 14]

The avascular spaces are potential spaces in the pelvic retroperitoneum which can be exposed through careful dissection, during radical and sometimes challenging simple hysterectomies. These spaces are devoid of major vascular structures and provide havens from which anatomic planes can be developed safely and by which anatomic distortions can be overcome, by safe pedicle division, and mobilization of pelvic viscera.

Retropubic space: This space lies in front of the bladder. Boundaries—Pubic bone anteriorly, bladder inferoposteriorly – obliterated internal iliac arteries laterally. The floor is formed by the urethra and bladder neck.

Vesicouterine space: This is the space between the bladder and uterus. Boundaries—Bladder anteriorly, anterior surface of the uterus and vagina posteriorly, and bladder pillars and distal uterine arteries laterally.

Paravesical space on each side: This space lies lateral to the bladder. Boundaries—Superior pubic ramus anteriorly, bladder medially, external iliac vessels laterally, and cardinal ligament posteriorly. The obliterated portion of internal iliac artery separates this space from the retropubic space.

Rectovaginal space: This is the space between the bladder and the anterior surface of the rectum, accessed below the peritoneal covering of the cul-de-sac. Boundaries—Posterior vaginal wall anteriorly, anterior surface of the rectum posteriorly, uterosacral ligaments, and mesorectal pillars laterally. This space can be developed down to the perineum.

Para-rectal space on each side: This space lies lateral to the rectum. Boundaries—Cardinal ligament anteriorly, presacral area posteriorly, rectum and ureter medially, and internal iliac artery laterally.

Retrorectal space: This space lies behind the rectum. It can be accessed by resecting the rectosigmoid colon mesentery and superior rectal artery. The space can be developed down to the posterior rectum and perineum. Boundaries—Rectosigmoid colon anteriorly, anterior sacrum and presacral vessels posteriorly, lateral aspect of the rectosigmoid colon medially, and levator muscles laterally.

## 7 Surgical Goals

The primary goal of laparoscopic hysterectomy is to safely remove the uterus using endoscopic dissection and avoid inadvertent injury or compromise of surrounding viscera, nerves, and blood vessels.

Following uterine removal, secondary goals of surgery are the safe closure of the vaginal cuff (or cervical stump in supracervical hysterectomy), hemostasis, and restoration of residual pelvic anatomy as much as is feasible.

To this end, the surgeon and operating team must have an assessment of the feasibility of the surgery, any factors that could impact the success of the operation, and a plan to deal with intraoperative adverse events. This process begins at the initial outpatient consultation and continues right into the operating room, until the patient is safely extubated and transitions to the recovery phase of care.

Safe surgery is the culmination of multiple steps of care that include other care providers and allied staff.

## 8 Laparoscopic Hysterectomy

### 8.1 Surgical Technique [15]

An abdominal and pelvic examination, bladder catheterization, and insertion of a uterine manipulation device are usually done after patient identification, confirmation of surgical site, skin cleansing, and final pre-procedure safety review. After abdominal entry, the dissection begins by making a curvilinear incision on the pelvic peritoneum and round ligaments bilaterally. This exposes the retroperitoneal space, and the filmy sub-peritoneal tissue can be bluntly dissected away to reveal the underlying viscera. The ureters should be visualized at the pelvic brim and followed down into the deep pelvis, along the medial leaf of the broad ligament. Ureteral exposure is facilitated by extending the pelvic peritoneum incision in a cephalad direction, following the curve of the pelvic sidewall, and continuing along the lateral peritoneal border of the respective right and left colon. Medial retraction of the uterus and infundibopelvic ligament, along with blunt dissection of the adventitial sub-peritoneal layer, should enable visualization of the ureter medially. In addition, the ureter can be visualized from a medial to lateral direction against the broad ligament, by retracting the infundibulopelvic ligament laterally. A peritoneal incision on the broad ligament is made between the ureter and the infundibulopelvic ligament and carried caudad down to the uterine artery at the lateral border of the uterus. This peritoneal incision creates a window that separates the infundibulopelvic ligament superiorly, from the ureter below, which should safeguard the ureter from inadvertent cautery or ligation. The peritoneal window incision also helps to proactively develop a space through which pedicles can be ligated easily. Thus, if the adnexae are to be preserved, then the utero-ovarian ligaments on the lateral aspect of the uterine cornua are cauterized and cut through the aforementioned peritoneal window. Ligation of the utero-ovarian ligament frees up the uterine specimen, disconnecting the organ from the abdominal blood supply carried within the gonadal vessels. Having already ligated the round ligaments at the start of the dissection, the peritoneum overlying the bladder-uterine tissue plane is incised, and the bladder is dissected off inferiorly; the peritoneal incision can be started from a lateral direction, or from medial to lateral. Care should be taken over the lateral aspect, in order to safely dissect the bladder pillars and avoid the uterine artery branches in this area. The bladder mobilization should be continued below the level of the vaginal cuff; pushing up on the uterine manipulator should help to delineate the cervical-vaginal junction. Loose peritoneal tissue around the uterine artery is bluntly resected to skeletonize if necessary, prior to clamping and cautery of the artery. The uterine artery should be clamped initially at the level of the internal os, perpendicular to the artery, prior to cautery. The cardinal ligament and uterosacral ligaments on the inferolateral aspect of the cervical-vaginal junction are then cauterized and resected, placing the cautery burn and subsequent cut in a position that is medial to the uterine artery pedicle. The next step is to make the colpotomy incision, which can be started at any position. During colpotomy, important structures to protect, using a retractor if necessary, are the rectosigmoid colon, ureter and uterine artery pedicles at the vaginal angles, and the bladder. The uterus is then retrieved through the vagina. To prevent sudden loss of pneumoperitoneum during uterine specimen removal, a pneumo-inflator is found on some uterine manipulator devices and is deflated to remove the uterus; alternatively, the authors insert a moist laparotomy sponge at the time of placement of the uterine manipulator. The vaginal cuff closure can be performed using a variety of absorbable sutures in running or interlocking fashion; transvaginal cuff closure is an acceptable alternative. Once hemostasis is confirmed adequate, all operating instruments should be removed from the patient to avoid inadvertent visceral burn or injury.

The author routinely performs cystoscopy to evaluate the integrity of the bladder and ureters at the end of the hysterectomy surgery. Cystoscopy has been shown to have high detection rate for intraoperative bladder and ureteral injury [16, 17]; however, thermal injury is not amenable to early detection using this method. Urinary tract injuries at hysterectomy are uncommon but usually go unrecognized at the time of occurrence. Bladder or ureteral injury can be addressed at the same operation, to prevent postoperative morbidity and secondary operations. Intraoperative detection and primary repair of urinary tract injury are associated with up to 95% success rate.

## 9 Major Complications

A full discussion of complications is outside the scope of discussion of this chapter; however, few major noteworthy issues are mentioned below.

Vascular injury: The major causes of intraoperative vascular injury are trocar placement and inadvertent abrasion or puncture during dissection. Most small injuries can be safely repaired using suturing. Large rents with brisk, life-threatening blood loss require conversion to laparotomy [15, 18, 19]. With trocar insertion into a large blood vessel, the trocar should be left in place as laparotomy is being performed, until exposure allows safe removal of the offending trocar.

Bladder injury: The rate of bladder injury with open hysterectomy is between 1 and 3%; however, data for laparoscopic hysterectomy is limited [17]. Bladder perforations typically occur during dissection of the bladder off of the uterus and are seen more frequently in patients with prior cesareans sections. Most bladder injuries occur above the trigone area, in the base of the bladder posteriorly. These injuries can be repaired by mobilizing the bladder base off the vagina to facilitate a tension-free repair. The repair is performed using absorbable suture in two layers. Bladder rest with suprapubic or transurethral catheter is standard. Urinary retention can occur with significant bladder denervation during challenging dissections. Vesicovaginal fistula can occur with unrecognized bladder injury.

Ureteral injury: Ureteral injuries occur much less commonly than bladder injuries, with an incidence of approximately 0.5% [17]. The ureter is most commonly injured during clamping of the uterine artery, and maneuvers around the vaginal cuff, as it crosses beneath the uterine artery. Kinking injuries are common and can be addressed by releasing the offending suture if possible. As with transection injuries, severe kinking may require reimplantation of the ureter into the bladder. Ureteral stent placement following repair is standard management.

Bowel injury: Bowel injury is a potentially life-threatening complication. These injuries may occur during trocar insertion, or challenging dissections with enterolysis, and adhesiolysis. Primary repair is the ideal situation if the injury is recognized at the time of surgery. In certain instances, open or laparoscopic assisted enterostomy or colostomy may be prudent [15]. Postoperative presentation of bowel injury may be in the setting of enterocutaneous fistula, sepsis, rectovaginal fistula, or bowel ileus.

Nerve injury: These injuries are uncommon, seen in less than 2% of cases, based on sparse available data [20, 21]. Over-abduction or hyperflexion of the hip can result in femoral and obturator nerve paresthesias. Inadequate protection of the lateral knee prominence can result in peroneal nerve injury. In cases where the upper extremities are left untucked, overabduction of the shoulder can result in brachial plexus injury. Neurapraxia and neuronotmesis injuries usually recover spontaneously and with physiotherapy aid; however, nerve transections require surgical repair.

## 10 Conclusion

### 10.1 A Note on Robotic-Assisted Laparoscopic Hysterectomy

Laparoscopic surgery has been refined over several decades to become an established standard of care option for hysterectomy, with demonstrated benefits for the patient. The increasing uptake of laparoscopic gynecologic surgery is a welcome feature of patient care in resource-challenged environments, and, if well implemented, the advantages to the patient, as well as to health systems, would be enormous. Upfront, sufficient resources have to be expended on the didactic and practical training of younger surgeons, in order to navigate the steep learning curve, build a critical mass of skilled laparoscopists, and sustain proficiency. Over time, these factors should result in more favorable patient outcomes and more cost-effective care.

The limitations of laparoscopy in the hands of the individual surgeon have been poor tactile feedback, two-dimensional visualization, lack of hands-free camera operation, and elbow-driven anatomical movements for instrument maneuvers. Assisted laparoscopy using the Da Vinci surgical platform (robotic surgery) has overcome some of the above limitations and transferred the surgeon from tableside to an operating console, with three-dimensional camera vision, and wrist motions for dissection [22]. As with the development of conventional laparoscopy, the indications for robotic assisted laparoscopy continue to expand rapidly. Robotic-assisted hysterectomy is now used for endoscopic treatment of benign and malignant uterine conditions, and multiple reports in the surgical literature have demonstrated comparable outcomes with robotic assisted and conventional laparoscopic hysterectomy [23–25]. The major drawbacks to robotic-assisted laparoscopy are setup time for robot platform docking, assimilation period for learner surgeons, and increased average procedure cost. There are also reports that have questioned the role of robotic-assisted laparoscopy in benign gynecologic surgery [26–28], in spite of the advantages noted above. It appears that conventional laparoscopic surgical facilities may be cheaper and less time-consuming to implement in resource-challenged settings, such that the advantages of robotic surgery may be of less impact in these environments. As such, it is safe to assume that laparoscopic techniques will continue to remain in use among gynecologists, for the foreseeable future. It is hoped that this surgical modality can be developed into a sustainable alternative to laparotomy in resource-challenged environments.

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# Laparoscopic Radical Hysterectomy

Olusegun Badejoko, Prashant Bhamare, and Okechukwu Ibeanu

## 1 Historical Perspective

The first laparoscopic radical hysterectomy in recorded history was performed by the American gynaecologist Camran Nezhat in 1989 [1]. This feat was the culmination of parallel advancements in the fields of surgical oncology and minimal access gynaecology, which were masterly brought together in 'holy matrimony' by Nezhat and his team. Sert and Abeler in Europe subsequently performed the first robotic radical hysterectomy in 2006 [2]. The actual origin of radical hysterectomy is intricately linked to the evolution of elective surgical management of cervical cancer. This by most accounts can be traced back to the pioneering work in 1902 of two great surgeons—Ernst Wertheim of Vienna and Thoma Ionescu of Romania, who refined the primitive radical hysterectomy earlier described in 1895 by Clark [3, 4]. Wertheim and Ionescu described an extended abdominal hysterectomy in which the adjoining connective tissues (parametrium) and upper vagina were all excised, along with routine bloc removal of the pelvic lymph nodes.

Radical hysterectomy has since undergone various phases in its evolution, including a downturn and resurgence [3, 4]. As a result of its initially high morbidity and mortality, Wertheim's hysterectomy was completely overtaken by radiotherapy as the preferred method of choice for treatment of all but the earliest stage of cervical cancer. Indeed, radical hysterectomy remained unpopular for decades, until the mid-twentieth century when Meigs in 1944 modified the procedure and reported a much-improved survival rate [3, 4]. It is to him that the resurgence of radical hysterectomy is owed. Mention must however also be made of the contribution of Okabayashi and Takayama who described the autonomic nerve (hypogastric plexus) sparing technique of radical hysterectomy in 1921 [3–5].

## 2 Classification of Radical Hysterectomy

There are different degrees of 'radicality' to radical hysterectomy. The earliest documented attempts at classification or staging of radical hysterectomy date back to 1974, when Piver, Rutlege and Smith proposed their extremely pop-

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ular classification system, shown in Table 1 [4, 6]. Another classification system was later developed by the Surgeons Committee of the Gynecologic Cancer Group, a subsidiary of the European Organization of Research and Treatment of Cancer (GCG-EORTC) in 2007 (see Table 1) [4, 7]. However, in 2008, Querleu and Morrow came up with a new classification system which, unlike the pre-existing classifications, specifically also considered the laparoscopic approach, the autonomic nerve-sparing technique and paracervical lymphadenectomy

**Table 1** Comparison of the three classification systems of radical hysterectomy

| Piver-Rutlege-Smith | | GCG-EORTC | | Querleu and Morrow | | |
|---|---|---|---|---|---|---|
| Class I | Extrafascial hysterectomy<br>– Ureters identified but not dissected<br>– Uterine artery ligated and cut at the uterine isthmus<br>– Uterosacral and cardinal ligaments divided at uterine attachments<br>– No vaginal cuff excised | Type I | Simple hysterectomy | Type A | | Extrafascial hysterectomy<br>– Ureters identified but not dissected<br>– Uterine arteries, cardinal and uterosacral ligaments resected as close to uterus as possible<br>– <10 mm marginal cuff removed |
| Class II | Wertheim hysterectomy<br>– Ureters dissected, but not isolated from pubocervical ligament<br>– Uterine arteries sectioned just medial to ureters<br>– Resection of uterine half of cardinal and uterosacral ligaments<br>– Upper 1/3 of vagina is excised<br>– Pelvic lymphadenectomy | Type II | Modified radical hysterectomy<br>– Ureters are dissected to bladder entry<br>– Uterine arteries sectioned in medial half<br>– Uterine half of cardinal and uterosacral ligaments resected<br>– 1–2 cm vaginal cuff taken | Type B | B1 | – Ureters deperitonealized and rolled laterally<br>– Partial resection of uterosacral and vesicouterine ligaments<br>– Paracervix section at ureteric tunnel level<br>– 10 mm of vaginal cuff from cervix or tumour<br>– Lateral paracervical nodes not removed |
| | | | | | B2 | B1 but with removal of lateral paracervical nodes |
| Class III | Classical radical (Meigs) hysterectomy<br>– Complete dissection of the ureter except for terminal portion<br>– Uterine arteries divided at origin<br>– Uterosacral ligament detached at sacral attachment<br>Cardinal ligament resected at pelvic side wall<br>– Upper half of vagina resected<br>– Routine pelvic lymphadenectomy | Type III | Radical hysterectomy<br>– Resection of uterosacral ligaments as far as possible<br>– Parametrium resected as near as possible to pelvic side wall<br>– Uterine arteries ligated at origin<br>– Upper 1/3 of vagina resected | Type C | C1 | – Ureters fully mobilized<br>– Uterosacrals sectioned at level of rectum<br>– Vesicouterines sectioned at level of bladder<br>– Complete resection of paracervical tissue<br>– 15–20 mm of vaginal cuff taken including paracolpos<br>– With preservation of autonomic nerves |
| | | | | | C2 | C1, but without preservation of autonomic nerves |

**Table 1** (continued)

| Piver-Rutlege-Smith | | GCG-EORTC | | Querleu and Morrow | | |
|---|---|---|---|---|---|---|
| Class IV | Class III, but with<br>– Complete dissection of the ureter<br>– Umbilical-vesical artery is sacrificed<br>– Upper 3/4 of vagina removed | Type IV | Extended radical hysterectomy<br>– Similar to type III, but with removal of 3/4 of vagina and paracolpium | Type D | D1 | – Full resection of paracervix up to wall of pelvic bone, including hypogastric vessels exploding the sciatic nerve roots<br>– Ureter fully ambulant |
| | | | | | D2 | D1, with added resection of muscles and adjacent fascia |
| Class V | Class IV, plus:<br>– Partial excision of the ureter or bladder, with ureteric reimplantation | Type V | Partial pelvectomy<br>– Terminal ureter or bladder partly excised together with uterus and parametrium (supralevator) | | | |

(see Table 1) [4, 8]. For this reason, the Querleu and Morrow classification has gained wide acclaim.

## 3 Indications and Contraindications to Laparoscopic Radical Hysterectomy

The indications for laparoscopic radical hysterectomy are the same as for the open procedure. Worldwide, the foremost indication for radical hysterectomy is cancer of the cervix [9]. Indeed, radical hysterectomy has regained its place as the treatment of choice for early-stage cervical cancer up to FIGO stage IIA, with the exception of stage IA1 without lympho-vascular space involvement, for which cervical conization is considered adequate treatment [9, 10]. Radical hysterectomy is also indicated in selected patients with FIGO stage II endometrial cancer [9, 10]. In these patients, the procedure is also combined with para-aortic and pelvic lymphadenectomy [9].

Contraindications to laparoscopic radical hysterectomy include evidence of metastatic disease beyond the uterus, an enlarged uterus of more than 12-week size, a bulky cervical lesion of >4 cm, or the presence of known absolute contraindications to laparoscopy, such as severe cardiac and/or respiratory disease, and intestinal obstruction. Previous pelvic or abdominal surgery, prior radiotherapy, obesity, and the presence of coexisting pathology such as endometriosis are not regarded as contraindications to laparoscopic radical hysterectomy [11].

## 4 Advantages and Limitations of Laparoscopic Radical Hysterectomy

The laparoscopic approach offers numerous advantages over abdominal radical hysterectomy. These advantages include image magnification which enhances accuracy of tissue dissection, less blood loss and less need for blood transfusion, reduced need for analgesia, shorter hospital stay and quicker postoperative recovery. It is also associated with a lower rate of infections and wound morbidity [11]. However, there are some challenges and limitations to the use of laparoscopy for radical hysterectomy. These include its difficult learning curve due partly to the non-intuitive nature of laparoscopic movements and the absence of depth perception and tactile feedback. Studies have however shown that the operation time can be comparable between the laparoscopic and open methods [11, 12].

Without a doubt, the most important yardstick for comparing the laparoscopic with the open technique of radical hysterectomy would be their effects on disease outcomes such as disease recurrence, disease-free survival, progression-free survival and overall 5-year survival in the cancer patients for whom these procedures are indicated. All the early studies comparing these outcomes between laparoscopic and abdominal radical hysterectomy showed no statistically significant difference between the two approaches. However, these studies were small, mostly retrospective, and none of them was randomized [12].

In a landmark multinational randomized-controlled trial published in 2018, Ramirez et al. [13] compared laparoscopic (including robotic) against abdominal radical hysterectomy. This non-inferiority trial aimed to randomize a total of 740 women between the 2 arms and compare both short- and long-term outcomes between them. The trial however had to be terminated early (at 631 patients) when preliminary analysis revealed a statistically significant long-term outcome disadvantage in the laparoscopic/robotic radical hysterectomy arm. Although all the immediate and short-term advantages reported for laparoscopic radical hysterectomy in the earlier studies were confirmed in this trial, the trial also revealed overwhelming evidence of higher disease recurrence and lower disease-free survival and overall 3-year survival in the laparoscopy/robotic group. Although there is no proven explanation for these findings yet, a cloud of uncertainty has already gathered around the future of laparoscopic radical hysterectomy.

## 5 The Procedure for Laparoscopic Radical Hysterectomy

### 5.1 Bowel Preparation

- Liquid diet for 24 h prior to surgery.
- Polyethylene glycol is given orally in the evening before the day of the operation to empty the bowel.

### 5.2 Operating Room Setup

- Patient under general anaesthesia with or without regional anaesthesia.
- Perioperative antibiotics are administered.

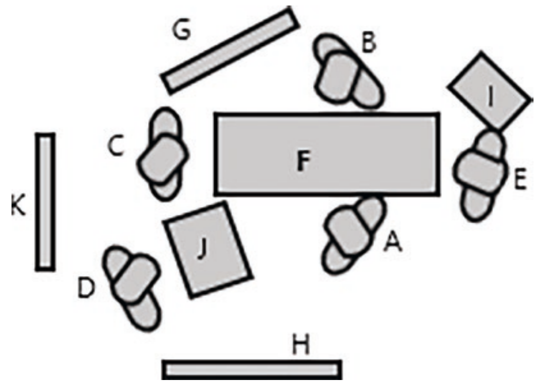


**Fig. 1** Operating room setup for laparoscopic radical hysterectomy (A, surgeon; B, first assistant; C, second assistant; D, scrub nurse; E, anaesthetist; F, patient; G, surgeon's monitor and equipment stack; H, assistant's monitor; I, anaesthetic machine; J, Mayo trolley; K, accessory screen)

- Patient is placed in modified lithotomy position using Allen's stirrups with thighs and legs apart and a slight flexion at both the hip and knee joints.
- Compression stockings are applied to prevent deep vein thrombosis.
- Both arms are positioned along the side of the body.
- Shoulder support should be used to prevent patient from sliding 'up' the table.
- Gastric tube and bladder catheter to be placed.
- Warming device may be used.
- Surgeon stands to the left of the patient (see Fig. 1).
- First assistant to the right of the patient (see Fig. 1).
- Second assistant seated between legs of the patient (see Fig. 1).
- Laparoscopic trolley placed at the leg end of the patient (see Fig. 1).

### 5.3 Trocar Placement (Using the Ipsilateral Port Placement)

- 10 mm camera port placed at the umbilicus (see Fig. 2).
- Secondary ports are placed under vision. These will include the following:
  – One 5 mm port in each iliac fossa, placed 2 fingerbreadths above and medial to the anterior superior iliac spine (see Fig. 2).

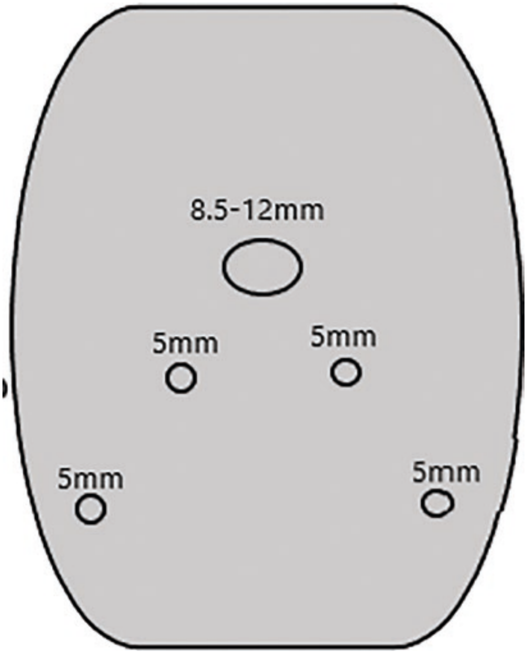


**Fig. 2** Suggested port placement and sizes for laparoscopic radical hysterectomy

– One 5 mm port on the midclavicular line at the level of the umbilicus or a midline 5 mm port between umbilicus and pubic symphysis can be placed depending upon the surgeon's comfort (see Fig. 2).

- Patient is subsequently placed in Trendelenburg position.

### 5.4 Uterine Manipulation

An intrauterine manipulator is inserted if possible. This may not be accomplishable in some patients with cervical cancer. In such cases, a laparoscopic myoma screw may be applied on the uterine fundus through a secondary port for effective uterine manipulation.

Proceeding with a radical hysterectomy requires that six avascular pelvic spaces be developed and that the bladder and rectum be mobilized. This is in addition to the four vascular pedicles. Energy sources therefore have a particularly important role to play. Harmonic®, because of its excellent performance in tissue dissection, is widely favoured [11–16]. However, where any of the vessels to be divided exceeds 5 mm, other advanced energy sources like Ligasure® and Enseal® would be called upon [11–16]. In the absence of these however, bipolar Maryland forceps for coagulation and monopolar diathermy on curved laparoscopic scissors for cutting will also serve. In fact, larger vessels such as the uterines and infundibulopelvics may even simply be suture ligated or clipped.

The procedure of a Querleu and Morrow type C1 laparoscopic radical hysterectomy is described below, i.e. with:

- Full mobilization of the ureters
- Resection of the uterosacral ligaments at level of rectum
- Resection of the vesicouterine ligaments at level of bladder
- Complete resection of paracervical tissue
- 15–20 mm of vaginal cuff taken, including paracolpos
- Preservation of the autonomic nerves

## 6 Procedure

### 6.1 Diagnostic Exploration

A thorough diagnostic exploration of the abdominal and pelvic cavities is performed to detect any secondary lesions involving the upper abdomen, diaphragmatic surfaces, hepatic capsule, omentum, visualized bowel, retroperitoneal contours facing the lumbo-aortic axis and the pelvis. Any suspicious lesion is biopsied and sent for frozen section histology. The malignancy must not involve the bladder, and the surgeon should be able to mobilize it—an important prerequisite for radical hysterectomy.

### 6.2 Dissection of Lateral Peritoneum and Pararectal Space

The left round ligament is lifted and cut close to the pelvic sidewall. This incision is extended along the lateral peritoneum covering the psoas muscle lateral to the genitofemoral nerve, till the base of the infundibulopelvic ligament is reached, lateral to the common iliac artery. Continuing on the posterior aspect of the base of the infundibulopelvic ligament, the incision is carried medially, dividing the peritoneum overlying the ureter, from lateral to medial side, up to the uterosacral ligament. Please see Image 1a.

Blunt dissection is then carried on laterally to open the pararectal space and expose the ureter. This blunt dissection is continued, lateral and parallel to the ureter to visualise the internal iliac artery, until the obliterated umbilical artery and the uterine artery are seen crossing the ureter transversely at the top of pararectal space. Thus, the internal iliac artery forms the lateral boundary and the ureter the medial boundary of the pararectal space. Please see Image 1b, c.

The uterine artery is then isolated, coagulated and divided at its origin from the internal iliac artery. This can be facilitated by gentle traction on the obliterated umbilical artery, to better expose the uterine artery at its origin. Please see Image 1d. The deep uterine vein is then coagulated and divided separately (Image 1e). This deep uterine vein is an important landmark in nerve-sparing radical hysterectomy, as the target nerve, i.e. the

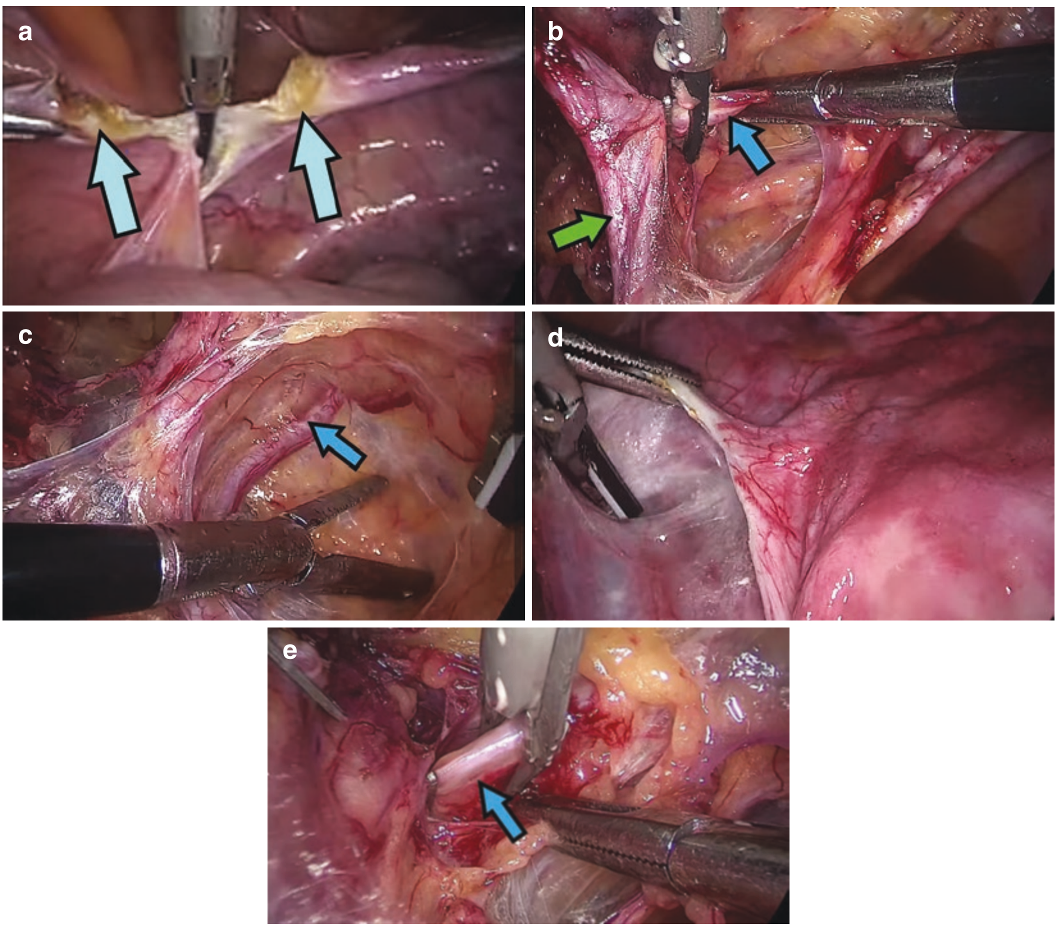


**Image 1** (**a**) Dividing of the left round ligament close to the pelvic sidewall. Blue arrows: cut ends of the round ligament. (**b**) Commencing left retroperitoneal dissection. (**c**) Dissecting the left pararectal space. Blue arrow: left external iliac vessels. (**d**) Dividing the left uterine artery after clipping it at its origin. Blue arrow: left uterine artery; green arrow, left internal iliac artery. (**e**) Clipping and dividing the left deep uterine vein separately. Blue arrow: left deep uterine vein. (Adapted from Reitan Ribeiro. Nerve sparing radical hysterectomy for cervical cancer—Technique update (minimal edition). Accessed at: https://www.youtube.com/watch?v=9aQAqTpGxr8)

pelvic splanchnic nerves which are the autonomic nerves from the hypogastric plexus are located just dorsomedial to the deep uterine vein; hence, dissection should not be carried out beyond it. This procedure is then repeated on the right site.

### 6.3 Dissection of the Rectovaginal Space

The peritoneum of the pouch of Douglas is pulled, and a cut is made, with the uterus in the anteverted position. Please see Image 2a. The dissection is carried out between the two layers of Denonvellier's fascia, keeping in mind that the fat belongs to the rectum and not to go too much toward the vagina, as it might injure the vessels. A swab on stick inserted vaginally can help to further delineate the posterior fornix. The dissection is carried on until the pelvic floor and rectum move away from the vagina completely.

### 6.4 Dissection of the Vesicovaginal Space

The uterus is retroverted, and starting from the lateral stump of the round ligament, the peritoneal incision is extended in the anterior leaf of the broad ligament. The vesicocervical fascial plane is developed between the bladder and the uterus, and the dissection is carried out between these two fascial planes way down the vesicovaginal space, so as to enable the removal of at least 2–3 cm of vagina distal to the cervical tumour.

### 6.5 Dissection of the Paravesical Space

The space anterior to uterine artery and medial to each obliterated umbilical artery is bluntly dissected down to the levator ani muscle.

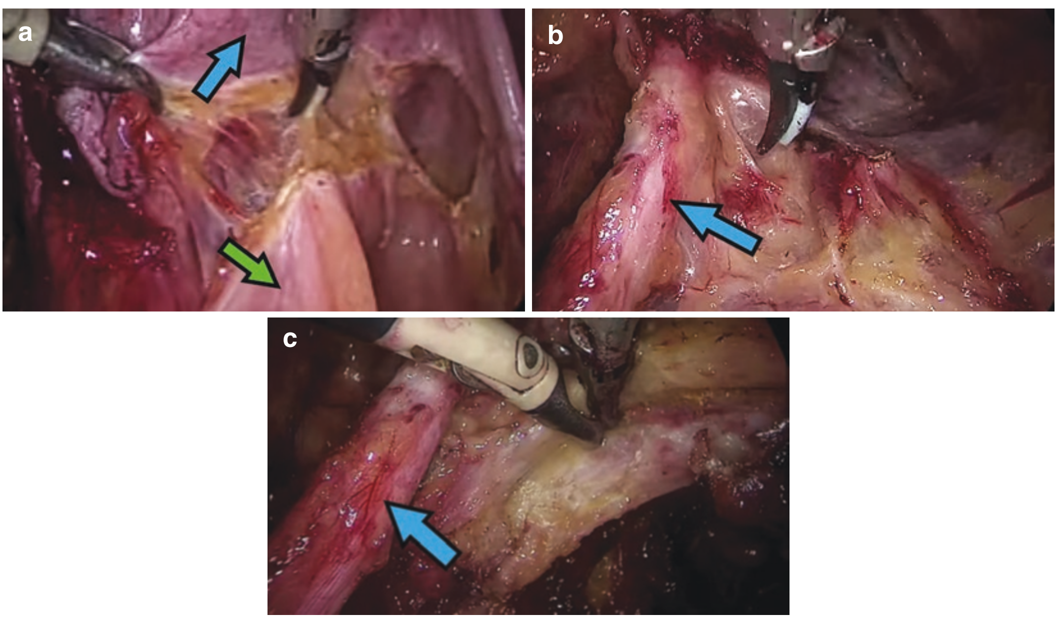


**Image 2** (**a**) Dissecting the rectovaginal space. Blue arrow, vagina; green arrow, rectum. (**b**) Unroofing the left ureteric tunnel. Blue arrow: left ureter. (**c**) Resecting the left paracervix and paracolpos medial to the left ureter. Blue arrow: left ureter. (Adapted from Reitan Ribeiro. Nerve sparing radical hysterectomy for cervical cancer—Technique update (minimal edition). Accessed at: https://www.youtube.com/watch?v=9aQAqTpGxr8)

### 6.6 Dissection of the Ureter and Hysterectomy

With the uterus displaced to the right side, the left uterine artery pedicle is held up and pulled medially to expose the roof of the ureteric tunnel just beneath it. The ureteric tunnel needs to be unroofed to free the ureter. Please see Image 2b. The roof of the ureteric tunnel contains two veins, which are carefully desiccated and cut, and the ureter is freed from its tunnel. This lateralizes the ureter, and its course into the bladder can be seen, and the bladder further dissected away. The paracolpos is then cut as laterally as possible, keeping the ureter lateral (Image 2c). The same steps are repeated on the right side.

Colpotomy is done taking the appropriate length of vaginal cuff (15–20 mm) along with the cervix. Please see Image 3a. At this stage, an assistant inserts a swab-stuffed sterile glove into the vagina to maintain pneumoperitoneum. The infundibulopelvic ligaments are then coagulated or ligated and cut, and the entire specimen is retrieved vaginally (Image 3b).

### 6.7 Pelvic Lymphadenectomy

Lymph node dissection is done by gentle traction on the lymphatic tissues with a grasper, combined with blunt and occasional sharp dissection. It is commenced at the bifurcation of the common iliac artery, which marks the superior limit of pelvic lymphadenectomy (Image 4a). All the fibrofatty tissues along the external iliac vein are dissected by staying parallel to these structures up to the genitofemoral nerve on the psoas muscle which is the lateral limit (Image 4b). The lymphatic tissues should be cleared all the way to the ureter which forms the medial limit (Image 4c). The mobilization of these lymph nodes exposes the obturator nerve which forms the inferior limit of the dissection. No dissection should proceed below the level of obturator nerve (Image 4d). The corona mortis (deep circumflex iliac vein) marks the anterior limit of pelvic lymph node dissection (Image 4e, f). The dissection of lymph nodes proceeds in a cranio-caudal direction, i.e. from common iliac to obturator nodes. This procedure is then repeated on the opposite side.

The resected lymphatic tissues are placed in the endobag and removed vaginally. The vaginal vault is sutured with No. 0 Vicryl (Image 5a, b). Saline irrigation is done and haemostasis confirmed. Indigo carmine is injected intravenously, and the ureters are viewed to rule out ureteric injury. The bladder is distended with saline or cystoscopy which is performed to rule out bladder injury, and rectal insufflation is done to exclude rectal injury. The pneumoperitoneum is then reduced for a final haemostasis check. The ports are removed under vision, and the port sites are closed.

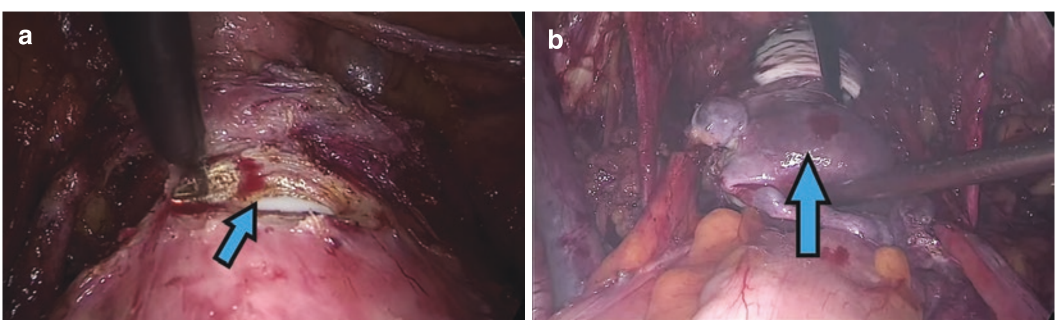


**Image 3** (**a**) Performing the anterior colpotomy. Blue arrow: anterior colpotomy. (**b**) Retrieval of the uterus through the vagina. Blue arrow: the uterus. (Adapted from Reitan Ribeiro. Nerve sparing radical hysterectomy for cervical cancer—Technique update (minimal edition). Accessed at: https://www.youtube.com/watch?v=9aQAqTpGxr8)

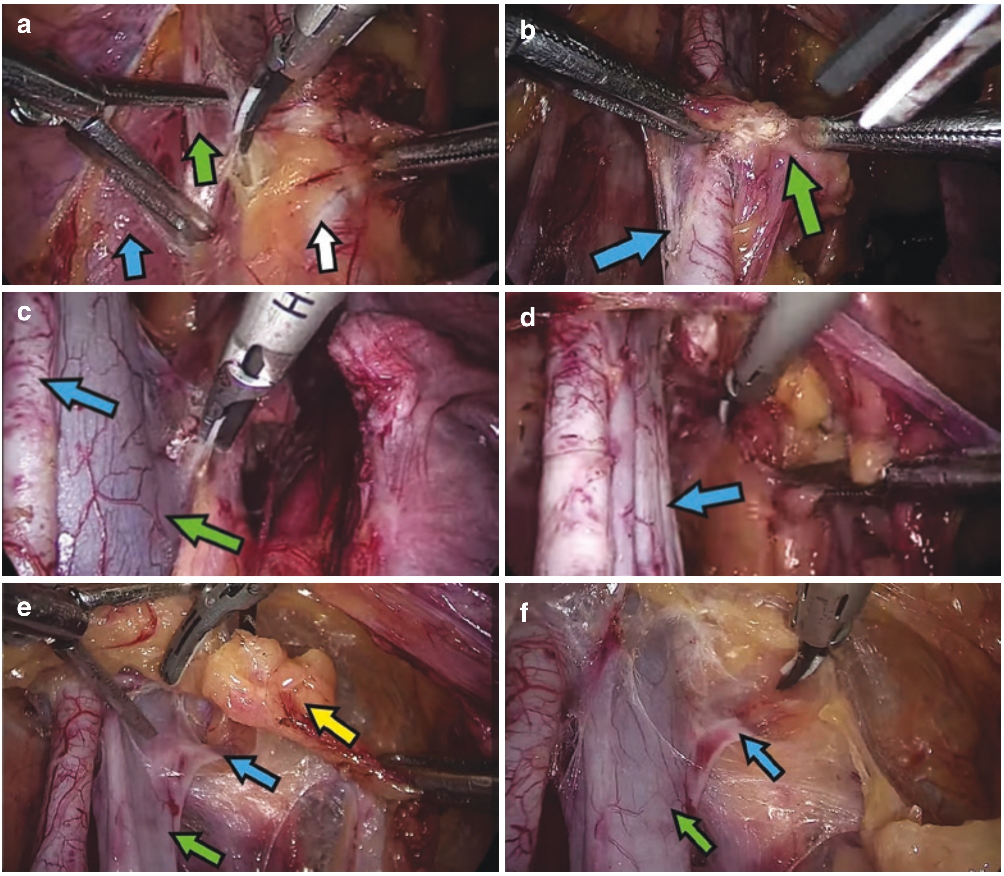


**Image 4** (**a**) Commencing pelvic lymphadenectomy on the left. Blue arrow, psoas muscle; green arrow, genitofemoral nerve. White arrow: external iliac artery. (**b**) Clearing of lymphatic tissue from the bifurcation of the common iliac vessels proximally. Blue arrow, left external iliac artery; green arrow, lymphatic tissue. (**c**) Clearing of all lymphatic tissues from the external iliac vein. Blue arrow, left external iliac artery; green arrow, left external iliac vein. (**d**) Dissecting the obturator group of lymph nodes. Blue arrow: skeletonized external iliac vessels. (**e**) Resecting the obturator nodes up to the corona mortis (deep circumflex iliac vein). Green arrow, external iliac vein; blue arrow, corona mortis. Yellow arrow: obturator nodes. (**f**) Lymphadenectomy completed anteriorly. Green arrow, external iliac vein; blue arrow, corona mortis. (Adapted from Reitan Ribeiro. Nerve sparing radical hysterectomy for cervical cancer—Technique update (minimal edition). Accessed at: https://www.youtube.com/watch?v=9aQAqTpGxr8)

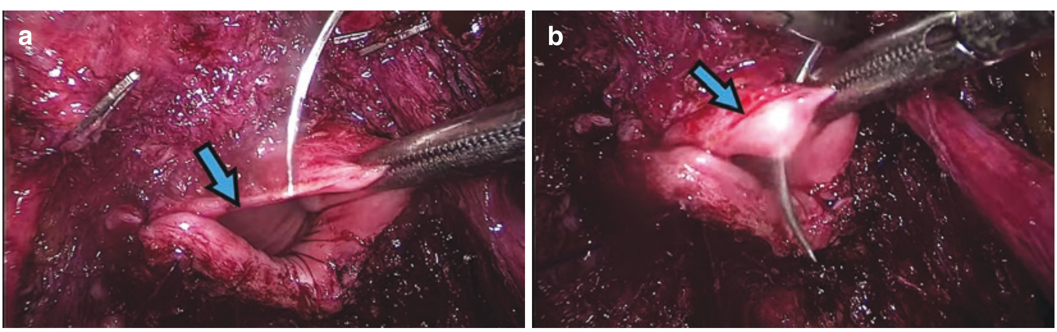


**Image 5** (**a**) Laparoscopic vaginal vault closure. Blue arrow: vaginal vault. (**b**) Suturing of the vaginal vault. Blue arrow: vaginal vault. (Adapted from: Reitan Ribeiro. Nerve sparing radical hysterectomy for cervical cancer—Technique update (minimal edition). Accessed at: https://www.youtube.com/watch?v=9aQAqTpGxr8)

## 7 Complications of Laparoscopic Radical Hysterectomy

- Bleeding
- Bladder injury
- Ureteric injury
- Bowel injury
- Nerve injury
- Fistulas
- Cancer recurrence
- Death

## 8 Conclusion

Laparoscopic radical hysterectomy is one of the most advanced and complex laparoscopic gynaecological procedures. The surgery requires a combination of flawless understanding of retroperitoneal anatomy and advanced operative laparoscopy skills. Indeed, with the introduction of robotics, radical hysterectomy had become one of the procedures increasingly being performed robotically [12, 13]. Unfortunately, in the light of the findings of the large randomized controlled trial which demonstrated worse outcomes in terms of disease recurrence, disease-free survival and overall survival among women with early-stage cancer of the cervix who underwent laparoscopic radical hysterectomy are compared to abdominal radical hysterectomy; the future of this fascinating surgical procedure currently hangs in the balance [13].

**Learning Points**

- Radical hysterectomy is a treatment option for early-stage cervical cancer.
- The first laparoscopic radical hysterectomy was performed by Camran Nezhat in 1989.
- Laparoscopic radical hysterectomy is associated with less postoperative morbidity, faster recovery and shorter hospital stay.
- A large RCT has associated laparoscopic radical hysterectomy with a higher disease recurrence, and lower disease-free survival and overall 3-year survival when compared with open abdominal radical hysterectomy.
- The future of laparoscopic radical hysterectomy is therefore still uncertain.
- Laparoscopic radical hysterectomy requires and therefore encourages the development of excellent retroperitoneal dissection skills.

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# Complications of Laparoscopy

Olusoji Jagun and Adekeye Olaore

**Summary Box**

- Complications from laparoscopy procedures range from mild to severe. Complications may occur as a result of entry, insufflation, dissection or the use of energy. Most of the complications occur during entry.
- When complication occurs, early recognition and prompt and appropriate management will minimise morbidity and mortality.
- Adequate training, adherence to safety rules and regulations, optimal condition of equipment and proper patient selection will reduce the rate of complications.

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## 1 Introduction

Surgical complications are adverse effects that are known or previously unknown to occur after a procedure. They are mostly preventable and better envisaged for every surgery to have a successful outcome. Endoscopic surgeries are peculiar in that they are associated with energy use, reduced operating space and longer operating time. No surgeon wants to have complications, but it occurs as part of the learning curve. Fewer complications are expected as more years are put into practice. It is difficult to determine the real incidence of complications of laparoscopy because of definitions of what a complication is. The actual incidence is likely more than reported in most instances, coupled with bias in reporting especially for minor cases, while some complications could go unrecognized.

Complications generally occur in about 0.2–10.3% of all gynaecological endoscopy with majority of them occurring following major surgical procedures [1]. Complication rates are about 0.6–18% after major surgeries and 0.06–7.0% after minor ones. Mortality could result quite commonly from vascular injuries and, to a lesser extent, unrecognized intestinal injuries.

The majority of complications occur at the time of entry into the abdomen for the purpose of creating a pneumoperitoneum. The open entry


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technique is associated with less risk of vascular injuries compared with the closed entry method. Other reasons for complications are thermal and energy source injuries, operative manipulations and suturing, and the presence of $CO_2$ outside the peritoneal cavity.

Other possible causes of complications include poor suturing skills, $CO_2$ gas embolism, poor case selection and inexperienced surgeon. Patients-related factors will include previous pelvic surgeries, pelvic adhesions, irradiation, older age and obesity [2].

## 2 Classification of Complications

Many attempts have been made at classifying complications, and one of the most used is the Clavien-Dindo classification which is general for all surgeries. It is a standardized system for recording complications which contribute to a structured quality assurance and thus to a higher quality of care. It defines the occurrence of a complication as any deviation from the ideal post-operative course that is not inherent to the operation and that cannot be considered as a therapeutic failure of the operation [3]. Other simplified ones include classification as major and minor complications, based on the site of injury, the phase where complications occur or according to technical severity.

### 2.1 Clavien-Dindo Classification of Surgical Complications

| | |
|---|---|
| Grade I | Any deviation from the normal course without the need for pharmacological treatment or surgical, endoscopic and radiologic interventions<br>Allowed therapeutic regimens are drugs as antiemetics, antipyretics, analgesics, diuretics, electrolytes and physiotherapy. This grade also includes wound infections opened at the bedside |
| Grade II | Requiring pharmacological treatment with drugs other than such allowed for grade I complications<br>Blood transfusions and total parenteral nutrition are also included |
| Grade III | Requiring surgical, endoscopic or radiological intervention |
| IIIa | Intervention not under general anesthesia |
| IIIb | Intervention under general anesthesia |
| Grade IV | Life-threatening complication (including CNS complications)[a] requiring IC/ICU management |
| IVa | Single organ dysfunction (including dialysis) |
| IVb | Multiorgan dysfunction |
| Grade V | Death of a patient |

*CNS* central nervous system, *IC* intermediate care, *ICU* intensive care unit

[a] Brain haemorrhage, ischaemic stroke and subarrachnoidal bleeding, but excluding transient ischaemic attacks

### 2.2 Classification Based on Type and Site of Injury

- Anaesthesia
  - Gas and positioning
    Hypoventilation, gastro-oesophageal reflux, hypotension, cardiac arrhythmias
- Entry-related injury
  - Port injury
  - Abdominal wall injuries
  - Hernias
- Electrosurgical or electro-thermal
  - Electrode trauma, remote injury, insulation failure and capacitive coupling
- Haemorrhagic
  - Associated with entry, abdominal wall vessels, intraperitoneal
- Gastrointestinal
  - Insufflation needle injuries, trocar injuries
- Urologic
  - Bladder and ureter
- Neurological injuries
  - Peripheral nerve injuries due to positioning of the patient
  - Direct injuries during dissection
- Infections
- Port site metastasis

| Complications | Rate (%) | Causes |
|---|---|---|
| Abdominal wall Vascular injury | 0.5 | Entry related |
| Intestinal injury | 0–0.5 | Entry-related/ thermal injury |

| Complications | Rate (%) | Causes |
|---|---|---|
| Ureteral injury | 0.025–2.0 | Electrocautery main cause, trocar, laser dissection, staples and suturing |
| Bladder injury | 0.02–8.3 | Entry-related, thermal, dissection |
| Major vascular injury | 0.04–0.5 | Entry, energy, operative |
| Hernia at trocar site | 0.17–2.0 | Entry related |
| Subcutaneous emphysema | 2.3 | $CO_2$ in subcutaneous tissue |
| Hypercarbia | 5.5 | Longer operative times, high end-tidal $CO_2$, older age patient |
| Cardiac arrythmia | 27 | |
| Pneumothorax/ pneumomediastinum | 0.2–19 | Pneumoperitoneum diaphragmatic defect |
| Port-site metastasis | 1.1–2.3 | Pneumoperitoneum and $CO_2$ related |

### 2.2.1 Anaesthesia

Laparoscopic surgery comes with peculiar anaesthetic challenges, and some of these include the effects of pneumoperitoneum, patient positioning, extraperitoneal gas insufflation and venous gas embolism.

#### Pneumoperitoneum

Gas insufflation for the purpose of pneumoperitoneum can cause cardiopulmonary instability. Initial gas insufflation may cause vasovagal reflex from peritoneal stretch resulting in pronounced bradyarrhythmias and even asystole. This needs to be differentiated from intravascular gas insufflation, intra-abdominal blood loss from vascular injury or anaphylactic reactions which may all present as shock. The release of pneumoperitoneum, with or without administration of short-acting adrenergic drugs such as atropine or adrenaline, should result in rapid reversal of the bradycardia and may be followed by re-insufflation at a slower rate. Once the procedure is underway, the continuing raised intra-abdominal pressure can cause a reduction in venous return via the inferior vena cava and a rise in systemic vascular resistance (SVR). These changes can result in a fall in cardiac output (CO). Pneumoperitoneum may also affect lung mechanics causing a significant reduction in compliance and increase in airway pressures. Alterations in lung unit ventilation–perfusion (V/Q) ratios can lead to increased mismatching and consequent effects on $O_2$ and $CO_2$ blood concentrations, notably hypoxaemia and hypercarbia.

#### Positioning

The Trendelenburg position may partially offset the changes to venous return compensating for the pneumoperitoneum by increasing cerebral perfusion; it may however lead to a number of pulmonary effects such as a decrease in vital lung capacity and increase in airway pressure caused by cephalad movement of abdominal viscera onto the diaphragm. The endotracheal tube may slip into the right bronchus with the cephalad shift of the trachea carina. Prolonged Trendelenburg positioning may lead to a significant increase in central venous pressure and cause central and cerebral venous congestion. To counter some of these side effects, the intra-abdominal pressure should be kept to less than 15 cm of water and ventilation pressures to less than 30 cm of water while maintaining adequate minute ventilation and minimizing duration of surgery to decrease cerebral venous congestion.

#### Extraperitoneal Gas Insufflation

$CO_2$ under pressure can pass through pericardial and pleural spaces through anatomic, congenital paths or acquired diaphragmatic defects. Significant extraperitoneal gas insufflations can lead to pneumomediastinum, pneumopericardium and pneumothorax. Similarly, $CO_2$ can pass retroperitoneally through vast potential spaces causing subcutaneous emphysema. This can also occur with the wrong placement of the Veress needle or leakage of gas around the cannula sites and in the obese patients. The incidence for pneumothorax/pneumomediastinum is 0.2–1.9% [4].

Prolonged operations, higher maximum measured end-tidal $CO_2$, a greater number of surgical ports and older patient age increase the risk. Hypercarbia and therefore acidosis develop due to absorption of $CO_2$ in prolonged operations with an incidence of 5.5% [4].

Intraoperative treatment of extraperitoneal $CO_2$ insufflation includes the use of positive end expiratory pressure (PEEP), increased minute ventilation to open collapsed alveoli and increased pressure to decrease the abdominal pressure gradient (or decrease abdominal pressure) to splint or seal the defect.

Post-operatively, entrapped $CO_2$ gas will diffuse out using treatment with 100% oxygen and adequate ventilation in an upright sitting position.

#### $CO_2$ Embolism

This rare but mortal complication can lead to sudden cardiovascular collapse, profound neurological deficit and is associated with a mortality rate as high as 28.5% [5]. The incidence varies from 0.001% to 0.59% of cases. This complication may occur soon after commencement of gas insufflations and is due to direct intravascular gas entry into the arterial or venous system.

Small amounts of $CO_2$ embolism may be inconsequential as $CO_2$ is highly soluble in blood. However, when large volumes of gas are lodged directly onto the pulmonary outflow trunk, this can lead to increase in pulmonary arterial pressure (PAP), increased resistance to right ventricular outflow and diminished pulmonary venous return. The consequent decrease in left ventricular preload results in diminished cardiac output, asystole and systemic cardiovascular collapse. In addition, the alteration in the resistance of the pulmonary vessels and ventilation perfusion (VQ) mismatch cause intrapulmonary right-to-left shunting and increased alveolar dead space, leading to arterial hypoxia and hypercapnia manifested by cyanosis and raised jugular venous pressure. Studies in dogs have shown that the median lethal dose of $CO_2$ embolism is 25 mL/kg, which amounts to about 1750 mL of $CO_2$ or 375 mL of air in a 70-kg person [6].

Diagnosis may be difficult because many disorders like anaphylaxis, pneumothorax, coronary events and haemorrhage can mimic gas embolism (hypotension, hypoxia, decreased end-tidal carbon dioxide); however, blood coming from the Veress needle is an alert, and the needle should not be removed. Initial resuscitation must include communication with the surgical team, release of pneumoperitoneum and basic life support measures while definite cause is being investigated.

### 2.2.2 Entry-Related Injury

Entry into the abdomen during laparoscopy involves gas insufflation and insertion of primary (most commonly at the umbilicus) and secondary trocars. More than 50% of all complications associated with laparoscopy occur during the abdominal entry phase. The potential complications include vascular, intestinal, urinary tract injury and hernias. Appropriate entry methods and procedures will reduce the risk of complications (Fig. 1).

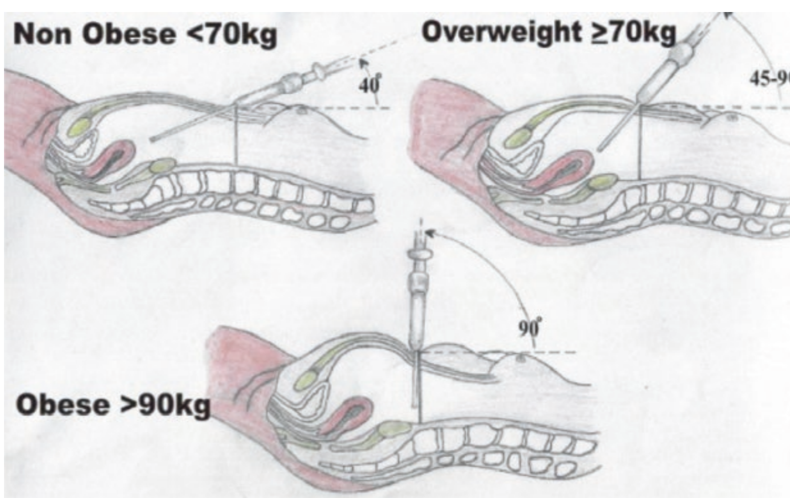


**Fig. 1** Entry method

**Abdominal Wall Vascular Injury**

Vascular injuries are the most alarming and serious laparoscopic complications with a 9–17% mortality rate [5, 7]. The reported incidence varies from 0.04% to 0.5% of all laparoscopies [5]. This can be major or minor bleedings. Bleeding resulting from anterior abdominal wall is regarded as minor but at the same time could be life-threatening. Most vascular injuries occur during insertion of the Veress needle or the trocar, and vascular injuries of aberrant vessels may also occur during the Hasson open and direct entry.

Significant bleeding arises from injury to the superficial epigastric, superficial circumflex, inferior epigastric or deep circumflex vessels from insertion of secondary trocars. The bleeding may present as a diffuse haematoma within the abdominal wall or profuse haemorrhage into the peritoneal cavity. At times, port-site bleeding may be tamponaded by the trocar and seems minimal during surgery but may present during the post-operative phase.

Prevention of abdominal wall vascular injury will involve the insertion of the secondary trocars always under direct vision to avoid injuring the vessels in the abdominal wall and the pelvic sidewall. The superficial epigastric and the superficial circumflex iliac vessels can be identified by transillumination, while the inferior epigastric vessels can be traced by direct visualization of the anterior abdomen.

**Hernia at Trocar Site**

Herniation through laparoscopic port sites is uncommon and preventable, with a reported incidence of 0.17–0.2%. It is believed that up to one-third of all trocar injuries cause incisional hernia formation. The risk is related to the size of the trocar with a 3.1% risk associated with 12-mm trocar wounds compared to 0.2% with 10-mm trocar wounds. Bowel herniation through 5-mm ports has also been reported though very rare [8]. Omental and Richter's herniation occurs if the primary cannula is withdrawn with its valve closed, and it is possible to draw a piece of omentum into the umbilical wound by the negative pressure produced. Intestines may also be involved. Signs of intestinal obstruction, increased bowel sounds, diarrhoea, nausea and vomiting may indicate a hernia.

Although repairing the hernia is enough in most of these cases, 19% require intestinal resection secondary to incarceration [9]. Hernias are repaired laparotomically or, less commonly, laparoscopically. Trocar sites >10 mm should be sutured for prevention. It is recommended that 5-mm trocar sites if enlarged during operative manipulations should be repaired. To minimize the risk of herniation, secondary trocars should be removed under direct vision before the primary one, and valves should be kept closed to prevent a sucking effect, and 5-mm trocars should be preferred.

### 2.2.3 Electrosurgical Injuries

Electrosurgical complications are an inevitable reality of laparoscopy, and it is important to have a systematic awareness of the types of complications and how to deal with them. It is noteworthy that complications occur more with monopolar and can be remote from the operation site.

Injury from inadvertent energy transfer has a reported incidence of 1–5 recognized injuries per 1000 cases and can occur by direct application, stray current, direct coupling, capacitive coupling or return electrode or alternative site burns [10, 11].

Direct application injuries occur due to unintended activation of the electrosurgical probe or mistaken targeting (overshooting). This can cause desiccation or fulguration of the tissue. The length of activation will determine the extent of injury (overcooking).

Stray current or defective insulation. Stray current from defective insulation causes bowel or blood vessel injury (Fig. 2). The causes of defective insulation include the use of high-voltage currents and the frequent resterilization of instruments, which can weaken and break insulation. Prevention is by careful pre- and post-operative inspection of equipment. It is also recommended to use an electrosurgical unit that has active electrode monitoring (AEM) technology.

Direct coupling occurs when the electrosurgical unit is accidentally activated, while the active electrode is in close proximity to another metal instrument. Current from the active electrode

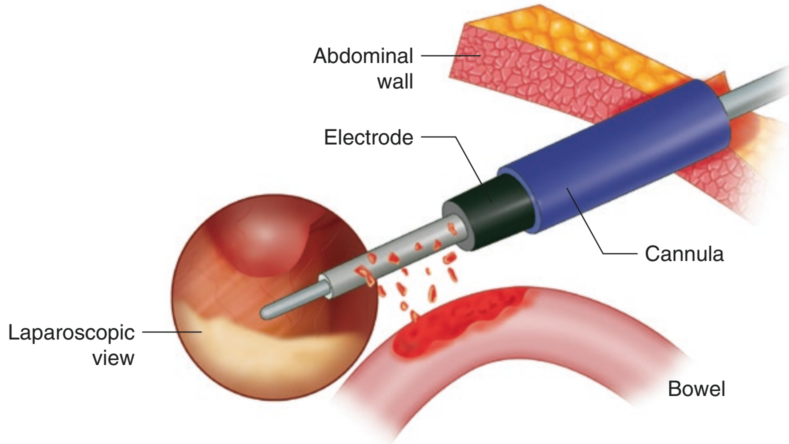


**Fig. 2** Insulation failure

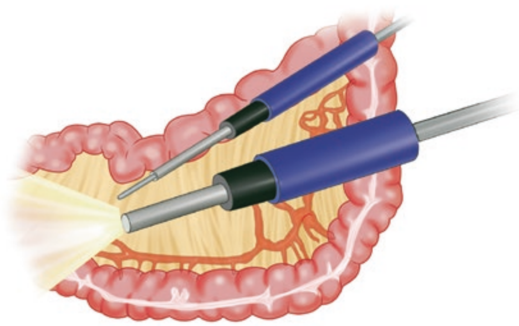

**Fig. 3** Direct coupling

flows through the adjacent instrument through the pathway of least resistance and potentially damages adjacent structures or organs not within the visual field that are in direct contact with the secondary instrument. It can be prevented with visualization of the electrode in contact with the target tissue and avoiding contact with any other conductive instruments prior to activating the electrode (Fig. 3).

#### Capacitive Coupling

Capacitive coupling is electrical current that is established in tissue or in metal instruments running parallel to but not directly in contact with the active electrode. This occurs when electric current is transferred from one conductor (the active electrode) through intact insulation and into adjacent conductive materials (e.g. bowel) without direct contact. It is usually a problem associated with monopolar.

#### Return Electrode or Alternate Site Burns

The dispersive pad or return electrode may not be completely in contact with the patients' skin or is not able to disperse the current safely; the exiting current can have a high enough density to produce an unintended burn. A burn at an alternative site can occur if the dispersive pad is compromised in quantity or quality of the pad or patients' interface. The electrical circuit can be completed by some small grounded contact points like clips, drip stands which will produce high current densities, causing a burn.

### 2.2.4 Haemorrhagic (Major Vascular) Injury

Most vascular injuries occur during insertion of the Veress needle or the trocar. The proximity of the distal aorta and the right common iliac vessels to the umbilicus put them at higher risk of injury than the inferior vena cava, the left common, the internal and external iliac vessels. Vascular injuries can occur irrespective of the mode of entry into the abdomen whether by the Hasson open entry, direct entry or with Veress. Bleeding on aspiration of the Veress needle or through the trocar, frank or concealed bleeding within the pelvis or abdomen and unexplained hypotension should warrant exploration and identification of the bleeding vessel immediately. Due to delayed recognition, vascular injury during the entry phase is associated with greater morbidity and mortality than injury during the surgical phase of a laparoscopic procedure.

Risk factors contributing to major vascular injury include the surgeon's skill, instrument sharpness, angle of insertion, patient's position, degree of abdominal wall elevation and volume of pneumoperitoneum. To eliminate some of these, angle of entry is very important, and the body build should always be a consideration. Also insufflating with an entry pressure of 20–25 mmHg decreases the chances of damage to the major abdominal vessels.

### 2.2.5 Intestinal Injury

Approximately half of bowel injuries occur during entry, and the rest occur during the operation. Entry-related bowel injuries are mostly lacerations, and intraoperative injuries are mostly thermal. Most bowel injuries are not diagnosed during surgery. Delayed intervention may be life-threatening. Therefore, this complication is reported to be the most common cause of laparoscopy-related mortality, and this is increased if the diagnosis is delayed more than 72 h. Rates of small and large bowel injuries are similar, but small bowel injuries have an edge in incidence, and the mean time from operation to diagnosis could take about 4 days, but recognition of thermal injury may lag behind by 10 days. It is estimated that only 30–50% of intestinal injuries are recognized during surgery. The remainder may present any time from 1 to 30 days after surgery [12, 13].

The extent of adhesiolysis performed intraoperatively has been found to be a significant risk factor for intestinal injury [5]. An open entry technique has not been shown to reduce the incidence of entry-related bowel complications but may allow immediate recognition of the bowel injuries. Intestinal trauma may result from inappropriate use of grasping forceps, bowel retraction, insertion and reinsertion of instruments or sharp dissection. Thermal injuries during surgery may be caused by direct, capacitive coupling or insulation failure.

When bowel is entered via Veress needle or trocar, bowel content or gas passage may be observed or may be confirmed with a syringe if suspected. A laparoscope will show bowel lumen in such a case. If intraoperatively unrecognized, patients present with nonspecific complaints not exactly pointing to peritonitis, such as mild abdominal pain, fever, diarrhoea and abdominal distension, further delaying the diagnosis. Late consequences may be generalized peritonitis, abscess formation and septic shock.

Intestinal injuries are repaired laparotomically in about 50–90% of cases [9, 12, 13]. Injury caused by the Veress needle may be managed conservatively. However, trocar injuries deserve laparotomic repair according to the size and location of the injury. Primary closure in two layers is adequate in small bowel injuries. If the large bowel is involved, the treatment options include primary repair, colostomy or segmental resection. Resection is mandatory in thermal injuries. Intraoperative lacerations may however be repaired laparoscopically according to the size of the lesion, surgeon experience and whether or not preoperative bowel preparation was performed.

### 2.2.6 Urologic Injuries

#### Bladder Injuries

Bladder injury is the most common urinary tract injury during laparoscopy, and this may occur due to insertion of a suprapubic trocar into a full bladder, bladder dissection during laparoscopic hysterectomy, excision of endometriosis or removal of pelvic masses such as uterine myoma or ovarian tumours. Adhesions from previous caesarean section or radiation can also increase the risk of bladder injury. Bladder perforation is the most common with an incidence of 0.02–8.3%, and the most common injury site is the bladder dome in 90% of cases followed by the posterior bladder base [14]. The mechanisms of bladder injury during laparoscopic surgery include electrocautery, blunt dissection or trauma from laser, scissors and from trocars.

Few bladder injuries are not recognized intraoperatively; therefore, morbidity is low. In suspected cases, filling the bladder with methylene blue dye to observe dye leakage will help with diagnosis. Patients with unrecognized cases presented with abdominal discomfort and oliguria as a cardinal sign. According to type, size and localization of injury, conservative or surgical management via laparoscopic, laparotomic or vaginal approaches may be considered.

Prevention of bladder injuries involves (1) perform a very careful dissection of the vesico-vaginal pouch and use uterine cannulation; (2) fill the bladder with a methylene blue dye solution to visualize its limits in case of difficult dissection, such as previous surgery (caesarean delivery, endometriosis surgery, conization, and others); (3) perform very careful and restricted use of bipolar coagulation in the vesico-vaginal space for haemostasis; and (4) follow the safety rules of introduction, in particular avoiding the Pfannenstiel scar. The routine use of intraoperative cystoscopy for patients undergoing major gynaecological surgery has been proposed as a secondary preventive measure for urinary tract injury. This procedure appears to reduce the rate of urinary tract injuries discovered post-operatively [15]. Surgeons should be highly vigilant especially if a procedure is difficult or complicated.

#### Ureteral Injury

Pelvic surgery is the most common cause of iatrogenic ureteral injury, and the chances of ureteric injuries during laparoscopic surgeries are higher than during abdominal surgeries [16]. This is attributed to increasing deep pelvic laparoscopic surgeries. The majority of patients with ureteral injuries have no identifiable predisposing risk factors. Ureteral injuries have an incidence ranging from 0.025% to 2% and accounts for 4.3% to 7% of the total laparoscopy complications.

Electrocautery, whether unipolar or bipolar, was identified as the leading cause of laparoscopic ureteral injury. Injuries with loop suturing, trocars, laser devices, staples and sharp dissection were also described. The three most common locations for the risk for ureteral injury during laparoscopic surgeries are (1) pelvic brim, where the ureters lie beneath the insertions of the infundibulopelvic ligaments; (2) deep ovarian fossa where the ureter passes; and (3) the ureteral canal. The most common site of injury was near the infundibulopelvic ligament. Injuries may include transection, ligation, avulsion, crush injury, devascularization, resection, fulguration and perforation. A significant amount of the injuries occurred during laparoscopic-assisted vaginal hysterectomy, oophorectomy and during laparoscopic pelvic lymphadenectomy. These injuries are frequently undetected. Delayed diagnosis of urinary tract injury is associated with serious morbidity such as fistula formation, peritonitis, loss of renal function and is a frequent cause of medicolegal litigation. Depending on the type of injury, patients may present in the early post-operative period (first 3 days), or presentation of the thermal or laceration injuries may be delayed by several days or weeks. A study showed that only 9% of ureteral injuries were diagnosed intraoperatively, 70% post-operatively, and in 21%, the time of ureteral injury was not specified [17].

Methods for identifying ureteral injury include (1) retrograde ureteral dye injection; (2) intravenous excretory urography; (3) intraoperative ureteral catheterization; (4) cystoscopy after 5–10 mL intravenous indigo carmine injection; (5) dissection of the ureter; (6) failure to freely pass a ureteric stent; and (7) blanching of a segment of the ureter following a diathermy use. A coagulated or ligated ureter may not demonstrate an intraperitoneal urine leak when tested intraoperatively. The lack of a ureteral jet at cystoscopic examination will indicate the problem clearly in such a case.

Post-operative presentation may include acute pelvic pain, loin pain in hydronephrosis, nausea, vomiting, malaise, leakage of fluid via the trocar sites, abdominal distension and an inflammatory reaction in the serum (elevated CRP and leucocytosis), elevated creatinine level, costovertebral angle tenderness, ileus, fever, flank pain and peritonitis. Plain X-ray of the abdomen may reveal a ground-glass appearance indicative of fluid collection. A computed tomography scan may also reveal the presence of urine in the peritoneal cavity after intravenous contrast medium injection. Ligation of the ureter, for example, with stapling, or stricture resulting from thermal injury, may lead to obstructive uropathy and superimposed pyelonephrosis. The diagnosis should be confirmed by an intravenous urogram. Diathermy injury may result in necrosis, urinary leakage and urinary peritonitis.

Laparoscopic repair is frequently used in cases recognized intraoperatively and when the lesion is less than 1.5 cm, while the laparotomic approach is performed in patients diagnosed post-operatively. Focal ureteral injuries can be treated using a double J-shaped catheter allowing for spontaneous healing. However, more extensive damage may require laparotomy to perform an end-to-end anastomosis or ureteral implantation. In delayed recognition of ureteral injury, initial treatment with ureteral stenting may not be useful, and early open repair (ureteral reconstruction, ureteroneocystostomy) for these injuries is advocated. Where there is a loss of ureteric length, a psoas hitch or Boari flap may be considered to ensure a tension-free anastomosis.

To minimize ureteral injury, the use of sutures should be preferred instead of staplers or electrocautery in close proximity to ureters. Visualization of ureters during the operation, the use of ureteral catheters and creating hydroprotection by injection of saline into the parietal peritoneum are the other protective measures.

### 2.2.7 Neurologic Injuries

Nerve injuries are rare, but they do occur. They can either be transient or permanent damage. Transient nerve injuries may occur during any procedure with incorrect positioning causing stretching of the nerves, and this may affect brachial plexus, common peroneal nerve and also the saphenous nerve. Permanent damage may occur as a direct injury during pelvic lymphadenectomy or removal of a pelvic sidewall mass.

Treatment of nerve injury is quite difficult and is associated with unpredictable outcomes, and prevention is therefore the most crucial step in dealing with laparoscopy-associated nerve damage. Proper positioning of the patient in the low lithotomy position using boot stirrups is obligatory for every laparoscopic procedure. This includes mild flexion of the hip to around 170° in relation to the trunk and 90°–120° flexion of the knee. Abduction of the thighs should result in no more than 90° between the legs, and there should be minimal external rotation of the hips. The patient's arms should be adjacent to the body.

Direct nerve injuries are best handled by neurosurgeons where available.

### 2.2.8 Infections

Any surgical procedure is prone to infection, and laparoscopic surgeries are not exempted though the risk is low due to prophylactic antibiotics that are given. Some of the infections include:

- Pelvic inflammatory disease. This can occur following chromotubation and uterine cannulation or combined laparoscopic and hysteroscopic surgeries.
- Surgical site infection. This is not usual and is treated as a minor complication.
- Septicaemia. This usually occurs following unidentified bowel perforation or thermal injury and following endometriotic surgeries especially the deep infiltrating type when bowel perforation is involved.

### 2.2.9 Port-Site Metastasis

The rate of port-site metastases in patients with gynaecological malignancies is 1.1–2.3% which is similar to the rate of wound metastasis seen in laparotomy during gynaecologic malignancy operations [9, 18].

Risk factors proposed for port-site metastasis include:

1. Aggressive disease
2. The use of $CO_2$, compared with other insufflating agents, is associated with significantly increased tumour growth
3. Creation of pneumoperitoneum increases risk compared with gasless laparoscopy
4. High efflux of gas from the abdominal cavity through the space around the trocars
5. Decreased influence of the local immune system during laparoscopy

The risk of port-site metastases is highest in patients with recurrence of ovarian or primary peritoneal malignancies with ascites. The lavage of port sites with cytotoxic agents (heparin, taurolidine, combination of heparin and taurolidine, 5-fluorouracil, doxorubicin, povidine–iodine solution, and methotrexate) can be suggested as a preventive measure.

## 3 Conclusion

While the benefits of laparoscopic surgery are clear, the laparoscopic surgeon should always be mindful of the potential complications, taking steps along the way, toward avoiding them. Majority of the complications occur during entry into the abdomen. Therefore, good entry techniques are advocated. Adequate training and proper selection of patients will go a long way in preventing complications.

**Learning Points**

- Complications are common occurrence in endoscopic procedures.
- High index of suspicion and early recognition and treatment reduce morbidity and mortality.
- Complication rates reduce with experience.
- Since most complications occur at entry, it is preferable to choose a safe entry technique.
- When in doubt, seek a second opinion.

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# Part III

# Hysteroscopy

# Tips and Tricks to Facilitate the Art of Intrauterine Surgery

Osama Shawki, Yehia Shawki, and Jude Ehiabhi Okohue

## 1 Introduction

Hysteroscopy is a form of surgery, different from other forms of surgery in a number of ways. It combines the difficulty of operating in a confined space, without any aid or assistants, with managing the hysteroscope and instruments simultaneously, while deliberating on appropriate decisions. During hysteroscopy, you do not have the luxury of assistants as in laparoscopy, no cameraman, additional instruments, nor do you have the time to spend on decision-making, especially during office or outpatient hysteroscopy where while being gentle, the desire is to complete the procedure as quickly as possible with minimal discomfort.

As with most surgical procedures, experience comes with practice. You must perform a number of cases and be exposed to different scenarios which implicitly prepare you for the future.

To start with, the most important aspect of a good intrauterine surgeon, a terminology I choose to call hysteroscopic surgeons, is the ability to navigate and manoeuvre the hysteroscope. It must become your second nature to access the uterine cavity and manipulate the hysteroscope in order to reach any designated point. Gaining this skill requires changing the action from a conscious pyramidal action to an extra-pyramidal subconscious one, just like in other forms of surgery. The same way we learn to move our arms while walking, driving a car or riding a bicycle.

Hysteroscopy is a rather easy art to learn, and this chapter aims at assisting to further shorten the learning curve [1].

## 2 Set-Up and General Considerations

Initial set-up is crucial to the success of the operation, and patient positioning is of utmost importance in hysteroscopy.

### 2.1 Patient Position and Operating Room Table Manipulation

A separate chapter completely describes the patient positioning and principles of ergonomics and would therefore not be discussed here.

In cases of the acutely anteverted uterus, your entry through the cervical canal should be directly vertical, requiring you to lower your hands and have the sheath perpendicular to the patient's

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body. This is only made feasible by having the patient's buttocks at the edge of the operating table allowing for hand lowering to negotiate the fixed uterus. Adjustments of the operating table may also be of use during the procedure. In order to access the acutely anteverted uterus, the table must be high enough to allow the surgeon to lower his hands to the maximum.

Similarly, tilting the head down can also help straighten the axis of the uterus. This head-down tilt can however be associated with an increased risk of air embolism [2]. In this position, the uterus is above the level of the heart, and diastole creates a negative intravenous pressure that facilitates air advancement into venous channels. While head-down tilt may sometimes help to straighten the uterus, it should be discouraged.

## 2.2 Eyes on the Screen

Proper visibility is the key to a successful hysteroscopic intrauterine surgery. It is naturally common to have your eyes follow the direction of your commands. When surgeons ask for instruments, their eyes usually deviate towards the assistant's tray, the instrument itself, or the stop cock and channel. During hysteroscopic procedures however, the surgeon should try and resist this and maintain his vision on the monitor.

The narrow uterine cavity requires constant vigilance to avoid unnecessarily raising endometrial flakes, which might obscure your view. The trick is to have trained accessory staff (either a doctor or a scrub nurse), who should be aware of all the surgeon's needs. The surgeon's eyes therefore steadily gaze at the monitor, while the assistant provides accessory instruments, sometimes even assisting to introduce the instruments through the sheath.

## 2.3 Avoid Multiple Entries

A famous saying in hysteroscopy is that the first entry is always the best. Even with the most experienced hands and application of the non-touch technique of entry, the pressure of the distending media causes minute capillaries to rupture. This is not evident during the initial entry as the fluid pressure also stops any bleeding. However, removal of the hysteroscope will likely lead to some degree of bleeding, obscuring your landmarks at subsequent entries. Continuous in-and-out motions are also dangerous during operative hysteroscopy. They increase the risk of gas entry, which in the presence of open vascular channels could be problematic. The risk of air embolism is small, but the proper surgical technique could negate such a risk.

## 2.4 Vaginal Distention

For any organ to be examined adequately, proper exposure and visualization are of paramount importance. This has not been the case with vaginoscopy, as the introitus allows the easy escape of fluid, and thus the vagina might not be adequately distended enough for proper inspection.

The trick here is to have an assistant occlude the introitus. The assistant should stand behind the patient's flexed, abducted hips and use the thumb and index finger on either side of the labia majora, to occlude the vagina. This prevents the escape of fluid, and a beautifully distended vagina is achieved, allowing the surgeon to clearly visualize the vaginal walls, fornices, and the external os.

## 2.5 Cervical Canal

Negotiating the cervix can be one of the most difficult aspects of hysteroscopy. A mere 2–3 cm cervical canal can feel like an unsurmountable canyon.

The following tips might help in navigating the cervical canal:

- Allow time for the distention media to enter the uterus, dilating the cervical canal. The tunnel view is seen, and easy access can be achieved. Do not attempt to navigate the cervix without properly visualizing the canal, as false passages can be created.
- Follow the cervical mucosa. The crypts and glands form a railroad that eventually leads to the internal os.
- The use of misoprostol in the evening or a few hours before the hysteroscopic procedure, especially in premenopausal women [3].

## 3 Diagnostic Procedures

For most diagnostic procedures, the most important aspect is vision. Ideally, you must avoid friction and endometrial sloughs to maintain a clear view. Understanding the simple fact that the sheath is a vertical oval while the internal os is a transverse oval helps the surgeon achieve a seamless entry into the uterine cavity. For an anteverted uterus, a downward movement of the hands allows a view of the anterior wall or the semilunar appearing internal os. This places the cervical canal at the 6 'o'clock position. A simple rotation will give you better entry and fewer endometrial flakes. Additionally, you may wish to employ a diagnostic procedure for the proximal fallopian tubes.

## 4 Shawki Bubble Test and Methylene Blue Test

The Shawki Bubble test (SBT) is an easy and reproducible way to test the function and patency of the proximal salpinx.

The following steps are required to produce the best results:

1. Station syringe containing 5 cc of air in the outflow channel.
2. Close the inflow channel to stop fluid entry.
3. Direct the hysteroscope towards an ostium, very slowly inject the air.
   An important means to avoid a sudden rush of air into the uterine cavity is to simultaneously include 2 cc of saline in the syringe, hindering the progress of the gas.
4. Slowly observe the air bubbles produced, and see if they are suctioned into the tubal ostium (Fig. 1).
5. If the progress is not seen, slowly open the inflow channel, and attempt to guide the bubbles into the ostium.

The methylene blue test (MBT) is similar in steps to the SBT. The main difference lies in the position of the application.

To test both tubal ostia, the surgeon must position the hysteroscope cranial to the internal os and slowly begin the injection of concentrated methylene blue or indigo carmine dye.

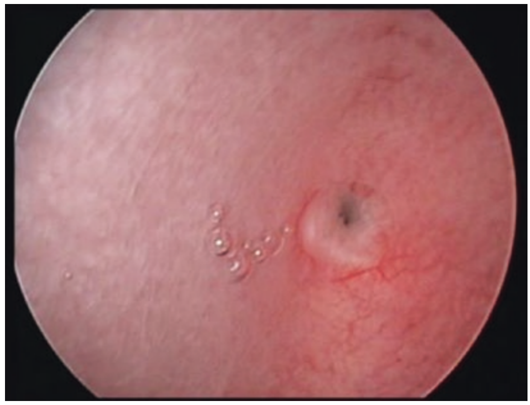

**Fig. 1** Shawki Bubble test

A functioning tube will cause an arrow of dye to aim directly into the ostium.

## 5 Endometrial and Endocervical Polyp

As simple as it sounds, the key to a successful excision of any polyp is visualizing the base and detecting the plane of cleavage between the mucosa and the pathology. This may seem easy with fundal polyps or easily accessible polyps (Fig. 2). However, when it comes to more difficult locations, the initial incision may require a semi-blind approach.

The first cut usually provides the plane. One must analyse the location of the cleavage point and then access it by manoeuvring both the hysteroscope and scissors (Fig. 3a, b).

Endocervical polyps are more challenging because their bases are usually more difficult to identify. The endocervical ridges can cause disorientation to the surgeon as to the extent of its base. Careful inspection of the circumference of the entire cervical canal resolves this issue.

Applying an angled volsellum to occlude the external os can also aid in further cervical distention and better visualization.

The final point of reference is assessing the use of scissors versus a resectoscope in cervical polyps (Fig. 4a, b).

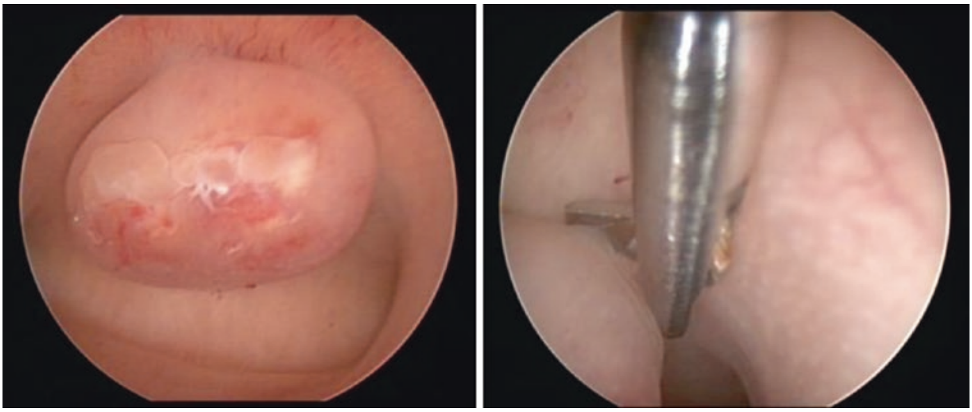

**Fig. 2** Endometrial polyp

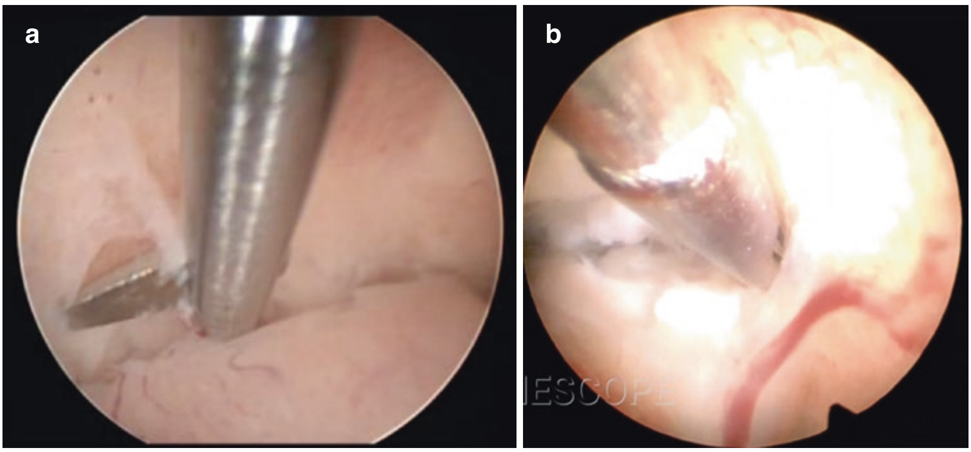


**Fig. 3** (**a**, **b**) Hysteroscopic polypectomy with scissors

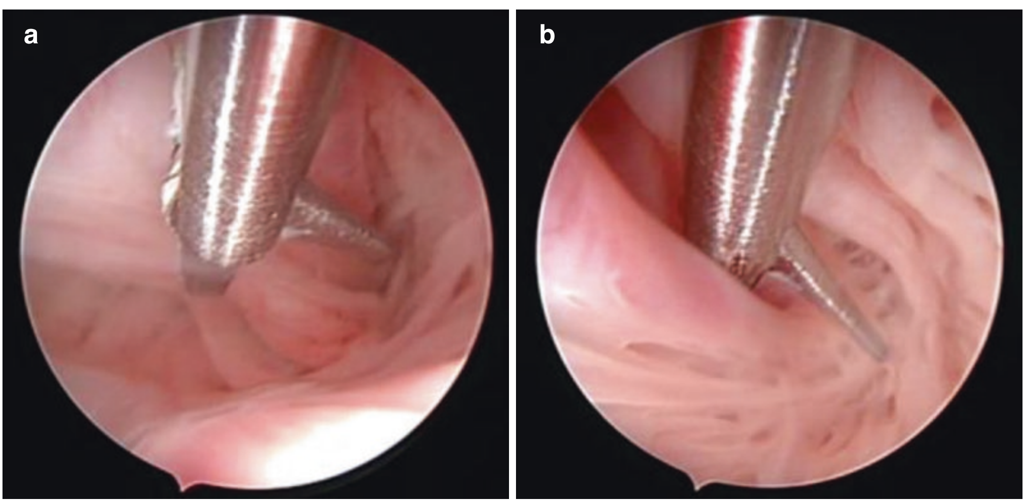


**Fig. 4** (**a**, **b**) Endocervical polyp

## 6 Septal Metroplasty

In every essence of the word, correction of a uterine septum should be likened to plastic surgery. It should not simply be a "job done" procedure. The surgeon must aim to restore the cavity to as close to its anatomical state as possible.

The key to achieving this is analysing the perfect site to incise the septum and the plane you wish to follow.

A few tricks to achieve this include:

1. In a panoramic view, estimate the site, exactly bisecting the septum (Fig. 5).
2. Near the base of the septum, visualize the tubal ostium (Fig. 6), and trace the line midway through the septum's anteroposterior thickness which cuts the tubal plane perpendicularly.

Septoplasty can be accomplished with hysteroscopic scissors (Fig. 7). To utilize the resectoscope (Fig. 8a–c), there are a few tips that can help improve practice:

1. Slightly angulate Collin's knife loop before assembling the resectoscope to allow access into the cornua.
2. Knowledge of the size of the resectoscope will provide you with the appropriate cervical dilatation required to insert the resectoscope. Storz resectoscopes come in 22 and 26 Fr. Hegar's dilators are calibrated in millimetres. The conversion is 1 mm = 3 Fr. Using the 26 Fr resectoscope requires dilation up to 8.5 or 9 Hegar. If the cervix is tough or shows rebound elasticity, it is prudent to dilate higher.
3. Always use the tubal ostia to mark your plane.

**Fig. 6** Identifying the tubal ostium

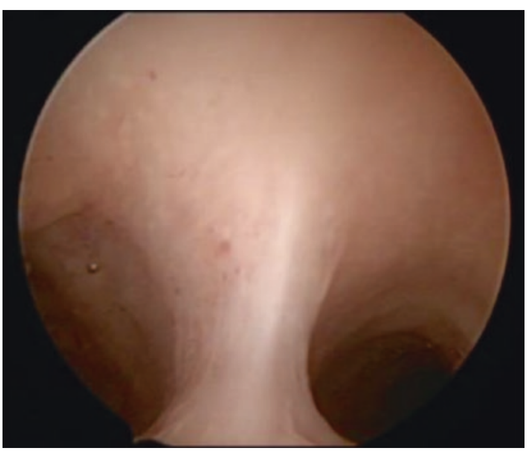

**Fig. 5** Uterine septum

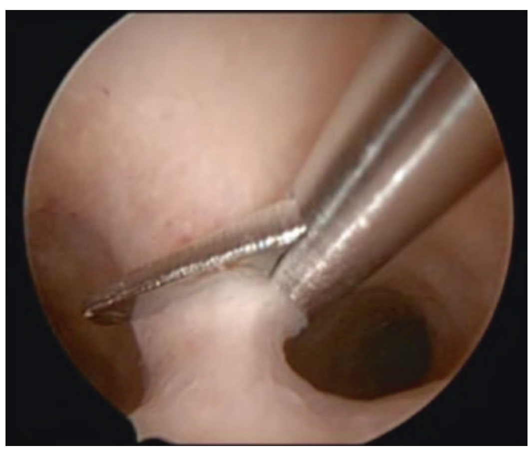

**Fig. 7** Septoplasty with scissors

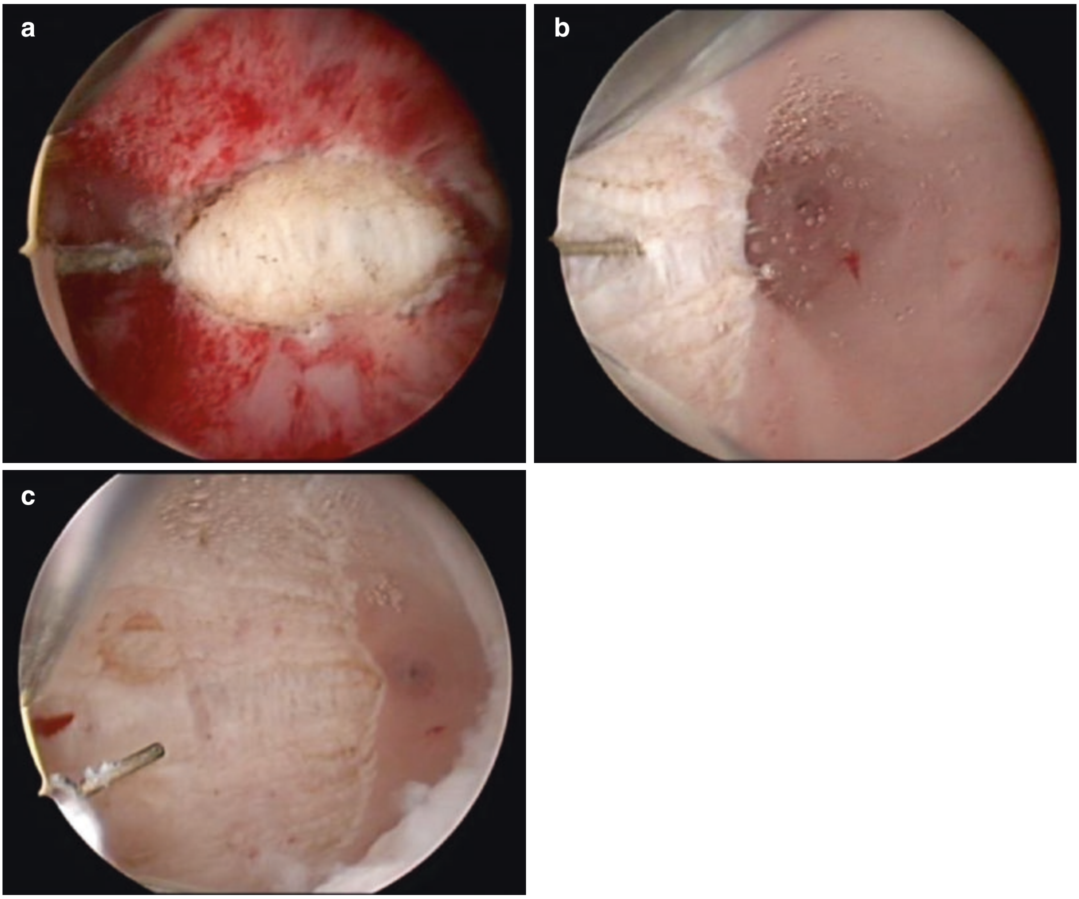


**Fig. 8** (**a**–**c**) Septoplasty with a resectoscope

## 7 Submucous Fibroid

Submucous fibroids are known to have a negative effect on fertility [4]. Hysteroscopic myomectomy should ideally be a simple and well-tolerated procedure. Fibroids described as Type 0 (completely within the endometrial cavity) and size 3 cm and less are the easiest to resect. Resection techniques are usually decided on the spot, following the entry into the uterine cavity (Fig. 9a, b). This topic has been covered in a separate chapter.

The following tips are however advised:

1. Assess the extent of the base of the fibroid.
2. Manipulating intrauterine fluid pressure will allow descent of the intramyometrial portion of the fibroid.
3. Coagulation of bleeders will prevent blurring of vision from bleeding.
4. The closer you get to the base, the larger the vascular channels, and thus fluid absorption will increase. During this phase of the procedure, the surgeon must aim to finish as quickly as possible.

Some surgeons tend to take very superficial cuts, thus prolonging the operating time with the subsequent incomplete procedures. Simultaneously moving the entire hysteroscope and working element may optimize resection of fibroid chips. A deeper depth is achieved by the gross movement of the hysteroscope. At some point, the fibroid chips prevent proper visualization. At this point, use the loop to evacuate as many myoma chips as possible, without applying current.

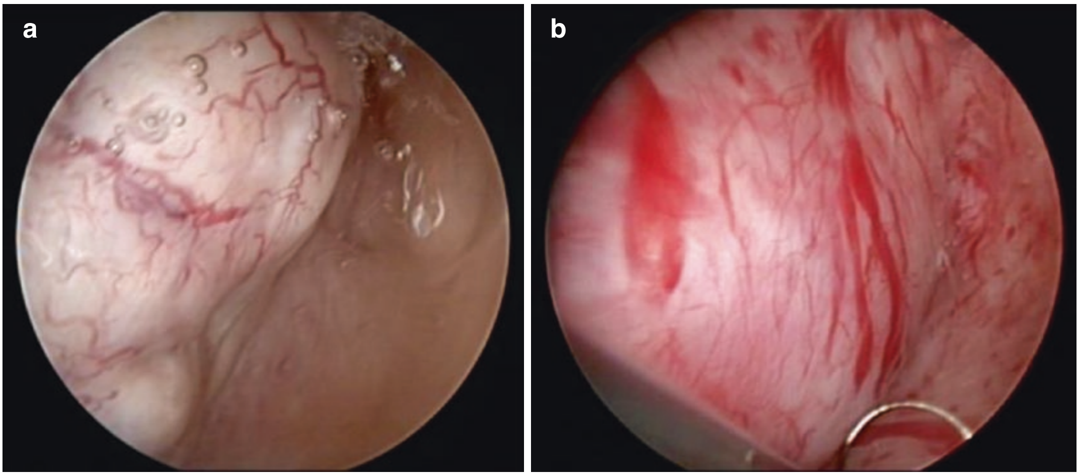

**Fig. 9** (**a**) Submucous fibroid. (**b**) Submucous fibroid resection

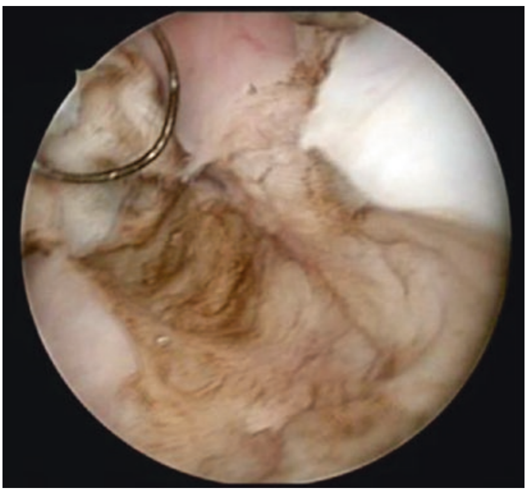

**Fig. 10** Pushing fibroid chips away

If a myoma chip is not completely resected, the part still connected to the main fibroid mass will prevent its removal from the uterine cavity. You could complete the resection or push this chip away to restore a clearer view and progress to the next chip (Fig. 10).

The end point is the appearance of myometrium which differs from fibroid tissue by:

1. Its pinkish colour
2. Loss of whorled appearance

## 8 Transcervical Resection of the Endometrium (TCRE)

This minimally invasive alternative to hysterectomy comes with its fair share of difficulty if not performed following a pattern. The main difficulty arises from the loss of orientation as endometrial tissues accumulate.

The following are useful tips in providing a landmark during surgery:

1. Choose a starting point, usually a transverse line at the fundus, or a lateral vertical line extending from below the tubal ostium to the internal os.
2. Stop at the level of the basal layer (whitish in colour), and shift to the next pink endometrial strip until you are left with a completely white cavity.
3. Any remaining endometrial patches can be coagulated using the rollerball electrode.

## 9 Intrauterine Adhesions

Intrauterine adhesions occur as a result of scar tissues within the endometrial cavity (Fig. 11a, b). The association of uterine adhesions with symptoms such as menstrual abnormalities, recurrent

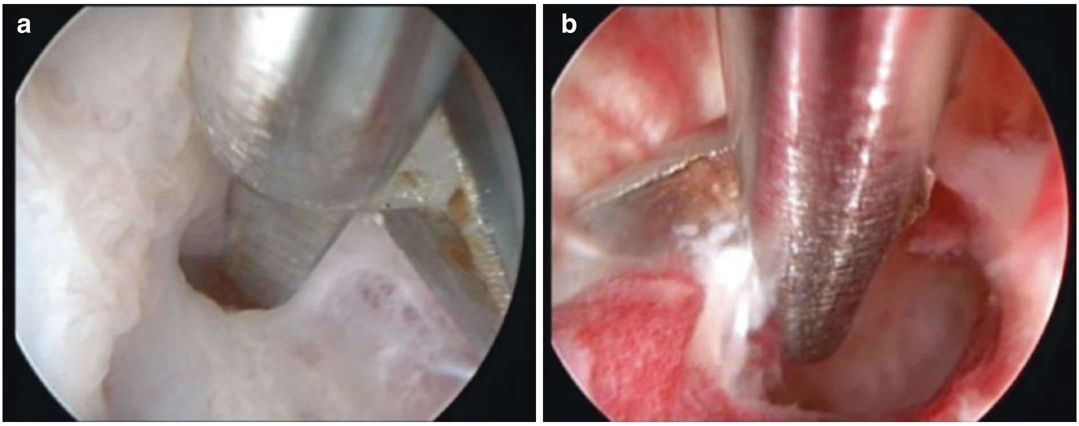


**Fig. 11** (**a**, **b**) Hysteroscopic adhesiolysis

miscarriages, or infertility is called Asherman syndrome.

There are different classifications of intrauterine adhesions. The simplest is the March classification which classifies the adhesions into mild, moderate, and severe.

There are also classifications by the European Society of Hysteroscopy, the American Fertility Society, among others.

This topic is also well covered in a separate chapter.

The following tips are helpful:

1. Always follow the normal direction of the cavity, and use your scissors to probe, where necessary.
2. Singular strands of adhesions are easily identified, separated by fluid pressure, the tip of the hysteroscope, or cut with scissors.
3. The true difficulty arises when half or more of the cavity is obliterated.
4. For a hemi-cavity, the trick is to imagine the normal cavity by visualizing the present tubal ostium and cut in the same plane required to reach the hidden ostium.
5. For completely obliterated cavities with adhesions at the level of the internal os, the following might be helpful:
   (a) Follow the direction of cervical mucosa.
   (b) Preoperative and intraoperative abdominal ultrasound scan.
   (c) Intraoperative use of fluoroscopy.
   (d) Concomitant use of laparoscopy.
   (e) Yielding of adhesions when cut and pushed with scissors.
   (f) Identification of adhesions and differentiating them from the firmer, pinkish, and fasciculated muscle fibres.

## 10 Conclusion

Hysteroscopy, especially diagnostic hysteroscopy, is a relatively easy skill to learn. Avoiding catastrophes entails paying attention to details and understanding the principles of hysteroscopy. Learning from experts in the field is a sure way towards becoming a versatile intrauterine surgeon.

**Learning Points**

- Hysteroscopy relies on your ability to work seamlessly and simultaneously with both hands.
- It is important to remain calm and have very carefully structured movements, without rushing or sudden purposeless movements.
- Determination and constant practice are important.
- Liaise with an experienced hysteroscopist for proper guidance.
- The future is bright for aspiring “intrauterine surgeons”.

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# Anaesthesia for Operative Hysteroscopy

Uyoata Udo Johnson and Job Gogo Otokwala

## 1 Introduction

Hysteroscopy is the telescopic examination of the uterine cavity, and it is gradually becoming routine practice in Nigeria by increasing awareness of the advantages of outpatient endoscopic services, especially in the private health facilities [1, 2] and in some of the bigger public hospitals [3]. Hysteroscopy remains an essential tool for the diagnosis and/or treatment of certain intrauterine pathologies [4], and patients presenting with abnormal uterine bleeding intrauterine synechiae, etc. are common indications for hysteroscopy [5]. Proper pre-anaesthetic evaluation to detect comorbid conditions such as allergy, anaemia, cardiac and pulmonary diseases will suffice. Anaesthetic management takes into consideration the influence of positioning and the distension fluid on the patient and the need to fast track recovery. Diagnostic hysteroscopic procedures are usually of short duration and are done as day cases. All anaesthetic options are tenable. General anaesthesia with drugs that ensure rapid onset and offset times can be used, but regional anaesthesia which is a reasonable alternative for operative hysteroscopy procedures is commonly done.

## 2 Anaesthetic Considerations

Operative hysteroscopy is usually of short duration except for the time it takes to set up the instruments. Irrespective of the anaesthetic technique that is used, the risk associated with the distension fluid and positioning should be properly assessed, and efforts should be made to prevent possible complications.

## 3 Position

Lithotomy is the preferred position for hysteroscopy. This involves flexion of the hip and knee, with some degrees of abduction and external rotation. The leg could be positioned low, standard, or high as requested by the surgical team [6]. Leg elevation may result in a transient rise in cardiac output due to increased venous return from the lower extremities. The reverse may also occur if the legs are suddenly brought down, with the risk of hypotension. Lithotomy position contributes to decreases in functional residual capacity (FRC) and lung compliance when compared to the supine position due to the cephalad displacement of abdominal contents, and this could

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be worse in Trendelenburg which is sometimes required for adequate visualization.

Nerve injury may occur, and the nerves commonly affected are sciatic, femoral, and common peroneal nerves [6–8]. The risk of peroneal nerve injury often results from lateral thigh and knee compression by the stirrups, and the risk has a direct relationship with the length of surgery. Common peroneal nerve injury results in loss of dorsiflexion. Excessive flexion of the thigh may result in compression of the obturator and femoral nerves against the inguinal ligament anteriorly and stretching of the sciatic nerve posteriorly. Care should therefore be taken not to flex hips beyond 90°.

Compartment syndrome is another known complication of the lithotomy position [7–9]. Acute compartment syndrome occurs as a result of prolonged compression of the vascular bundle in the popliteal fossa by the leg support or kinking of the popliteal artery from extreme flexion of the knee. The decrease in arterial pressure and an increase in venous pressure, followed by reperfusion, give rise to elevated compartment pressure from tissue oedema [10]. These changes may be more profound in the presence of hypotension [11]. High leg elevation above heart level ("high" lithotomy position) has been associated with increased risk of compartment syndrome, [12] and this risk rises sharply after more than 2 h in the lithotomy position [12, 13].

## 4 Distension Fluid

Significant physiological changes may be associated with the various types of distension or irrigation solutions in common use. The distension media can be classed into electrolyte-containing solutions and non-electrolyte solutions [14]. The non-electrolyte media include water, glucose, glycine, dextran, mannitol, sorbitol, and a mixture of sorbitol and mannitol. Irrigation with water provides excellent visibility because it is hypo-tonic and low viscosity and lyses the red cells. Marked absorption associated with water irrigation predisposes to water intoxication, hyponatremia, and hypo-osmolality which may present as hypertension, bradycardia, altered mental status, nausea, vomiting, seizures, headache, sudden hypotension, and death [14, 15].

Water was used initially, and it is still being used at some centres. Glycine remains the fluid of choice if monopolar diathermy is used, although absorption can still occur especially at high irrigation pressures and/or prolonged irrigation. Excessive use of glycine may result in the inhibition of neurotransmitters in the CNS, in cardiovascular overload, pulmonary, and cerebral oedema. Mannitol and sorbitol are hyperosmolar solutions and can cause osmotic fluid shifts with haemodynamic instability, mental status changes, and electrolyte abnormalities, especially sodium, potassium, bicarbonate, and chloride imbalance.

Electrolyte-based crystalloids include Ringer's lactate and normal saline. The accepted limits of a negative balance of 2.5 L are generally used for electrolyte-based solutions to avoid the risk of fluid overload. This requires careful use of perioperative fluids either for preloading for spinal anaesthesia or maintenance. Close monitoring of the irrigation fluid is key, and prompt communication between the endoscopists and the perioperative physician is expedient (Fig. 1).

Carbon dioxide is routinely used in laparoscopy, and it has also been found to be useful as a

POST HYSTEROSCOPY IRRIGATION FLUID

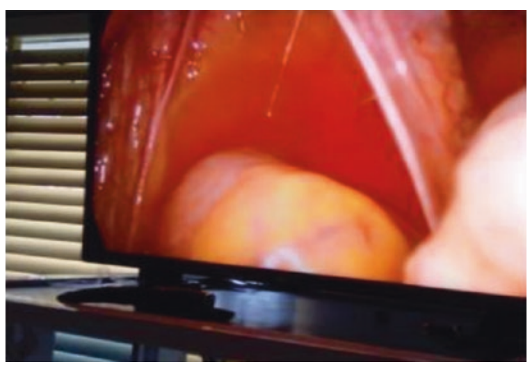

**Fig. 1** Post hysteroscopy irrigation fluid. [*The authors observed this pool of fluid in the pouch of Douglas after diagnostic hysteroscopy when the same patient was subjected to diagnostic laparoscopy. It underscores the need for vigilance with distension fluids during hysteroscopy*]

uterine distending medium in diagnostic hysteroscopy. Carbon dioxide is generally not recommended for operative hysteroscopy because the gas may obscure the optical view of the surgical field and also due to an increased risk of air embolism and post-procedure pain [15] and trans-tubal peritoneal insufflation.

## 5 Day Case Anaesthesia

Most interventional or operative hysteroscopy procedures are short (under 90 min) and are typically scheduled as same-day or outpatient cases. The patient is either assessed through an online questionnaire, by telephone interview conducted by perioperative nurses, or on the actual procedure day. Fasting instructions should be made available to the patient and verified and documented. Patients (and their legal guardians, if applicable) should be counselled as part of the informed consent process, and preoperative antibiotics and thromboembolism prophylaxis should be given as indicated and verified.

## 6 Preoperative Preparations for Operative Hysteroscopy

This involves a review of the history of the presenting complaint, significant past and current medications, allergies, and past surgical and anaesthesia history. Physical examination with particular reference to the cardiorespiratory systems is imperative. Basic laboratory investigations to be done include haemoglobin level, urinalysis, and serum electrolytes. Other investigations can also be requested as indicated. Airway assessment is important especially if general anaesthesia is the preferred option and in situations where regional anaesthesia is contraindicated. Lithotomy and Trendelenburg positions increase the risk of aspiration of gastric contents and aspiration pneumonitis. Premedication with prokinetic agents and H-2 receptor antagonist is beneficial. Pre-procedure use of antibiotics is not typically used due to the reported low infection rate [16].

## 7 Anaesthetic Options

Uncomplicated operative hysteroscopy is usually carried out as same-day procedures. All anaesthetic options are tenable, be it general anaesthesia with or without tracheal intubation to regional anaesthesia. General anaesthesia is offered to anxious patients and patients with absolute contraindications to regional anaesthesia. Medications that ensure rapid onset and recovery are preferred. Propofol and sevoflurane with laryngeal mask airway (LMA) will suffice with the patient breathing spontaneously, although airway protection is not guaranteed with the risk of aspiration and hypoventilation. In morbidly obese patients, tracheal intubation and ventilation are a safer option.

Regional anaesthesia and its subtypes: Epidural or spinal or combined spinal-epidural increases patients' turn over time because of the onset and offset times; however, this option is preferred for procedures lasting longer than 30 min. Low doses of hyperbaric bupivacaine in combination with fentanyl are effective and reduce the incidence of post-spinal hypotension. Fluid preload should be avoided or administered with caution because of the potential risk of hypervolemia from absorption of the irrigating fluid. Post-spinal hypotension can safely be treated with vasoconstrictors. Regional anaesthesia can mask the symptoms of compartment syndrome, and signs such as leg swelling should be promptly evaluated whenever it is observed.

Monitored anaesthesia care (MAC), paracervical block, and instillation of local anaesthetic in combination with hypnotics have also been documented for hysteroscopic procedures.

## 8 Monitoring

Standard monitoring protocol for patients under anaesthesia is mandatory during operative hysteroscopy, as in any other surgical procedure. Baseline values of these parameters, non-invasive blood pressure (NIBP), ECG, pulse oximetry, and end-tidal capnography (compulsory for sedated patients) must be obtained. Urine output measurement also provides a simple but effective ancillary measure of perfusion and fluid balance. Proper positioning to minimize compression and compartment pressure in the legs while maintaining blood pressure reduces the risk of compartment syndrome. Importantly, there should be communication between the surgeon, anaesthetist, and the circulating nurse, regarding the patient's general status, and fluid balance, as a matter of patient safety.

## 9 Complications of Operative Hysteroscopy

Fluid overload is one of the common complications of operative hysteroscopy and arises from excessive absorption of distension fluid, and it is associated with dilutional hyponatremia which is managed by intravenous fluid restriction and the use of diuretics. Hyponatremia associated with fluid overload can be treated with hypertonic saline at a rate not exceeding 100 mL/h. Fluid overload can lead to pulmonary oedema and hypoxia. Mild to moderate pulmonary oedema can be treated with continuous positive airway pressure (CPAP) and oxygen therapy, in addition to diuretic therapy [14]. If severe, intermittent positive pressure ventilation (IPPV) with positive end-expiratory pressure (PEEP) can be instituted [17, 18]. Hypothermia is another complication and should be prevented by intravenous fluid warming and the use of warming devices such as force-air warmer, radiant heater, among others [7]. Uterine perforation and visceral damage may occur and should be suspected if there is unexplained anaemia, generalized abdominal pains in an awake patient, cardiovascular collapse, and poor return of irrigation fluid [18].

## 10 Conclusion

Operative hysteroscopy is a commonly indicated gynaecologic endoscopic procedure, which is increasing in use in developing countries like Nigeria. It is particularly suited for outpatient setting, with significant cost and logistic advantages. Though hysteroscopy is minimally invasive, potential complications could affect the outcome. The role of proper preoperative evaluation, appropriate choice of anaesthesia, and careful perioperative monitoring for patient safety improves the outcome.

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# Distension Media in Hysteroscopy

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## 1 Introduction

Hysteroscopy is invaluable for diagnosing and treating intrauterine pathologies. To achieve this, adequate visualisation is very important. The uterine cavity, being a narrow and virtual space, requires to be distended in order to achieve adequate visualisation. Uterine distension can be achieved with gas or liquid media [1]. Despite its usefulness, excessive systemic absorption of any distension media is associated with adverse effects, including life-threatening complications. Therefore, understanding the physical properties, mode of administration, and the potential risks associated with the use of the various distending media is critical for the safe performance of hysteroscopy.

## 2 Brief Historical Background

Hysteroscopic procedures were first described by Commander Pantaleoni in 1869; instrumentation was elementary, and expansion of the uterine cavity was inadequate. He used a modified cystoscope to cauterize a haemorrhagic uterine growth [2]. In 1925, Rubin IC used $CO_2$ to distend the uterus [3, 4]. In 1928, Gauss CJ used fluid to achieve uterine distension in order to visualize the uterine cavity [5]. By 1980, the use of liquid distension media had become a routine [4].

In 1969, Leidenheimer first described office hysteroscopy with normal saline as the distending medium [6].

At the beginning, single-sheath hysteroscopes were used. The commonly used distending media, carbon dioxide and occasionally normal saline were delivered through the inflow port, while the effluent passes through the intervening space between the sheath and the internal cervical Os. In the absence of such a space, as seen when the diameter of the sheath is similar or bigger than the diameter of the internal cervical Os, continuous flow is prevented, and fluid stagnates in the uterine cavity with resultant poor visibility, increased risk of intravasation and spillage of fluid into the peritoneal cavity. Currently, small diameter, continuous flow and double-sheath hysteroscopes are used. With this, office hysteroscopy is feasible; cervical dilatation and anaesthesia are often unnecessary; pain is minimised; and clarity is achieved during the procedure.

Also currently, low viscosity electrolyte-free and electrolyte-rich media are used instead of the gas and the high viscosity fluid media commonly used in the past. They are effective, versatile and safer.

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Fluid delivery system has witnessed remarkable improvement, from the simple gravity and gravity-modified systems commonly used in the past to the specially designed hysteroscopic pumps and, most recently, the automated pressure-sensitive fluid delivery systems.

## 3 Principles of Maintaining Adequate Intrauterine Pressure (IUP) During Hysteroscopy

Adequate IUP is required to distend the normally collapsed uterus for improved visibility and clarity during hysteroscopy. A pressure of 40 and 70 mmHg is required to expand the normally collapsed uterus and to clearly visualize the uterine cavity, respectively [7]. Ideally, the intrauterine pressure should not exceed 70 mmHg, the intratubal pressure, beyond which fluid spill into the peritoneal cavity [8]. Also the distending IUP should not exceed the mean arterial pressure (MAP) beyond which intravasation occurs with the associated risk of fluid overload. Achieving the required pressure will depend on the flow rate of the distending media, the irrigation pressure applied, the diameter of the inflow channel, the capacity of the uterus, the mean MAP and the intratubal pressure.

In fact, it has been suggested that when the distension media is delivered by the automated delivery systems at a flow rate of about 200 mL/min, an irrigation pressure of about 70 mmHg and a suction pressure of 0.2 bar, an IUP of about 30–40 mmHg is generated at which adequate uterine distension is achieved with good visibility and clarity [9, 10]. However, Anupama S et al. showed that better visibility is achieved in diagnostic hysteroscopy when a distending intrauterine pressure of 70–100 mmHg was used than when a distending pressure of 40 mmHg was used [11].

However, careful adjustment of the flow rate and irrigation pressure of the fluid should be done to achieve adequate distension in each patient.

Where cervical dilatation is needed, it should be just enough to allow the insertion of the hysteroscope. Excessive dilatation will lead to the loss of fluid from the side of the outer sheath and reduced intrauterine pressure and create poor uterine expansion and loss of visibility. Suboptimal pressure also predisposes to more bleeding from the easily traumatised endometrial vessels. Tight application of the sheath keeps the medium within the cavity; maintains adequate pressure within the cavity, often above the MAP; suppresses bleeding from the endometrium; and creates a clearer view, though with a greater tendency to intravasation and propulsion of medium through the fallopian tube into the peritoneal cavity.

## 4 Distending Media Delivery Systems in Hysteroscopy

Various methods are available for the delivery of distension media for hysteroscopic procedures. The method used depends on the type of media. While carbon dioxide is delivered through a special hysteroscopic insufflator, the high viscosity media (Hyskon) is delivered through a special Hyskon pump. However the low viscosity fluids are delivered by continuous flow, achieved through any of these approaches:

- Gravity alone
- Modified gravity system
- Specially designed calibrated infusion pumps
- Automated electronic pressure-sensitive irrigation-suction device

### 4.1 Gravity Delivery Systems

.Gravity-based systems utilize hydrostatic pressure to drive the fluid through the tubing and inflow channel in the hysteroscopic sheath into the uterine cavity. The fluid bag is hung on the drip stand at a height of about 1–1.5 m above the level of the pelvis to generate a flow rate of 150–200 mL/min, and an irrigation and IUP of

70–100 mmHg distend the uterus adequately [12, 13]. Further increase in pressure can be achieved by increasing the height at which the bag is hung. Though simple to operate, cheap and readily available, it is difficult to accurately calculate the IUP with this approach. It requires frequent manual fluid input/output calculations to determine the fluid deficit with a substantial margin of error. To function efficiently, kinking of the fluid delivery tubing should be avoided.

### 4.2 Modified Gravity Fluid Delivery System

This is a modification of the simple gravity fluid delivery system. It is created by positioning a pressure cuff around the bag filled with the distending media. When the pump is pressed, appropriate flow rate and pressure are generated, enough to distend the uterine cavity.

This approach does not guarantee good control of the IUP. Hence, it is associated with a high risk of intravasation especially in invasive hysteroscopic surgeries. This device is cheap, easy to use and readily available. The gravity-based systems are adequate for diagnostic hysteroscopy (Fig. 1).

**Fig. 1** Modified gravity delivery system

### 4.3 Continuous Flow Infusion Pumps

These are specially designed pumps that deliver fluid at a constant flow rate irrespective of how high or low the IUP is. Automatic adjustment of the flow rate, and consequently the IUP, is not possible, and thus, it is associated with a higher risk of intravasation and fluid overload, especially during prolonged or invasive procedures.

### 4.4 Automated Pressure-Sensitive Fluid Delivery Systems

Automated electronic pressure-sensitive irrigation-suction fluid delivery systems exemplified by the Hamou Endomat/Endomat Select by Karl Storz (Fig. 2) are the ideal means of fluid delivery in hysteroscopy. They incorporate a preset flow rate, inflow pressure and negative aspiration pressure settings which are adjusted to the levels that will guarantee a desired IUP adequate enough to distend the uterus within the acceptable safety limits. They also automatically adjust the IUP to be below the MAP, in order to reduce the risk of intravasation [14]. These pumps allow the fluid bags to be changed without interrupting the irrigation flow, a condition desirable in operative hysteroscopy with a resectoscope or mechanical morcellator. Some

**Fig. 2** Automated delivery system (Hamou Endomat/Endomat Select by Karl Storz)

can automatically calculate the total amount of fluid used with the 3–6% overfill often found in fluid bags [15] and the total amount retrieved and then determine the difference to arrive at a near accurate fluid deficit. In fact, some are equipped with safety alarm systems for abnormally high IUP and fluid deficit. Once heard, appropriate management protocols are activated to guarantee the safety of the patient.

## 5 Types of Distension Media

The type of distension media can be liquid or gaseous. The choice of distension media depends on the procedure to be performed, the electrosurgical device to be used, the patient's condition and the physician's preference. An ideal distension medium should be isotonic, non-haemolytic, non-conductive, non-toxic and hypoallergenic. It should be able to provide good visualisation and be rapidly eliminated from the body. Finally, it should be inexpensive.

### 5.1 Gaseous Distension Media

Carbon dioxide is the only gaseous medium recommended for uterine distension. It has the following properties [7]:

- A refractory index of 1.0.
- Colourless, which allows for excellent clarity.
- Inexpensive and readily available.
- Rapid absorption into the bloodstream and clearance through the respiratory system, hence low risk of intravasation.
- Easy flow through narrow channels and does not clog instruments.
- Allows entry evaluation of the endocervical canal.
- It is neat and does not soil the instruments and the office or operating room.

Considering the above qualities, it is currently recommended for diagnostic and office hysteroscopy [16]. However when compared with normal saline, it is less satisfactory because of higher need for local anaesthesia, more postoperative pain and longer duration of procedure [17].

Carbon dioxide is not ideal for operative hysteroscopy because it forms bubbles with blood thus reduces visibility and clarity.

When used, it should be delivered at a flow rate of about 40–60 mL/min and at a pressure between 80 and 100 mmHg. The maximum flow rate should not exceed 100 mL/min beyond which embolism, cardiac arrhythmias and arrest may occur [7, 18].

The major risk of carbon dioxide use as a distension media is air or gas embolism. To minimize this risk, the following precautionary measures should be taken:

- Use specially designed hysteroscopic insufflator that delivers a relatively small volume of gas per minute instead of the laparoscopic insufflator.
- The patient should not be kept in the steep Trendelenburg position.
- The vaginal speculum should be removed once the hysteroscope has been inserted into the cervix so as to reduce the exposure of the dilated cervix to room air.
- The entire tubing system should be flushed with $CO_2$ before starting the procedure.

### 5.2 Fluid Distension Media

Fluid distension media can be classified based on osmolality, viscosity and electrolyte content (Table 1). Unlike gas, fluid media offer the advantage of symmetric distension of the uterus and have the ability to flush blood, mucus, bubbles and small tissue fragments out of the visual field. Originally, sterile water was used for distending the bladder during resectoscopic urologic surgery but causes haemolysis when excessive amount is absorbed into the vascular system. This led to the addition of solutes such as glucose, sorbitol and glycine into water to

**Table 1** Classification of distension media based on osmolality, electrolyte content and viscosity [19, 21]

| Liquid media | Tonicity/osmolality | | | Electrolyte content | | Viscosity | |
|---|---|---|---|---|---|---|---|
| | Isotonic | Hypotonic | Hypertonic | Yes | No | Low | High |
| Normal saline | + | | | + | | + | |
| 5% dextrose water | | + | | | + | + | |
| 1.5% glycine | | + | | | + | + | |
| 5% mannitol | + | | | | + | + | |
| 3% sorbitol | | + | | | + | + | |
| Mannitol/sorbitol (Purisol) | | + | | | + | + | |
| Hyskon | | | + | | + | | + |
| Ringer's lactate | + | | | + | | + | |

increase the medium's osmolality to a degree that largely prevent haemolysis.

### 5.2.1 Types of Fluid Distension Media

#### High Viscosity Fluids

Thirty-two percent Dextran 70 in 10% dextrose (Hyskon) is a high viscosity, hyperosmolar and non-electrolyte media. It is appropriate for both diagnostic and operative hysteroscopy. Being a non-electrolyte media, it is compatible with all electrosurgical devices and lasers. Because it is colourless and immiscible, bleeding vessels are seen easily during procedures. Also, being hyperosmolar, it is associated with increased risk of intravasation that correlates directly with the degree of uterine injury and not necessarily with the volume of media used and the operation time [19]. Following intravasation, there is increased risk of pulmonary oedema, coagulation disorders, anaphylaxis and adult respiratory syndrome. Hence for safety reasons, not more than 500 mL of Hyskon should be used during a single procedure [20]. Currently, Hyskon is rarely used for distension in hysteroscopy because of the above risks.

#### Low Viscosity Fluids

These include:

1. Electrolyte-rich solutions such as isotonic normal saline (0.9%) and Ringer's lactate.
2. Electrolyte-free solutions such as glycine (1.5%), sorbitol (3%), mannitol (5%) and glycine (2.2%).

##### Electrolyte-Rich Solutions (Normal Saline, Ringer's Lactate)

Normal saline and Ringer's lactate are physiologic distension media. They are the ideal low-viscosity fluid media. They are the safest and most commonly used distension media for diagnostic hysteroscopy. They are compatible with operative devices such as lasers, bipolar electrodes, scissors and morcellators. When used with the above-mentioned instruments with the exception of the scissors, the fluid is ionised, and the ionised electrons disperse the energy away from the operating site with reduced current density and tissue injury. The ionisation property makes it incompatible with monopolar electrosurgical devices. Because isotonic solutions can now be used alongside the bipolar electrosurgical devices for operative hysteroscopic procedures, the use of non-electrolyte media for distension and the attendant complications of hyponatraemia have been prevented [7]. Saline leaks easily out of the uterus and mixes easily with blood. This means that the fluid must be continuously infused at a flow rate that will help achieve adequate IUP and distension. The large volume of fluid required to achieve distension increases the risk of fluid overload, pulmonary oedema, hypertension and cardiac failure.

##### Electrolyte-Free Solutions

- **5% Glucose in Water**
  It is a non-electrolytic, hyposmolar/hypotonic, low viscous media. It is cheap and readily

available. It is often packaged in 1 L bag and bottles. It is an appropriate and most commonly used distension media when monopolar electrosurgical devices are engaged in operative hysteroscopy. It is contraindicated in patients with glucose intolerance.

- **3% Sorbitol and 1.5% Glycine**
  They are hypotonic/hyposmolar, non-electrolytic and low viscosity media. They are the distension media for operative hysteroscopy with monopolar electrosurgical devices.
  Sorbitol is a reduced form of dextrose and an isomer of mannitol. When it is absorbed into the vascular system, it is either excreted intact by the kidney or rapidly metabolised in the liver by the fructose pathway to $CO_2$ and water. Hence, it should not be used in patients with fructose intolerance. Excessive intravasation of 3% sorbitol can lead to hyperglycaemia and hypocalcaemia.
  Glycine is a non-conductive amino acid with a plasma half-life of 85 min. When delivered by a high-pressure infusion pump, glycine has been reported to cause disturbances in oxygenation and coagulation [7]. Excessive intravasation of glycine and sorbitol causes hyponatraemia and cerebral oedema.

Tables 1 and 2 have classified the distension media based on their osmolality electrolyte content and viscosity and compared them based on the setting of best use, miscibility with blood and safety.

## 6 Fluid Monitoring in Hysteroscopy

Fluid monitoring is very important in hysteroscopy especially in operative cases. The objective is to determine the fluid deficit and promptly recognize the early onset of fluid overload. During hysteroscopy, some of the media escape into the vascular system, peritoneal cavity and outflow channel and from the sides of the cervix into the vagina to a reservoir and to the floor.

To accurately calculate the fluid deficit, all the fluids lost from the cervix to the drapes, reservoir and operating room floor; fluid remnants in the used fluid bags; and the 3–6% overfill of some distension media bags must be factored in and recorded [22]. This amount will then be subtracted from the total amount of fluid used to get the approximate amount of fluid that escaped into the vascular system which is the fluid deficit.

Fluid monitoring can be by the manual (open) or the automated (closed) system approach.

In the simpler but less accurate manual approach, the fluid lost from the cervix and outflow channel are harvested and measured with a calibrated container. But in the more accurate but complex automated closed system, all the fluid lost from the cervix and the outflow channel are automatically collected and continuously measured. The fluid deficit is then automatically determined. Occasionally, an alarm system is incorporated to sound when a preset fluid deficit is reached.

**Table 2** Classification of distension media based on the setting of best use, miscibility with blood and safety [19, 21]

| Type | Operative use | Office use | Miscibility with blood | Complex procedure | Safety |
|---|---|---|---|---|---|
| Gaseous | | | | | |
| $CO_2$ | + | +++ | + | + | ++ |
| Liquid non-electrolytic | | | | | |
| Hyskon | +++ | +++ | +++ | ++ | ++ |
| Glycine | +++ | + | ++ | +++ | + |
| Sorbitol | +++ | + | ++ | +++ | + |
| Mannitol | +++ | + | ++ | +++ | ++ |
| Liquid electrolytic | | | | | |
| NS | +++ | + | ++ | +++ | +++ |
| RL | +++ | + | ++ | +++ | +++ |

## 7 Intravasation, Fluid Deficit and Circulatory Overload

Some degree of intravasation of the distension media is inevitable during hysteroscopy but should be within the acceptable fluid deficit level for each type of fluid. Once it goes beyond the acceptable limit, fluid overload is said to occur [23]. The incidence of fluid overload is about 0.1–0.2% with operative hysteroscopy [24].

The maximum acceptable fluid deficit for hypotonic and isotonic solution is 1000 mL and 2500 mL, respectively. However for elderly patients and those with chronic cardiac and renal disease, it is 750 mL for hypotonic solutions and 1500 mL for isotonic solutions [21, 23].

The risk of intravasation during hysteroscopy is increased when:

- The distending intrauterine pressure is high, especially when it is above the patient's mean arterial blood pressure [25].
- Invasive procedures such as hysteroscopic myomectomy or uterine septum.
- Resection is performed with increased vascular openings [23].
- The procedure is prolonged [26].
- The patient is post-menopausal or has concurrent renal and cardiovascular disease [27].
- The surgeon is unskilled, and the uterine cavity is large.

Fluid overload causes the patient to develop generalised body swelling, weight gain and high blood pressure, hypervolemia with the risk of pulmonary oedema and heart failure. The other manifestations of fluid overload depend largely on the type of distension media used. When the non-electrolyte low viscosity fluid such as glycine, sorbitol and mannitol are used, dilutional hyponatraemia occur. Mild to moderate hyponatraemia with little change in osmolality is asymptomatic, while severe hyponatraemia (osmolality <125 mOsm/L) causes cerebral oedema, cerebral irritation, agitation, apprehension, confusion, weakness, nausea, vomiting, visual disturbances, blindness and headache, coma and death. Also excessive intravasation of 3% sorbitol causes hyperglycaemia and hypocalcaemia.

The presence of the above symptoms and unacceptably high fluid deficit should alert the surgical team of the imminent danger to the life of the patient and consequently should provoke appropriate resuscitative measures to be taken.

## 8 Fluid Management in Hysteroscopy

Proper fluid management is imperative to mitigate the complications of fluid overload. The goals of fluid management are to choose the right distending medium less likely to cause complications in the event of excessive absorption, minimize systemic absorption during surgery, early recognition of excessive absorption and prompt management of complications.

Every facility should develop a realistic protocol that should contain the type of fluid and fluid delivery system to be used, state categorically when estimation of serum electrolytes, urea and creatinine should be done, diuretics should be given and the procedure should be stopped.

Cases must be properly selected, and the surgeon should have the requisite skill to perform hysteroscopic procedures, especially operative cases. The risk of fluid overload in resectoscopic myomectomy is directly related to the duration of the procedure [28]. A skilled surgeon will translate to reduced duration of the procedure, amount of fluid used and the surface area of the endometrium and myometrium affected.

The right distension media must be matched with the safer electrosurgical device available. The choice of distension media for hysteroscopy will depend on the procedure to be performed and the instruments to be used. For diagnostic hysteroscopy, $CO_2$, isotonic fluids and Hyskon can be used, but the ideal and safest is isotonic solutions.

Where feasible, bipolar electrosurgical devices with isotonic solutions, considered safer than monopolar electrosurgical devices with hypotonic solutions, should be used. Also, where available, mechanical morcellator with isotonic solution considered safer than bipolar resectoscopic devices should be used.

If it is available, the safer automated pressure-sensitive fluid delivery system should be used especially in operative cases because it is more efficient in measuring fluid deficit than the gravity system [23, 29].

Also, using the right anaesthesia is important. Studies have shown that the use of local anaesthesia with sedation than general anaesthesia is associated with lower fluid deficit [30]. However, general anaesthesia is considered better than epidural anaesthesia [31].

Appropriate measures to reduce intravasation should be adopted. Some studies have shown that intracervical injection of dilute vasopressin (8 mL of 0.05 U/mL) prior to cervical dilation, a prelude to inserting the hysteroscope, is associated with reduced intravasation of the distending media [32]. Also treatment with gonadotrophin-releasing hormone agonist prior to hysteroscopic myomectomy known to reduce the risk of fluid overload should be considered [33].

From the inception of the procedure, the vital signs should be continuously monitored, and transurethral bladder catheterisation should be maintained with a good input and output fluid chart kept. The signs of fluid overload must be sort for. Once the vital signs become abnormal or features suggestive of fluid overload are noted, the entire surgical team must be informed and prompt actions taken.

In severe cases of fluid overload, a multidisciplinary approach that involves the gynaecologist, anaesthesiologist, nephrologist and cardiologist must be adopted in the management of the patient. Serum electrolytes, urea and creatinine should be estimated which will help to identify the presence of and severity of hyponatraemia. In suspected cases of pulmonary oedema, chest X-ray and electrocardiogram should be performed.

In mild asymptomatic hyponatraemia from fluid overload with hypotonic solutions, loop diuretics (intravenous frusemide 40 mg) should be given, and daily fluid intake should be restricted to 1 L/day. However in severe hyponatraemia, 100 mL bolus of 3% saline should be given intravenously for 10 min; this can be repeated up to three times, followed by intravenous 3% NaCl at the rate of 1–2 mmol/L/h [23, 28]. The aim is to achieve a serum level of 130 mmol/L. If the fluid overload is from 3% sorbitol with resultant hyperglycaemia, the blood sugar level should be monitored and insulin titrated until normoglycaemia is restored. If hypocalcaemia ensue, 3 g of calcium gluconate should be given intravenously in over 10 min.

The mainstays of management of fluid overload from isotonic distension media are fluid restriction, intravenous diuretics and close monitoring of vital signs.

**Learning Points**

- In hysteroscopy, the uterine cavity distension with gas or fluid is important for proper visualisation.
- A distending IUP below the MAP should be used to minimize the risk of fluid overload and its complications.
- The choice of distension media depends on the procedure to be performed, surgical device to be used and individual characteristics.
- $CO_2$, the only rarely used gaseous distension medium, is appropriate for office diagnostic hysteroscopy.
- Currently, uterine distension is mainly by the fluid media especially the low viscosity electrolyte-rich solutions such as normal saline because they are safer and compatible with the safer bipolar electrosurgical devices.
- The non-electrolyte-containing fluids such as glycine and sorbitol, best used with monopolar electrosurgical devices, are associated with increased risk of hyponatraemia and its complications.
- The low viscosity media are delivered through gravity alone, modified gravity, pressurised pump and automated pressure-sensitive mechanisms.
- Intravasation can occur due to prolonged procedure, increased IUP more than MAP and nature of surgical procedure with much trauma to endometrium/myometrium, also based on

individual characteristics like post-menopausal status.

- Maximum fluid deficit for a healthy patient using isotonic and hypotonic media should not exceed 2500 mL and 1000 mL, respectively. For elderly patients and those with cardiac and renal comorbidities, a maximum fluid deficit of 750 mL for hypotonic solutions and 1500 mL for isotonic solutions is recommended.
- Strict fluid monitoring especially by the automated approach reduces the risk of fluid overload.
- Appropriate fluid management entails choosing a safe distending media compatible with the available electrosurgical device, minimising systemic absorption, early recognition of excessive intravasation of fluid and prompt management of associated complications.

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# Hysteroscopic Management of Uterine Synechiae

Jude Ehiabhi Okohue, Angelo B. Hooker, and Preye Owen Fiebai

## 1 Introduction

Intrauterine adhesions (IUAs) or uterine synechiae describe situations where scar tissues develop within the uterine cavity. This eventually leads to partial or complete agglutination between the uterine walls and can result in clinical manifestations. It was first described and published by a German gynaecologist, named Henrich Fritsch in 1894 following postpartum dilatation and curettage (D&C) [1]. This condition however was characterized by Joseph Asherman, who in 1948, identified the aetiology and frequency of this syndrome, since known as the Asherman syndrome. He described a series of 29 cases with intrauterine cavity involvement following hysterography and linked endometrial trauma and adhesions to menstrual irregularities and infertility [2].

The terms IUAs and Asherman syndrome are often used interchangeably, although the syndrome, as described by Asherman, requires signs and symptoms: when IUAs become associated with menstrual irregularities or infertility. Sometimes the same symptoms are present, but the cause of the IUA is not pregnancy-related. While some authors believe the term Asherman syndrome can still be used in such situations, others suggest it should be restricted to cases of IUAs resulting from endometrial damage related to a gravid uterus [3].

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## 2 Aetiology

Intrauterine adhesion formation is multifactorial with multiple predisposing and causal factors, while the pathogenetic mechanism is still poorly understood. The true prevalence of IUAs remains unknown; the condition is considered rare in the general population. Intrauterine adhesions are thought to develop following trauma to the uterine cavity. The damage to the basal layer of the endometrium results in the formation of granulation tissue on the opposing surfaces of the uterine cavity. Once these coalesce, adhesions form,


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leading to a partial or total obliteration of the uterine cavity. Hooker and colleagues recently performed a systematic review of the literature and reported a prevalence of 19.1% among 912 women hysteroscopically evaluated within 12 months following a spontaneous miscarriage or after medical or surgical management, 86% of the patients following D&C [4]. In a study of 1856 women with Asherman syndrome, Schenker and Margaloith found that 90.8% of the cases were pregnancy-related, following termination of pregnancy, miscarriage, vaginal birth, or caesarean section [5]. Dilatation and curettage of a pregnant or recently pregnant uterus, therefore, appear to be the most common predisposing factor for uterine synechiae.

Other causes of uterine synechiae or IUAs include myomectomy, the use of the B-lynch compression sutures, the use of intrauterine devices, uterine artery embolization, infections such as tuberculosis of the genital tract, and following surgeries for Mullerian abnormalities [6–8].

## 3 Classification

A variety of classification systems exist, but none have been validated or linked to reproductive performance. To date, no comparative analysis of studies has been performed, making a comparison between different studies difficult to interpret. The internationally most used classification systems are those of March et al., the American Fertility Society (AFS), and the European Society of Gynecological Endoscopy (ESGE).

In the classification system of March et al. (1978), the adhesions are categorized in minimal, moderate, and severe groups based on a combination of the type of adhesions and cavity involvement. The AFS classification (1988) is based on the extent of cavity involvement, type of adhesions, and menstrual pattern. Cumulative scores determine the severity ranging from stage I to III. The ESGE classification emerged from the European Society of Hysteroscopy; both classifications are based on a combination of the type of adhesions, site, and extent of cavity involvement and the presence of amenorrhea or pronounced hypomenorrhoea. The severity of the adhesion is classified into seven grades.

The European Society of Hysteroscopy classification of intrauterine adhesions is presented in Table 1, while the American Fertility Society classification system is presented in Table 2.

**Table 1** European Society of Hysteroscopy classification of intrauterine adhesions

| Grade | Extent of intrauterine adhesions |
|---|---|
| I | Thin or filmy adhesions easily ruptured by hysteroscope sheath alone, cornual areas normal |
| II | Singular firm adhesions connecting separate parts of the uterine cavity, visualization of both tubal ostia possible, cannot be ruptured by hysteroscope sheath alone |
| IIA | Occluding adhesions only in the region of the internal cervical os. Upper uterine cavity normal |
| III | Multiple firm adhesions connecting separate parts of the uterine cavity, unilateral obliteration of ostial areas of the tubes |
| IIIA | Extensive scarring of the uterine cavity wall with amenorrhea or hypomenorrhoea |
| IIIB | Combination of III and IIIA |
| IV | Extensive firm adhesions with agglutination of the uterine walls. Both tubal ostial areas occluded |

**Table 2** The American Fertility Society (AFS) classification of intrauterine adhesions

| | | | |
|---|---|---|---|
| *Adhesion score* | | | |
| Extent of cavity involved<br>*(Score)* | <1/3<br>*(1)* | 1/3–2/3<br>*(2)* | >2/3<br>*(4)* |
| Type of adhesions<br>*(Score)* | Filmy<br>*(1)* | Filmy and dense<br>*(2)* | Dense<br>*(4)* |
| Menstrual pattern<br>*(Score)* | Normal<br>*(0)* | Hypomenorrhoea<br>*(2)* | Amenorrhoea<br>*(4)* |
| *Prognostic classification* | | | |
| Disease severity[a] | Scores | | |
| Stage I (mild) | 1–4 | | |
| Stage II (moderate) | 5–8 | | |
| Stage III (severe) | 9–12 | | |

[a] Disease severity is staged based on cumulative score

## 4 Presentation

Patients with IUAs can be asymptomatic, and therefore the diagnosis can remain undetected. It is uncertain whether the reproductive performance of asymptomatic women is influenced by the presence of IUAs.

Women with IUAs or Asherman syndrome can present with the following symptoms:

- Hypomenorrhoea/amenorrhea
- Cyclical lower abdominal/pelvic pain
- Recurrent pregnancy loss
- Infertility

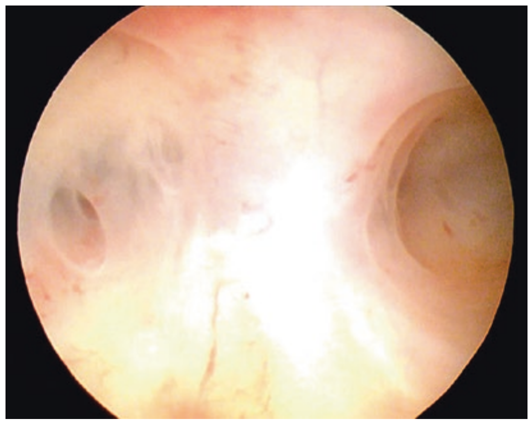

**Fig. 1** Intrauterine adhesions

## 5 Diagnosis

The diagnosis of intrauterine adhesion is made based on the clinical presentations and assessment of the endometrial cavity. The following investigative modalities assist in establishing a diagnosis of intrauterine adhesions:

### 5.1 Hysteroscopy

Hysteroscopy is still considered the gold standard for establishing and confirming the diagnosis of uterine synechiae or IUAs (Figs. 1, 2, 3, 4, and 5). Hysteroscopy enables visualization of the uterine cavity: the extent, localization, and

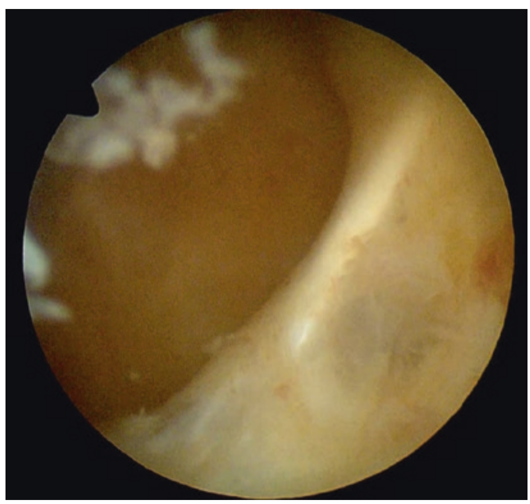

**Fig. 2** Adhesions on the left uterine wall

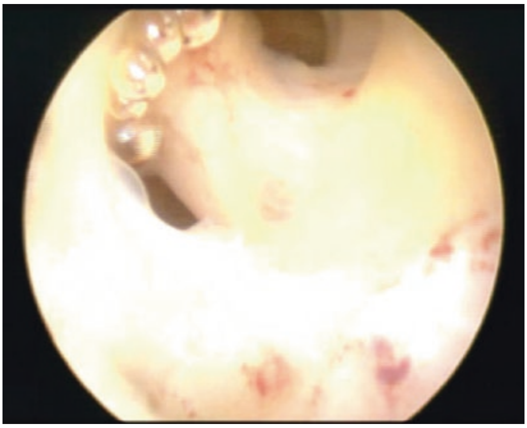

**Fig. 3** Column of adhesion just proximal to the internal os

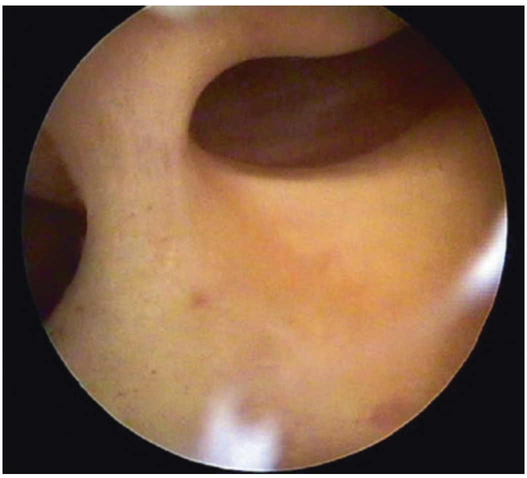

**Fig. 4** Another column of intrauterine adhesions

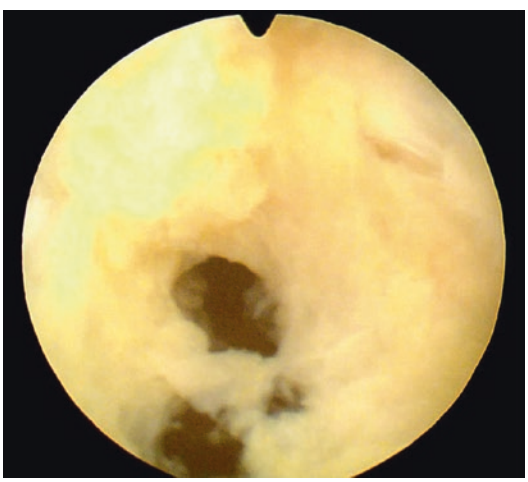

**Fig. 5** Severe intrauterine adhesions

degree of IUAs can be accurately determined, while other intrauterine abnormalities can also be detected. Furthermore, there is the possibility to perform adhesiolysis in the same session. In case hysteroscopy is not available or cannot be performed, other diagnostic modalities can be considered. Because of the high frequency of false-positive and diagnostic errors, hysterosalpingography, ultrasonography, and sonohysterography are less suitable for accurate detection of IUAs.

## 5.2 Hysterosalpingography

Hysterosalpingography can show filling defects within the endometrial cavity and in severe cases might show complete obliteration of the uterine cavity. It can be performed as an office procedure.

## 5.3 Saline Infusion Sonography

This is performed in an office setting using saline, instilled via a special intrauterine catheter.

## 5.4 Transvaginal Ultrasound Scan

Versatile sonologists might be able to establish a diagnosis of uterine synechiae with the help of a transvaginal scan. This should not be considered an accurate diagnostic modality.

## 5.5 Magnetic Resonance Imaging

It is less frequently used because of the exorbitant cost.

## 5.6 3D Ultrasonography

This may also be helpful in diagnosing intrauterine synechiae and seems a promising diagnostic modality. Further research is necessary.

## 6 Treatment

Hysteroscopic adhesiolysis is considered the appropriate treatment method for IUAs. Since the availability of hysteroscopy which allows a proper visualization of IUAs within the cavity, blind adhesiolysis has been relegated [9].

Hysteroscopic adhesiolysis aims at restoring the normal anatomy of the uterine cavity, while at the same time steps are taken towards preventing recurrence. Randomized controlled trials comparing different treatment modalities are lacking, and treatment, therefore, is essentially based on the personal experience of the gynaecologist, case series, and case reports, channelled towards the individual needs of the patient.

The rigid hysteroscope is the most used treatment modality for the treatment of IUAs. Over the years, developments in hysteroscopic equipment have occurred: refinement in optic and fibre-optic technology with newer accessories, which have led to an improvement in both visual resolution and surgical techniques [10].

The first hysteroscopes had diameters of about 5.5–6 mm but were associated with a reduction in quality of vision. Much later, the 2.9–4 mm diameter hysteroscopes were manufactured. Hysteroscopes with diameters less than 2 mm are now available, with good quality of vision.

The hysteroscopes are attached to inner and outer irrigation and suction sheaths, respectively, ensuring a continuous flow of fluid. Also attached is a 5 F operating channel through which hysteroscopic handheld instruments such as scissors and graspers can be introduced. In case of cervical stenosis, intravaginal misoprostol can be administered, facilitating dilatation of the cervical canal [11, 12].

Mild adhesions can be separated either because of the pressure effect of the distension medium or with the use of the tip of the hysteroscope [13]. Hysteroscopic scissors introduced through the operating channel is usually used for adhesiolysis (Fig. 6a–c). The scissors are preferred for this purpose as it is believed to be associated with less injury to the endometrium compared with the use of an energy source [14, 15]. In the vast majority of cases, the use of energy is not required.

In cases where energy is used, there is the choice between the monopolar and bipolar energy. While the monopolar energy uses hypotonic non-electrolyte-containing and therefore non-conductive fluids like 1.5% glycine, the bipolar uses isotonic, conductive fluids such as normal saline and lactated Ringer solution. It must be borne in mind that strict assessment and documentation of fluid input and output are essential for patient safety.

While a fluid deficit of up to 2.5 L can be allowed when using normal saline, the procedure needs to be stopped following a deficit of 1 L with 1.5% glycine and hence monopolar energy.

It is important to have a clear field with the lowest intrauterine pressure possible. Manual pressure cuffs and automated pumps are readily available for delivering fluids during hysteroscopy. Visualization is improved by the use of low-pressure and high-flow fluid delivery system rather than a high-pressure, low-flow system [16].

Intrauterine adhesions, centrally located within the uterine cavity, are dealt with first before treating those located at the periphery of the cavity [16]. Hysteroscopic adhesiolysis can be performed under ultrasound scan or simultaneous laparoscopy guidance, especially in cases where the anatomy is unclear, to minimize perforation. Fluoroscopy is another modality that can offer the needed guidance during hysteroscopic adhesiolysis. Fluoroscopy can identify unseen areas of the endometrial cavity inaccessible to the hysteroscope [17].

While all the above are meant to prevent uterine perforation, hysteroscopic adhesiolysis still remains the procedure with the greatest risk of perforation of the uterus [18]. If a perforation is suspected, the management should depend on the source of the perforation. Those caused by the introduction of the hysteroscope, scissors, or grasping forceps can be managed conservatively as severe intra-abdominal bleeding or bowel perforation would rarely occur [16]. Perforation caused by an energy device requires an emergency laparoscopy. The site of the perforation should be inspected, and severe haemorrhage ruled out. The bowel should also be inspected for

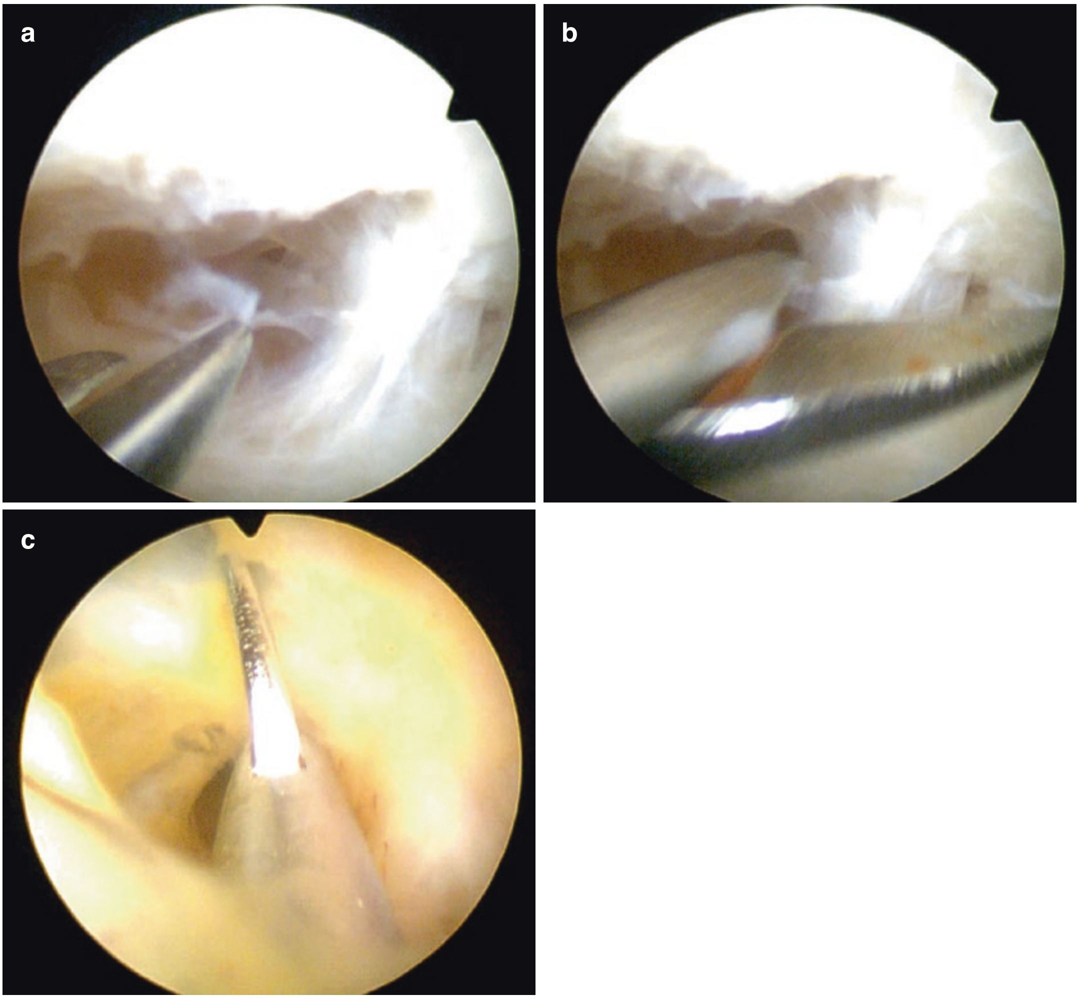


**Fig. 6** (**a**–**c**) Hysteroscopic adhesiolysis with scissors

any sign of injury, although this might not be immediately apparent.

Other reported modes of management of IUAs include the use of NdYAG (neodymium-doped yttrium aluminium garnet) and KTP (potassium-titanyl-phosphate) LASER, which are said to cause damage to the endometrium as well as being exorbitant [19].

Mccomb and Wagner reported their management of six cases with severe IUAs [20]. The uterine wall was separated into two hemi-cavities by inserting a 13 F Pratt cervical dilator. Under laparoscopic control, the fibrotic septum formed was cut up to the fundus with hysteroscopic scissors. The technique is associated with high morbidity and is therefore largely abandoned.

Another hysteroscopic technique was described by Protopapas and colleagues [21]. They described making 6–8 longitudinal incisions, 4 mm long into the myometrium from the fundus to the isthmus using a resectoscope fitted with a Collins knife electrode.

They aimed to enlarge the uterine cavity with the intention of uncovering functional endometrium. They reported an increase in menstrual bleeding in all cases. Hysteroscopic morcellation is emerging as a possible treatment modality in cases of IUAs.

In the management of IUAs, stem cell therapy is gaining popularity. Stem cells could proliferate and differentiate into matured specialized cells both in vivo and in vitro [22]. The use of stem cells in a patient with severe Asherman syndrome led to the development of endometrial thickness up to 8 mm with a subsequent successful IVF treatment [23].

## 7 Prevention of Adhesion Reformation

Numerous modalities have been employed with the aim of reducing the recurrence of uterine synechiae which should be considered an important problem, occurring in approximately 27% following adhesiolysis [3]. The available evidence on this subject remains limited.

### 7.1 Intrauterine Device (IUD)

This separates the walls of the endometrium following the completion of hysteroscopic adhesiolysis. Originally, the Lippes loop was used, but its manufacture was stopped for economic reasons [24]. The copper contained in the copper T IUD causes an unwanted endometrial inflammatory reaction, while the small surface area constitutes another disadvantage.

### 7.2 Intrauterine Foley Catheter

This also prevents the walls of the endometrium from colliding together thereby reducing the adhesion recurrence rate. A non-randomized study comparing the use of Foley's catheter for 10 days with IUD insertion for 3 months following adhesiolysis found fewer infections and a lower recurrence rate in the Foley catheter group [25]. Wrapping the Foley catheter balloon with fresh amnion has been shown to improve healing [26].

### 7.3 Intrauterine Balloon Stent

This acts in the same manner as a Foley catheter. Because of its triangular shape, it conforms to the shape of the endometrial cavity. Its use was recently found to be associated with a reduction in adhesions recurrence rate, compared with an IUD or hyaluronic acid [27].

### 7.4 Re-absorbable Agents: Intrauterine Gel

There are several re-absorbable agents that can be applied into the uterine cavity for the prevention of IUAs. Hyaluronic acid, a naturally occurring component of peritoneal fluid that aids in tissue lubrication and structural integrity, is an agent that is registered for the prevention of IUAs. It was found in a systematic review and meta-analysis to be effective in preventing adhesion formation, although the evidence is limited [28].

## 8 Endometrial Preparation

Various agents are used with the intention of stimulating residual growth of the endometrium following hysteroscopic adhesiolysis. One of such agents is oestrogens. There are few comparative studies investigating estrogen dosage and route of administration. A recent comparative study did not find any difference between using a daily oral dose of 2 mg, compared to 6 mg [29]. Other medications that increase blood flow such as aspirin, nitroglyceride, and sildenafil citrate have also been tried. Unfortunately, the number of women treated with these modalities to date remains small, while there are no large studies in which the modalities are examined.

The use of autologous platelet-rich plasma (PRP) has been shown to improve endometrial thickness in women with refractory thin endometrium and may play a role in the healing process following adhesiolysis [30]. About 1 mL of PRP is prepared and administered within the endometrial cavity. A transvaginal ultrasound scan is performed after 48–72 h, measuring the endometrial thickness. If found to be less than 7 mm, the PRP is again administered.

## 9 Follow-Up

Patients are usually assessed in order to detect any recurrence. This can be done via office hysteroscopy, saline infusion sonography, and hysterosalpingography. The aim is to detect a recurrence and offer treatment.

**Learning Points**

- Uterine synechiae are rare in the general population.
- The most important risk factor is pregnancy.
- There are no comparative analyses of the different classification systems.
- Hysteroscopy is the gold standard in the diagnosis and treatment of uterine synechiae.
- Hysteroscopic adhesiolysis remains the procedure with the greatest risk of uterine perforation.
- Available evidence on the prevention of adhesion reformation is limited.

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# Hysteroscopic Myomectomy

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and Rais S. Ibraheem

## 1 Introduction

Uterine leiomyoma or fibroids are benign tumours of the uterine muscle which are of monoclonal origin and rank the commonest tumour of the female reproductive system [1]. Based on location, uterine fibroids could be subserosal, intramural or submucosal. While submucosal fibroids constitute only 5.5–16.6% of all fibroids, they cause the most severe symptoms [2]. Most of the symptoms of submucosal fibroids are related to anatomical distortion of the endometrial cavity, manifesting as heavy menstrual bleeding (HMB), infertility and pregnancy loss among others [3].

Hysteroscopic myomectomy has now become the mainstay in the management of submucosal fibroids. Hysteroscopic myomectomy was first performed in 1976 by Neuwirth and Amin [4]. Over the last three decades, advances in instrument and techniques have continued to improve the possibility and ease of surgical removal of submucosal fibroid using the hysteroscope and thus joining the ranks of minimally invasive surgery (MAS) [5].

In current practice, hysteroscopic myomectomy could be achieved via mechanical means with cold scissors, graspers or morcellators, or by the use of energy like monopolar, bipolar, radio frequency and laser energy [6]. Most cases of hysteroscopic myomectomy are performed in the operating theatre under anaesthesia; however, a few cases can be performed as office procedures [6].

## 2 Classification of Submucosal Fibroids

There are varied classifications of submucosal fibroids which help in appropriate surgical management with resultant elimination or reduction in the attendant morbidities. The most popular classification is that by the European Society for Gynaecological Endoscopy (**ESGE**) [7]. This classifies submucosal fibroids into three groups as shown in Table 1 and Fig. 1.

There exists other methods of classification, notable among them is the **STEPW** Lasmar classification [8], which uses trans-vaginal ultrasound scan (TVUS) or magnetic resonance imaging (MRI) to assess the following parameters: size, topography, extension of the myoma base, depth of myoma penetration and lateral wall involvement.

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**Table 1** ESGE classification of submucosal fibroids

| | |
|---|---|
| Type 0 | Pedunculated submucosal fibroids without significant intramural extension |
| Type I | When the submucosal fibroid is sessile and the intramural part is less than 50% of the myoma volume |
| Type II | When the submucosal fibroid is sessile and the intramural portion is equal to or more than 50% of the myoma volume |

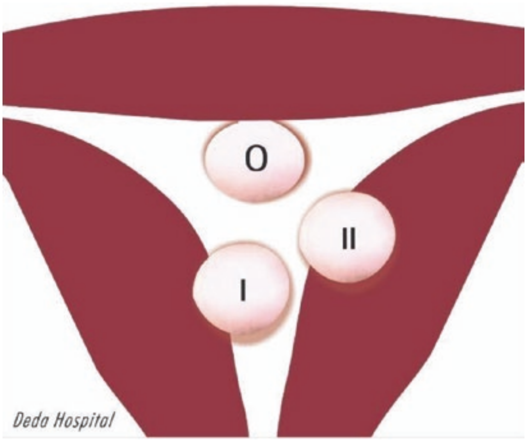


**Fig. 1** Submucosal fibroid classification (FIGO)

## 3 Patient Selection and Indications for Hysteroscopic Myomectomy

Patient selection is a key factor in considering hysteroscopic myomectomy in order to assess the feasibility of surgery and prevent complications. Myoma size of ≤3 cm, Type 0 or I myoma, and projected surgery time of less than 20 min serve as a guide in choosing patients that will likely have a favourable surgery outcome [3]. Factors to consider before embarking on hysteroscopic myomectomy are desire for future fertility, size, number and location of the submucosal fibroids, serosal-myoma distance (for type II myoma) [9]. Other important considerations include the presence of other coexisting pelvic pathologies, expertise and bias of the surgeon. These all could influence the route of myomectomy.

### 3.1 Indications for Hysteroscopic Myomectomy

The major indications for hysteroscopic myomectomy are abnormal uterine bleeding (AUB), infertility and recurrent pregnancy losses [3]. Infertility was shown to be the commonest indication for hysteroscopic myomectomy in Nigeria, followed by heavy menstrual bleeding [10].

- ***Abnormal uterine bleeding***: This manifests in most cases as heavy menstrual bleeding (HMB) due mainly to the increase in endometrial surface area. In cases where fertility is no longer desirous, concomitant endometrial ablation produces a better outcome than hysteroscopic myomectomy alone [11, 12].
- ***Infertility***: Submucosal fibroids lower fertility rate, and the removal of such fibroids has been found to improve fertility outcome [11].
- ***Recurrent pregnancy loss***: The relationship between submucosal fibroids and recurrent pregnancy loss (particularly first trimester) remains unclear; however, some studies have shown clear benefits of removing such myomas in preventing recurrent miscarriages [11].

In other situations, hysteroscopic myomectomy could be indicated where a patient with submucosal fibroid has symptoms which appear unrelated to the myoma but other management modalities have failed. These conditions include:

- Dysmenorrhoea
- Cervical ectopic pregnancy
- Leucorrhoea
- Necrotic leiomyoma (from uterine artery embolization)
- Histologic evaluation of intracavitary lesions with unsure features on radiological studies
- History of preterm birth
- Postpartum haemorrhage
- Post menopause bleeding
- Puerperal infection arising in or aggravated by submucosal myoma

## 3.2 Contraindications

Contraindications to hysteroscopic myomectomy are under general contraindications to hysteroscopy, which are majorly:

- Intrauterine pregnancy
- Pelvic infection
- Cervical carcinoma
- Endometrial carcinoma

# 4 Consenting and Preoperative Evaluation

Informed consent is mandatory. The patient should know the details of the procedure and possible complications that could arise from the procedure and possibility of a recurrence. It should be explained to the patient the possibility of a second-stage procedure and possibility of conversion to laparotomy if the need arises (particularly for anticipated difficult cases). Counselling on interventional radiological procedures and their medical management are vital.

Preoperative evaluation involves detailed history, examination and relevant investigations to determine myoma-related symptoms and signs to confirm diagnosis and rule out contraindications and inoperability of the patient. General preoperative investigations are applicable to rule out any medical condition that could affect the outcome of surgery.

Specific investigations to assess the uterus for location of the myoma usually are mainly radiological [hysterosalpingography (HSG), saline infusion sonography (SIS), trans-vaginal ultrasound scan (TVUS), trans-abdominal ultrasound scan (TAUS) and magnetic resonance imaging (MRI)] and diagnostic hysteroscopy.

SIS appears to be a good choice among the imaging techniques as it is cheap, easier to use and able to study both the characteristics of the submucosal myoma and the depth of penetration into the myometrium [13].

TVUS shows the depth of the myometrial penetration, size and other fibroid locations.

MRI is very specific in location and relation and differentiation of the myoma; however, it is rather too expensive for use as a routine investigation tool in our environment.

HSG and CT scan are of limited value in revealing the depth of myometrial involvement.

Diagnostic hysteroscopy (which could be an office procedure) is of great value in the preoperative assessment of the endometrial cavity. It reveals the extent of the submucosal myoma protrusion into the endometrial cavity.

The prior knowledge of the myoma features helps to select patients, prevent and prepare for blood loss, minimize fluid overload and help with necessary instrument selection for the procedure [14].

# 5 Operating Tools and Distension Media

The procedure for hysteroscopic myomectomy could be achieved via the following instruments/methods:

- Operative hysteroscope sheath with scissors or grasper via channels
- Resectoscopes which could be (depending on the applied current) monopolar loop or bipolar loop
- Morcellators (e.g. Truclear and Myosure)
- Vaporization tools

Distension media used during hysteroscopy depend on the instrument used and the nature of current applied. Distention media/fluid is instilled into the uterine cavity to distend the cavity enabling visualization. Continuous flow sheath system is preferable to always clear the blood mixed media for enhanced visualization. Fluid delivery could be done under gravity, the use of pressure bags or by automated systems. The automated pressure system is preferable, delivering fluid at a pressure of 90–132 cm of water [15], maintaining intrauterine pressure at 70–80 mmHg [16].

The goal for fluid management includes preventing excess absorption, recognition of excess absorption in its early phase and choosing appropriate distension fluid which will likely cause the least complication should there be excess absorption [9].

The principal fluids used are:

Hypo-osmolar/hypotonic (electrolyte-free) fluid such as 1.5% glycine, 3% sorbitol, 5% mannitol and hyskon (32% dextran 70 in dextrose) are only used with monopolar electro-surgical current.

Iso-osmolar/isotonic (electrolyte containing) fluid such as normal saline and Ringers lactate should be used with bipolar electro-surgical current and mechanical devices.

Fluid management during surgery is very vital. There should be a monitoring system in place to observe fluid deficit. Fluid deficit has been observed to increase significantly with the degree of resection penetration. Lasmar in 2011 [17] observed an average fluid deficit of 450 mL, 957 mL and 1682 mL with type 0, I and II myoma resection, respectively. The maximum allowable fluid deficit recommended is 1000 mL when using hypotonic fluids (except hyskon which is 500 mL) and 2000–2500 mL when using isotonic fluid [3] while operating on a normal adult. Once the maximum deficit level is reached, it is advisable to abort the procedure.

## 6 Preoperative Preparation Medications

Some medications have been used either long before surgery or at surgery to enhance good outcome.

- *Gonadotropin-releasing hormones (GnRH) analogues*: The use of GnRH analogue (depot preparation) 2–3 months before surgery has been proven to be beneficial in the treatment of anaemia by creating amenorrhoea to aid restoration of haemoglobin and iron stores [18]. GnRH analogue also reduces volume of myoma, especially the intra-myometrial component. This allows for complete resection particularly in the type II submucosal fibroid. GnRH analogue pre-treatment could improve visualization during surgery and reduce the absorption rate of distension media. However, the general role of GnRH analogue in reduction of surgery time, reduction of systemic distension medium absorption and improving complete resection of myoma remains controversial [9].
- *Prostagladins* (*misoprostol*): Cervical dilatation prior to insertion of the hysteroscope could be a source of various forms of trauma. The use of misoprostol for cervical priming has been proven to reduce traumatic complication in pre-menopausal women [19, 20]. Misoprostol is used at doses of 200–400 μg orally or vaginally 12–24 h before surgery.
- *Vasoconstrictor agents*: Intracervical injection of vasopressin has been found to reduce haemorrhage during the procedure, thereby increasing visualization and also reducing systemic absorption of distension fluid [14, 21]. Also, intracervical injection of prostaglandin (carboprost) is effective in the reduction of systemic absorption of distension media [22].

## 7 The Procedure

Hysteroscopic myomectomy could be achieved using the following devices:

- Cold scissors or grasping forceps via a channel in the operating sheet
- Cutting with energy as applicable with the resectoscope and vaporization techniques
- Tissue extraction devices referred to as morcellators (intrauterine morcellator, Truclear and Myosure)

The most popular technique used is the wire loop resectoscopic technique (cutting with energy) [13].

Anaesthesia used could be general or regional and in some cases total intravenous anaesthesia.

The patient is placed in the lithotomy position, cleaned and draped. It is important to avoid the Trendelenburg position (as this position is

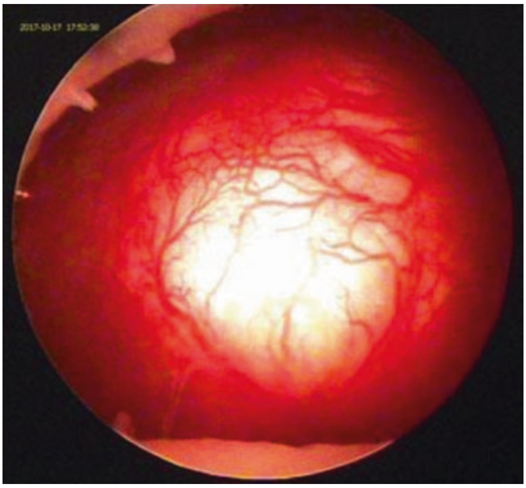


**Fig. 2** Type 0 submucosal fibroid. (Courtesy of Gynescope Specialist Hospital)

associated with air embolism) [3]. The urinary bladder should be emptied with a non-retaining catheter. A bimanual examination is performed to assess the pelvis. Sims speculum is introduced to expose the cervix. The anterior lip of the cervix is grasped with a tenaculum. Cervical dilation is performed. Some authors inject intracervical vasopressin or carboprost to induce vasoconstriction reducing haemorrhage and also absorption of distension media [15, 22]. The fluid delivery and collection systems are set up. Likewise, set up the energy system. For monopolar electrodes, set the cutting current at between 60 and 100 W and the coagulating current at 60 W. For the bipolar system, use the default setting on the machine.

The resectoscope is advanced under direct vision as the uterine cavity is distended with fluid. Within the uterine cavity, a thorough inspection is carried out noting the tubal ostia, the fibroid base, the number, location and size(s) of the fibroid(s) as in Fig. 2.

Inspection also reveals the presence of concomitant pathologies like adhesions. After inspection, start resecting the myoma by advancing the loop electrode beyond the area to be resected. Activate the generator, and start shaving towards the end of the hysteroscope. Always ensure that the loop is visible before activating the generator. Repeat the shaving process in the same manner until you get to the base of the fibroid. Do not keep the loop stationary for too long while applying current, thereby avoiding thermal injury to nearby endometrial tissues and even adjoining bowels and bladder. It is important to allow for uterine contraction by deflating the cavity a while during surgery. This action allows further protrusion of the myoma into the cavity. Some agents like prostaglandins have been used to aid uterine contractility [23, 24], while uterine massage by bimanual palpation has been described by some authors [25, 26]. It is advisable to bluntly dissect the intramural component of the myoma from its pseudo-capsular bed before applying energy to shave it. It is also important to avoid excision of the myometrial tissue as this could cause myometrial scarring, increase risk of haemorrhage, fluid absorption and uterine perforation. In an attempt to reduce some of these complications, some authors have advocated the cold loop hysteroscopic myomectomy [27]. This method is applicable to types I and II submucosal fibroids. The intra-cavitary component of the fibroid is removed by slicing (shaving) with energy, while the cold loop is used mechanically to remove the intramural component.

It is very important to know when to abort the procedure, particularly when dealing with a large fibroid or type II myomas. Generally, the use of ultrasound scan guidance may be of benefit in achieving complete resection [28].

*Tissue/specimen removal*: The tissue obtained from resection of the myoma can be removed via:

- Use of the loop without applying current
- Use of polyp forceps or grasper
- Use of ovum forceps blindly
- Suction curettage
- Slow removal of the hysteroscopy allowing the fragments to be washed out

*Rate of complete resection using the resectoscope*: The rate of complete resection largely depends on the type and size of the submucosal fibroid with the type II being more at risk of incomplete resection particularly when it is larger than 3 cm. Some series reported rate of complete resection for types 0, I and II as 96–97%, 86–90% and 61–83%, respectively [7, 29].

## 8 Further Consideration and Post-operative Care

The use of prophylactic antibiotics may be necessary, even though infection rates are generally very low. Where large fibroids are resected, development of Asherman's syndrome as a late complication becomes a factor to consider, hence the need to institute prophylactic measures to prevent adhesion formation. Intrauterine cook balloon or size 8–10 French gauge paediatric Foley catheter can be inserted and inflated with about 3 mL of saline or sterile water and left in situ for 5–10 days. In hypoestrogenic women, oestrogen therapy may help in expediting endometrial regeneration.

## 9 Newer Techniques: Morcellation and Vaporization of Submucosal Fibroids

These are newer techniques employed in the management of submucosal fibroid.

### 9.1 Morcellation

This method employs the use of a morcellator. Examples of intrauterine morcellators include the Truclear and Myosure. Most morcellators available today use rotatory blade for resection of the submucosal myomas, and resulting fragments of tissues are removed by suctioning. The symphonic system of morcellation, however, utilizes a bladeless device for resection with radio frequency energy. It has a self-contained fluid management and pressure system.

Advantages of the morcellation techniques over the loop electrode cutting technique are:

- It makes resection easier; this in effect shortens the duration of surgery [29, 30].
- It greatly reduces the number of times the hysteroscope is removed and reinserted during the procedure (this effect reduces the risk of cervical stenosis).
- It produces less tissue fragments.

Disadvantages

- Most available morcellators (with the exception of the Symphion device) cannot cauterize bleeding vessels.
- They are of limited use in the management of type II submucosal fibroids.

### 9.2 Vaporization Techniques

This technique utilizes vaporization electrodes at very high power density (120–220 W). Tissues are vaporized. Bipolar current is usually utilized, but monopolar current could be applicable. Vaporization techniques share similar advantages with the morcellation technique. The major disadvantage is that there is usually no tissue obtained for histopathological examination. This disadvantage could be overcome by replacing the vaporization process with loop electrode for completion of the procedure (thereby obtaining tissue for histology). The other disadvantage of the vaporization technique is bubble formation in the distension fluid affecting visibility.

## 10 Second-Stage Procedure

A second-stage hysteroscopic myomectomy is sometimes necessary for some cases [31]. These include myomas that are large, broad based or penetrate very deep within the myometrium. So also is the case when there are multiple myomas. In cases of second-stage procedure, the commonest reason for aborting the initial procedure is due to attainment of maximum distension fluid absorption level [29]. The patient must be re-evaluated before a second-stage procedure.

## 11 Advantages of Hysteroscopic Myomectomy Over Laparotomy for Myomectomy in Cases of Submucosal Fibroid

- No need for hospital admission
- No abdominal scar
- Early recourse to feeding
- No risk of intra-abdominal adhesions
- Minimal or no myometrial scarring
- Early return to work

## 12 Complications of Hysteroscopic Myomectomy

Generally the incidence of complications following hysteroscopic myomectomy is low. However, there are only few reports of large series regarding complications specific to hysteroscopic myomectomy. Complication rates of between 0.8% and 2.6% have been documented in some series [32, 33]. Some other series have shown that complication rates are lower for single fibroid resection (1.4%) compared with multiple fibroid resections (6.7%) [32].

*Traumatic complications*: This includes cervical laceration, uterine perforation, bladder or gut injury. Cervical trauma could result from a traumatic grasping instrument, the process of dilation or from the hysteroscopic or resectoscopic tools. Traumatic injuries could either be mechanical or thermal. Thermal injuries have the most consequences. Generally, traumatic complications are not frequent [3, 34]. Where uterine perforation is from mechanical factors, conservative management could be employed, but if it is thermal, then laparoscopy or laparotomy would be indicated to inspect and manage any resulting consequence.

*Haemorrhage*: Excessive bleeding as a complication of hysteroscopic myomectomy is uncommon. Usually estimated blood loss following the surgery is about 5–100 mL [3]. Where excessive bleeding occurs, it is mostly due to preoperative factors (history of heavy bleeding or operating on a big fibroid mass). Heavy bleeding could also occur from entering major myometrial vessels particularly when operating on deep fibroid on the lateral walls. The incidence of excessive bleeding has been reported to be 1.7% in a series [32]. In some cases, perioperative blood transfusion is required. To prevent excessive bleeding, intracervical injection of carboprost (prostaglandin F2 alpha analogue) or vasopressin has been used [22, 24]. Treatment of persistent heavy bleeding could be achieved by intracavitary insertion of Foley catheter/balloon inflated with saline to maintain pressure for some hours [34]. Packing of the uterine cavity with gauze soaked with vasopressin has been advocated [35]. However the risk of systemic absorption has made this approach unpopular. Uterine artery embolization has also been utilized to stop haemorrhage.

*Complications related to distension medium*: These complications result from excessive absorption of the distension medium. Even though less frequent, it could be life-threatening when it occurs. Specific complication is related to the type of distension fluid used. With isotonic solution, volume overload with resultant pulmonary and cerebral oedema and congestive cardiac failure is the major fear. With the use of hypotonic solution, in addition to volume overload, there exists another major risk of electrolyte imbalance. Hyperglycaemia characterizes the use of sorbitol, hyperammonemia, hyponatraemia and transient blindness with glycine. Hyskon is associated with coagulopathy and anaphylaxis [3].

*Other early complications are:*

- Infection
- Thermal damages (particularly with monopolar electrode)
- Vasovagal attack
- Anaesthetic-related complications

*Late Complications*

- Incomplete resection
- Recurrent fibroid
- Cervical stenosis with haematometria
- Intrauterine adhesions/Asherman's syndrome
- Cervical incompetence
- Uterine rupture in subsequent pregnancy from previous uterine perforation at surgery

**Learning Points**

- Not all submucosal fibroids are resectable hysteroscopically.
- Know when to abort a procedure with respect to excessive absorption of distension medium and the presence of other complications.
- When dealing with lateral fibroids (particularly type II), beware of large vessels.
- Take cognisance of the serosal-myoma distance for type II myoma to avoid uterine perforation.
- Recognition of pseudo-capsular margin is key to avoid myometrial scarring from cutting of the myometrium.
- Do not remain stationary while applying current.
- Always shave towards the hysterscopy lens (i.e. towards the operator) never away.
- Avoid the use of Trendelenburg position (as the risk of air embolism is high in that position).
- When using vasopressin, be conscious of the cardiovascular situation of the patient and always work with the anaesthesiologist.
- Avoid multiple removal and reinsertion of the hysteroscope (to prevent cervical stenosis).
- The use of a cervical priming agent reduces traumatic complications.

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# Complications Associated with Hysteroscopic Surgery

Emmanuel Kalu, Emily Nzeribe, and Charles Nzurumike

## 1 Introduction

An increasing number of gynaecologists are now performing hysteroscopy for diagnostic and therapeutic purposes. The experience of surgeons utilising this rapidly expanding technology varies. As the number of surgeons who take up intermediate and advanced hysteroscopic surgeries increases, there is always the risk of increased complications. It is therefore important that surgeons are familiar with complications that can arise from hysteroscopic surgery, since early recognition and appropriate intervention may minimise adverse outcomes.

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## 2 Prevalence

Basic hysteroscopy is generally a safe procedure with low complication rates. The risk of complications is influenced by various factors including experience of the surgeon, case mix and complexity of the procedures. Quoted incidence of complications that can occur during and following hysteroscopic surgery could be as low as 0.24% in Germany, 0.28% in Holland [1, 2] and as high as 4.4% in the UK MISTLETOE study [3] which was published over 20 years ago and where most complications were associated with first-generation endometrial ablation techniques. Development of more advanced second- and third-generation endometrial ablation techniques has now rendered the procedure much safer with much lower complication rates. Although diagnostic hysteroscopy is extremely low risk, more complicated procedures including fibroid resection, excision of uterine septum and intrauterine adhesiolysis of severe synechiae have been associated with complication rates as high as 10% [4]. In their series of hysteroscopic procedures in a private unit in Nigeria, Okohue et al. quoted an overall complication rate of 1.2% [5].

Complications associated with hysteroscopic surgery include anaesthetic complications (local and general anaesthesia), neurological sequelae following suboptimum positioning of the patient during the procedure, trauma to the vagina, cervix


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and uterus including lacerations and perforations, bleeding, visceral injury from electrosurgical and thermal damage, complications specific to various distension media, infection and other long-term sequelae of the procedure including post ablation pregnancy complications, uterine ruptures and chronic pelvic pain secondary to the uncommon post ablation tubal sterilisation syndrome.

## 3 Anaesthetic Complications

A detailed discussion on the risks of anaesthesia during hysteroscopy has been covered elsewhere in this book.

Availability of small calibre hysteroscopes with high-quality optics means that most simple procedures can now be performed in an outpatient (office) setting, with no requirement for anaesthesia. However, sometimes local anaesthetics may be required during outpatient procedures. Complications associated with local anaesthetics are uncommon but may be profound. Allergies, anaphylaxis and unintentional intravascular injection of local anaesthetic agents can have major implications. High doses can cause adverse cardiovascular and respiratory complications.

### 3.1 Prevention

To minimise this risk, care must be taken when administering injectable local anaesthetic agents to the cervix. Injecting at 4 and 8 o'clock on the cervix would avoid the vessels. Routinely aspirating before injecting is a good basic injection principle to avoid inadvertent intravascular injection. It is important to adhere to appropriate dosages and to avoid exceeding recommended doses of local anaesthetics. Careful patient selection would avoid the need to administer repeated doses of local anaesthetics for patients with poor tolerance to the procedure. Rather than risk overdosing with local anaesthetic agents, painful outpatient procedures can always be abandoned and rescheduled to be performed in theatres with appropriate anaesthetics.

## 4 Neurological Complications Associated with Suboptimum Patient Positioning

Hysteroscopy is performed with patients in lithotomy or modified lithotomy position. Leg perfusion has been shown to be reduced in lithotomy position especially in obese patients. During prolonged procedures, pressures in the muscle of an osteofascial compartment further compromise local vascular perfusion causing tissue ischaemia and oedema that can result in neuromuscular complications.

The common peroneal and femoral nerves are vulnerable to injury in lithotomy. The femoral nerve courses into the leg under the inguinal ligament and is susceptible to compression during hyperflexion, abduction and external rotation of the hip which can lead to extreme angulation of the femoral nerve. The patient may present with weakness in the quadriceps muscles and numbness over the media and lateral thigh. Although this femoral neuropathy tends to resolve with time, it may cause significant psychological and physical morbidity and may require physiotherapy.

The common peroneal nerve is also susceptible to injury with patients in the lithotomy position. This nerve runs around the head of the fibula and is easily compressed with legs in lithotomy. The patient presents with foot drop and inability to dorsiflex the foot.

### 4.1 Prevention

Ergonomically designed operating beds are well-padded to support the patient's legs safely in lithotomy or other positions without pressure on tissues or nerves. Where older beds with stirrups are still used, appropriate positioning would generally minimise the risk of nerve injury. Optimum lithotomy position requires only moderate flexion at the knee and hip with limited abduction and external rotation. This will minimise stretch or compression on the femoral and sciatic nerves. If stirrups are used to support the legs, conscious efforts must be made to avoid pressure on the femoral nerve.

It is not uncommon for the surgical assistant to lean over the patient's thigh with the risk of stretching the sciatic nerve.

Finally, surgeons in training must be educated to appreciate the importance of adequate patient positioning. The risks of these avoidable hysteroscopic complications could be minimised by highlighting the links between poor leg positioning and the development of compartment syndrome and nerve injuries.

## 5 Cervical Injury

Application of the vulsellum or tenaculum to stabilise the cervix during hysteroscopy can cause bleeding from tenaculum bite and avulsion of the cervix if the instrument detaches during traction.

Difficulties with cervical dilatation may cause cervical laceration and creation of false passages. Risk factors for cervical trauma include cervical stenosis, postmenopausal status, preoperative use of GnRH agonist, nulliparity, previous cervical surgery and acute uterine retroversion/anteversion. Anatomic variation and abnormalities of the cervix and cervical canal may render dilatation difficult and predispose to cervical injury. Stenosis may be at the level of the external or internal cervical os. Deviation of the course of the cervical canal by fibroids or other local lesions may render access difficult and lead to cervical trauma and creation of false passages during hysteroscopy.

### 5.1 Prevention

Routine use of the non-touch vaginoscopic technique will avoid tenaculum associated bleeding and cervical injury. Early exposure of the trainee surgeon to the non-touch vaginoscopic technique will enhance patient's experience especially during outpatient procedures and also minimise local cervical trauma.

A good understanding of the principles of the angle of the hysteroscopy is important in the practice of the non-touch technique. The appropriate view of the cervical canal depends on the angle of the view of the hysteroscopy lens. For instance, a zero-degree lens would give a panoramic view of the cervical canal and can be inserted directly. However, for a hysteroscope with an angled lens, the insertion should be at an angle such that cervical canal will be visible at 6 o'clock depending on the angle of the objective lens of the hysteroscope. For very retroverted uteri, it may be easier to rotate the hysteroscope 180° and keep the cervical canal at 12 o'clock (Fig. 1). Attempting to insert an angled hysteroscope with the cervical canal in a panoramic view would normally be unsuccessful and may predispose to creation of false passage and local tissue injuries.

Dilatation of the cervix is frequently not necessary during hysteroscopy, especially when a small calibre hysteroscope is used. It is the Authors' practice not to routinely dilate the cervix unless necessary. However cervical dilatation is usually required for most operative hysteroscopic procedures when hysteroscopes with wider diameters are required. Even in such cases, it is usually reasonable to initially attempt direct insertion without routine cervical dilation. We find that initial aqua dilatation makes subsequent mechanical dilatation easier. Furthermore, dilation will be easier and perforation less likely since the course and direction of the cervical canal would have been assessed using the hysteroscope and before dilatation.

A good vulsellum bite is required to minimise cervical tear/laceration but a 'good vulsellum bite' may also cause bleeding. The use of double vulsella without ratching either to the end groove would improve grip whilst minimising the risk of bleeding. When difficult dilatation is anticipated and in situations where the cervix is deficient in length, it is the Authors' practice to use double vulsellums. Whilst these may annoyingly get on the way of the surgeon, it provides the necessary cervical grip without increasing bleeding from the bite sites.

Other measures that have been proposed to facilitate cervical dilation and minimise risks of cervical trauma include preoperative use of cer-

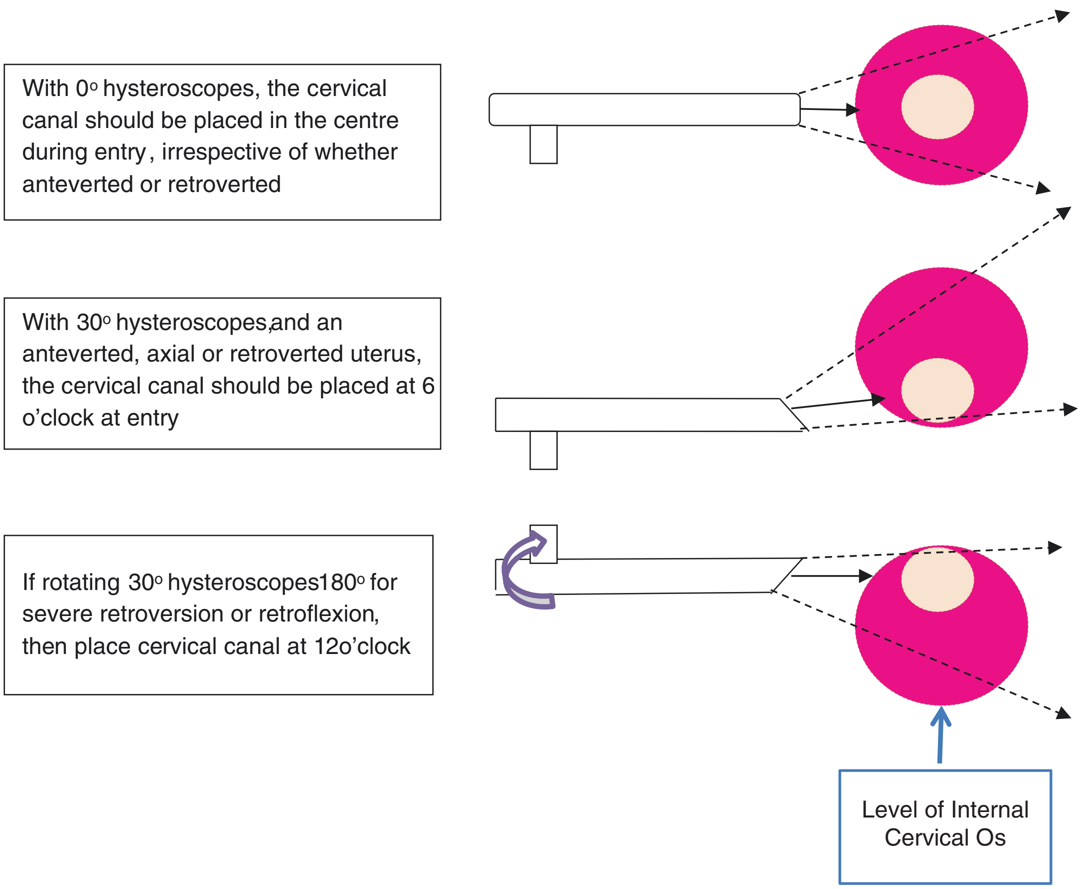



**Fig. 1** View of the cervical canal in relation to the angle of the lens of the hysteroscope

vical softening agents including oral or vaginal misoprostol (200–400 μg) usually 12–24 h before the procedure. Hygroscopic seaweed (laminaria tent) (commonly used in the USA but not in Europe or the UK) inserted before the procedure can be very effective. Hygroscopic dilators come in 3 and 4 mm diameters and swell to two to three times their original diameter. The seaweed versions act over 24 h, whereas the synthetic versions act over 4 h [6]. Others have also described deep intracervical injection of 20 mL of dilute vasopressin (4 U of vasopressin in 80 mL of normal saline at 0.05 U/mL) at 4 and 8 o'clock on the cervix to facilitate cervical dilatation [7].

## 6 Uterine Perforation

The incidence of uterine perforation during hysteroscopy ranges from 0.12% to 1.4% [3, 8]. Most perforations occur during dilatation. Cervical dilatation to Hagar 8 or 10 is usually required for operative hysteroscopy, and such dilatation increases the risk of uterine perforation. Other risk factors for uterine perforation are same as those discussed under cervical injury.

Uterine perforation can also occur during insertion of the hysteroscope or during resectoscopic procedures involving the use of sharp instruments like the scissors or by activated electrode.

The uterine fundus is the commonest site for perforations that occur during cervical dilatation. However, the uterine cornus with its thin myometrium is particularly susceptible to perforation during resection procedures in this area.

Early signs of uterine perforation include inability to distend the endometrial cavity or sudden loss of uterine distension, significant and sudden distension fluid imbalance (as the fluid rushes freely into the peritoneal cavity), bleeding and sometimes direct visualisation of pelvic/abdominal visceral organs.

Recognition of uterine perforation is important since early intervention and appropriate management would reduce morbidity.

Most perforations involving the use of dilators or the uterine sound are not associated with other injuries. However, when the uterus is perforated by sharp hysteroscopic instruments like the scissors or by an activated electrode, there is significant risk of injury to other pelvic structures including blood vessels and bowel.

### 6.1 Prevention

Since most simple perforations occur following cervical dilatation, measures described above aimed at facilitating cervical dilatation would help minimise risk of uterine perforation.

Insertion of the hysteroscope under direct vision minimises risk of uterine perforation caused by insertion of the hysteroscope.

To minimise uterine perforations caused by an activated electrode during resection, it is important to ensure the loop is retracted and protected within the hysteroscope when advancing the hysteroscope. Furthermore, the surgeon must avoid forward movements of the hysteroscope whilst activating the electrode as this increases the risk of perforation. These important basic hysteroscopic principles should be adhered to at all times to minimise risks associated with perforation whilst using activated electrodes.

Another important hysteroscopic principle is to always resect towards the surgeon and avoid resecting forward (so-called backhanding). Resecting towards the surgeon and into the ceramic sheath of the resectoscope is a safe technique that minimises the risk of uterine perforation but also limits the resection footprint and avoids collateral endometrial damage during resection of submucous fibroids.

### 6.2 Identification and Management

Failure to recognise significant uterine perforation may have serious consequences. Most simple fundal perforations caused by the dilator may not require any further intervention if there is no significant bleeding. It is the Authors' practice to give a course of prophylactic antibiotics and admitted such patients for overnight observation.

Non-fundal uterine perforations may be more problematic as these may involve other pelvic structures including uterine vessels, broad ligament injuries and bladder or bowel injuries. We would normally consider pelvic assessment by laparoscopy when non-fundal perforation occurs.

Uterine perforations caused by activated electrodes are usually more severe and warrant immediate laparoscopy and sometimes laparotomy to assess for visceral damage. The assistance of general surgical colleagues should be sought in such cases so that the bowel can be thoroughly assessed for injuries as such injuries may sometimes go unrecognised, with obvious consequences.

## 7 Occult Visceral Thermal Injuries

Occult thermal burns to pelvic/abdominal viscera may occur following the use of surgical energy. Dispersion of energy and stray current from monopolar electrodes can cause tissue damage beyond the view of the hysteroscope. For example, the use of monopolar energy during resection around the uterine corn and where the myometrium is thin including along a previous caesarean section scar can lead to increased risk of thermal injury to structures outside the uterine cavity. Bowel loops adherent to the serosal surface of the uterus are particularly vulnerable to heat energy generated inside the uterine cavity during resectoscopic procedures. Such thermal injuries might go unrecognised at the time of the procedure, and the patient may present much later with peritonitis, sepsis and fistula formation with fatal consequences.

### 7.1 Prevention

Bipolar energy is much less likely to cause occult thermal injuries as inadvertent energy spread is much less than monopolar. However, the risk of energy-related injuries is still very much possible even with bipolar energy and more so if perforation occurs.

Utmost care must be exercised when resecting over areas of thin myometrium, including uterine cornus and over Caesarean section scars. During first-generation global endometrial resection/ablation, it is good practice to use the rollerball to ablate over areas of thin myometrium rather than the loop. It is however still worth noting that rollerball ablation using monopolar energy has also been known to cause occult thermal visceral injuries.

Preoperative assessment of myometrial thickness using MRI or 3D ultrasound scan may aid surgical planning, although this has not been validated.

The safe technique of always withdrawing the activated electrode towards the hysteroscope minimises the risk of uterine perforation and also reduces the risk of thermal transfer following deep resection.

Procedures such as excision of uterine septa where the activated electrode is usually moved forward should only performed by surgeons with the appropriate skills.

## 8 Complications Associated with the Distension Media

The various distension media used for hysteroscopy have been discussed elsewhere in this book. Discussions here are limited to complications that arise whilst utilising the various distension media:

### 8.1 Gas Media

The use of gas ($CO_2$) for distension is limited to diagnostic procedures and no longer much used. Cavity distension using $CO_2$ has been shown to cause more discomfort with reduced patient satisfaction. Carbon dioxide embolisation is not uncommon. The incidence of subclinical $CO_2$ embolisation has been reported to be in the region of about 0.51%. Embolisation of small amounts of $CO_2$ is not dangerous. However, embolisation of large amounts of $CO_2$ (more likely to happen when the wrong type of $CO_2$ insufflator is used) has been associated with fatality. Laparoscopic insufflators should therefore never be used to insufflate the uterine cavity during hysteroscopy as CO2 embolism is more likely to occur with such high insufflation pressures.

### 8.2 Fluid Distension Media

The high-viscosity solution Dextran 70 (32% Dextran 70 in D10W) is no longer commonly used. Although Dextran gives clearer views especially in patients with ongoing bleeding (Dextran does not mix with blood), it requires significant pressures to infuse, and if high volumes are infused, its hydrophilic properties can lead to significant intravascular fluid shifts with consequent fluid overload, electrolyte imbalance and cardiac failure. Fluid overload can occur with much smaller volumes of Dextran compared with low-viscosity fluids.

Dextran has also been associated with significant anaphylaxis (1:10,000) and intravascular coagulopathy. The use of low-viscosity media where available is recommended and if Dextran must be used, then we suggest the use of small volumes, strict fluid balance surveillance and close monitoring of vital signs.

Commonly used low-viscosity media include 1.5% glycine, 3% sorbitol, 5% mannitol, normal saline, Ringer's lactate, amongst others. Complications associated with the use of low-viscosity media are mainly due to excessive fluid absorption that could occur during usually prolonged operative hysteroscopic procedures that involve transection and disruption of the numerous fine networks of blood vessels within the endometrium/myometrium or on fibroids.

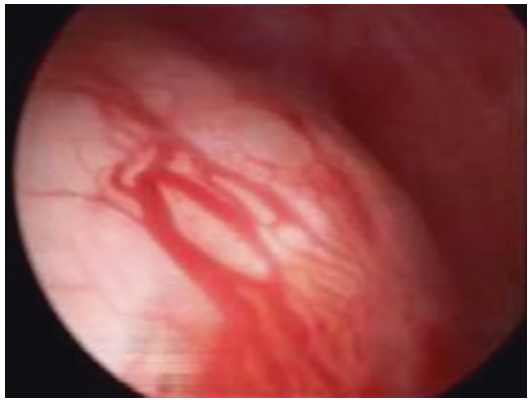
Excessive absorption of hypotonic low-viscosity fluids (1.5% glycine and 3.3% sorbitol) can cause fatal hyponatraemia with consequent neurological sequelae. Glycine is metabolised in the liver and kidney into glycolic acid and causes neurological symptoms. Also, excessive absorption of glycine can cause transient loss of vision.

Although isotonic solutions (normal saline and Ringer's lactate) are safer to use, massive absorption of large amounts of even these isotonic fluids can cause fluid overload with resultant pulmonary oedema and congestive cardiac failure.

## 8.3 Prevention, Recognition and Management of Excessive Fluid Absorption

Risk factors for increased fluid absorption include high intrauterine fluid delivery pressures, lengthy operating time and resectoscopic procedures, including resection of large fibroids (Pic. 1), division of uterine septum, endometrial ablation and division of synechia.

The risk of excessive fluid absorption during hysteroscopic myomectomy correlates with the duration of the procedure, the diameter of the fibroid and the proportion of fibroid in the myometrium [9].



**Pic. 1** Large vascular submucous fibroid. Risk factors for increased fluid absorption include resection of large fibroids. (Courtesy of Mr. E. Kalu)

Also, constant interruption of the resection procedure to clear the cavity of fibroid chippings during myomectomy would extend operating time and increase risk of fluid absorption.

Although the entire surgical team must pay due attention to fluid balance, it is good practice to assign a specific member of the team to keep a close eye and audibly announce fluid input-output balance at agreed regular intervals. This would enable early recognition of excessive fluid absorption and allow for early intervention.

Risk reduction strategies include appropriate choice of solution (isotonic solutions safer than hypotonic solutions), the use of lowest pressures required to achieve and maintain suitable uterine distension and keeping procedure time as short as necessary. Patients should be counselled that some procedures may not be completed in one setting and may require repeat procedures.

Removal of chippings to clear the uterine cavity should be kept to a minimum and performed only when the operating field is obscured by accumulation of chippings.

Preoperative use of GnRH analogues for pituitary down-regulation and reduction of size of the fibroid may minimise fluid absorption by shortening length of procedure.

The team should maintain strict fluid input and output balance chart at all time, and the oper-

**Pic. 2** A closed-circuit fluid delivery and collection systems

ating surgeon should be kept informed. The use of a closed-circuit fluid delivery and collection systems will facilitate fluid management by minimising fluid loss to the floor and perineal drape whilst enabling complete collection of fluid escaping from the uterine cavity and the resectoscope (Pic. 2).

It is advisable to discontinue the procedure at a fluid deficit of 1.0 L when using hypotonic solution and 2.0 L when using isotonic solution.

Early signs of fluid overload and hyponatraemia include headaches, severe nausea and vomiting as well as agitation, which may start shortly after the patient recovers from anaesthesia, and sometimes in the recovery room. Muscle cramps, restlessness and lethargy are other symptoms that patient develop especially when the fall in serum sodium level is rapid and severe.

Treatment of hyponatraemia is usually supportive and aimed at reducing fluid overload and correcting serum sodium levels. Furosemide 20–40 mg should be given intravenously to induce diuresis. An indwelling catheter should be inserted to facilitate measurement of urine output. Patients with severe hyponatraemia (when serum sodium levels go below 120 mmol/L) should ideally be nursed in an intensive care unit. Usually, normal saline is used to carefully and slowly restore sodium levels, although hypertonic saline could be used in cases of severe hyponatraemia who show neurologic and cardiac symptoms. The aim is to raise the sodium level by 1 mmol/h. There is significant risk of causing central pontine myelinolysis if sodium levels are corrected too rapidly.

Complications associated with fluid distension media are largely preventable by understanding risk factors. Meticulous attention to fluid management and early recognition of the complication will facilitate prompt intervention and avert adverse outcomes.

## 9 Air Embolism

Air embolism on the other hand is a potentially more serious complication. Thankfully it is not common, but when it occurs, it could be fatal. Air can gain access into the uterine cavity during cervical dilatation and when air in the infusion tubing is not flushed out before hysteroscopy. Air can also enter the cavity with repeated removal and insertion of the hysteroscope during an operative procedure. Such room air that accumulates into the uterine cavity is compressed into small venous blood vessels in the resected endometrium, and the high intrauterine pressure can push this air into venous channels and into the vena cava and the right atrium and ventricle.

The risk of air embolism is increased when patient is in the Trendelenburg position. In this position, the uterus is located above the level of the heart, and diastole creates a negative intravenous pressure that facilitates air advancement into venous channels.

The patient manifests decline in cardiac output, hypotension, decrease in arterial saturation, tachycardia, arrhythmia and a noticeable sudden decrease in end-tidal $CO_2$ and a decrease in oxygen saturation.

### 9.1 Prevention

The distension fluid should be allowed to run through and flush out any air column from the insufflation tubing before the hysteroscope is inserted into the patient. This routine step would minimise introduction of air pockets from the tubing.

For obvious reasons discussed above, the Trendelenburg position should be avoided during hysteroscopy.

Efforts should be made to minimise multiple repeat insertion and removal of the hysteroscope during a procedure. This will minimise risk of introducing room air in the cavity. Also, shorter operating time and the avoidance of excessive infusion pressures are all measures that will reduce risk of air embolism.

Finally, a drop in end-tidal $CO_2$ is a warning feature that should be recognised by the anaesthetist as a sign for air embolism.

## 10 Intraoperative and Post-operative Bleeding

Bleeding during hysteroscopic surgery is not uncommon with an incident of about 2.2–2.4%. Haemorrhage complicating hysteroscopy can occur during or after the procedure. Bleeding is usually secondary to injury to myometrial vessels especially during resection procedures. Bleeding can also be the result of uterine perforation especially non-fundal perforations that can involve vessels in the broad ligament, the uterine artery or other pelvic vessels. Bleeding can also occur following cervical trauma.

### 10.1 Prevention and Management

Risk of intraoperative bleeding can be minimised by preoperative administration of GnRH analogues. Limiting the depth of resection in the isthmic region will reduce the risk of lateral uterine perforation, which could involve the pelvic vessels.

Raising the intrauterine distension pressures can easily control small vessel bleed. Bleeding from larger vessels is usually more of a problem as hysteroscopy views become suboptimum, and the procedure may become difficult to continue. The use of coagulating current with a wire loop to coagulate bleeding vessels is usually successful in controlling bleeding from larger vessels [10, 11]. Other measures that may be helpful to control ongoing intrauterine bleeding include bimanual uterine massage, insertion of intrauterine balloon for tamponade, injection of vasopressin and intravenous administration of tranexamic acid. These measures are usually sufficient to bring bleeding under control. Uterine embolisation could be useful for bleeding from major pelvic vessels, and hysterectomy may be required in life-threatening cases where bleeding is refractory.

Finally, when there is suspicion of intraperitoneal bleeding following uterine perforation, laparoscopy or laparotomy should be performed as required.

## 11 Infection

Infection following hysteroscopy is uncommon. Rate of infection has been reported to be as low as 0.01–1.42% [2, 12]. Endometritis and even more rarely parametritis can occur. Risk factors for postoperative endometritis include inadequate aseptic precautions, extensive tissue destruction, prolonged operative procedures and pre-existing pelvic infection. There have been case reports of tubo-ovarian abscess following hysteroscopic procedure on a patient with a history of pelvic inflammatory disease [13].

Postoperative endometritis can occur several days after the procedure, and symptoms would include pain, vaginal discharge, pyrexia and uterine tenderness.

The benefits of routine use of antibiotics to prevent infection during hysteroscopy in patients with no risk factors have not been established.

## 12 Uterine Synechia Following Hysteroscopic Surgery

Intrauterine adhesions are a potential long-term complication of hysteroscopic surgery. They could be primary, occurring after hysteroscopic surgeries such as myomectomy or resection of intrauterine septum, or secondary when reoccurring after an initial hysteroscopic adhesiolysis has been performed [14]. These surgeries can cause adhesions as a result of surgical trauma to the endometrium.

The rate of adhesions following hysteroscopic uterine septa resection is about 6.7% which appears to be higher in hysteroscopic myomectomy [15]. Acknowledging these risks is therefore very important in the prevention of intrauterine adhesions. These risks along with the benefits of the surgery should always be considered and weighed against the risk of adhesions especially in patients with cavity-related subfertility issues.

### 12.1 Prevention and Management

It is common to use oestrogen therapy to prevent adhesions. This can be used alone or as ancillary treatment either with intrauterine device (IUCD) or pediatric Foley's catheter. Intrauterine application of gel barrier such as hyaluronic acid for secondary prevention of adhesions has been advocated.

A study comparing intrauterine balloon, IUCD and hyaluronic acid gel demonstrated that the balloon and IUCD were more effective than hyaluronic acid [16].

## 13 Risk of Morbidly Adherent Placenta Following Reproductive Hysteroscopic Surgery

The risk of morbidly adherent placenta (such as placenta accreta, increta and percreta) is increased by hysteroscopic surgeries [17]. As such, it should be considered a potential long-term complication in pregnancies following hysteroscopic surgical interventions such as adhesiolysis, metroplasty and myomectomy. Endometrial trauma that may be sustained during such procedures may lead to defects in the decidua basalis resulting in abnormal placentation when the anchoring placental villi adheres to the surface of the myometrium, beyond the endometrium [18].

## 14 Other Complications

Some other complications associated with hysteroscopic surgery include haematometria, which can occur if cervical stenosis complicates resectoscopic procedures. Patients would normally present with chronic pelvic pain.

Myometrial deficiency caused by deep hysteroscopic resections of fibroids or uterine septum may be a risk factor for uterine rupture when pregnancy occurs.

Pregnancy following global endometrial ablation can be associated with significant complications involving the foetus and placentation. Women requesting endometrial ablation should be counselled about the need to avoid pregnancy.

Haematometria and chronic pelvic pain have been reported in women who had tubal occlusion and endometrial ablation and who continue to have light bleeding with retrograde bleed into the occluded proximal fallopian tubes. Patients with this so-called post ablation tubal sterilisation syndrome may present up to a year after endometrial ablation with cyclical, cramping and lower abdominal pain which could be unilateral or bilateral. Laparoscopy is diagnostic, and salpingectomy is therapeutic. Ligating the fallopian tube as close as possible to the cornua would minimise the risk of occurrence of this uncommon complication of endometrial ablation.

Other long-term sequelae of global endometrial ablation include difficulties with the investigation and diagnosis of post ablation endometrial cancer. These women usually have islands of active endometrium left behind following ablation and may be unfortunate to develop endometrial adenocarcinoma. Radiological investigations including TVS and MRI are of limited values in assessing the endometrium in this situation, and hysteroscopy and endometrial biopsy could be difficult. The diagnosis of cancer can be delayed in these cases.

**Learning Points**

- Although basic hysteroscopy is a safe procedure, risk of complications increases with surgical complexity.
- Optimal positioning of the patient will minimise risk of nerve injury.
- A good understanding of the principles of the angle of the hysteroscopy is important to facilitate access into the cavity.

- It is important to ensure the loop is retracted and protected within the hysteroscope when advancing the hysteroscope. This will minimise uterine perforations caused by an activated electrode during resection.
- It is safe and good practice to resect towards the surgeon and avoid resecting forward.
- Uterine perforations caused by activated electrodes are usually more severe and warrant immediate laparoscopy and sometimes laparotomy to assess for visceral damage.
- Risk factors for increased fluid absorption include high intrauterine fluid delivery pressures, lengthy operating time and resectoscopic procedures, including resection of large fibroids.
- Attention must be paid to fluid balance to enable early recognition of excessive fluid absorption and timely intervention. It is advisable to terminate when fluid deficit exceeds 1 L with hypotonic solutions and 2.0 L when using isotonic solutions.

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