Gas Insufflation-less Laparoscopic Surgery

Jesudian Gnanaraj, Anurag Mishra, Lovenish Bains, Biju Islary, Peter Culmer & Noel Aruparayil

Editor's note: This excellent chapter describes the use of a proprietary device of the authors' design, the RAIS (Retractor for Abdominal Insufflation-less Surgery.) While it is possible to perform "gasless" reduced-pressure laparoscopy using ordinary laparoscopic equipment such as the Nathanson retractor, these authors show a better way. They present a compelling description of a well-designed device that is intended to be used in settings such as ours. The corresponding author's contact details are available at the end of this article for those who want further information. -RD

Introduction:

Laparoscopic surgery allows surgical procedures to be performed through tiny openings in the abdomen, through which special surgical instruments are introduced. The space necessary for performing the surgery is usually created using CO2 gas. A laparoscopic camera is used for visualizing the operative field. Although there are many advantages to laparoscopic surgery, there are disadvantages too. Some of them are the high costs, the need for general anaesthesia and the management of physiological changes due to carbon dioxide insufflation. The complications are few, but definite. Moreover, adoption of conventional laparoscopic surgery in low resource settings is complex and takes a longer time to set up.

In high-resource settings, gasless laparoscopic surgeries, also called isobaric laparoscopic surgeries, became popular in the 1990s, in an attempt to mitigate the problems associated with gas insufflation. However, the early equipment offered less than optimal exposure due to tenting, and the design was clunky. Hence most of the publications were from single centre experiences, although these indicated a potential usefulness of the modality. The Gas Insufflation-Less Laparoscopic Surgeries (GILLS) was adopted by rural surgeons in low-resource settings primarily because of the following advantages:

1. GILLS is less expensive and can be performed using the readily available spinal anaesthesia in rural areas
2. Overall costs are lower compared with open surgery or conventional laparoscopic procedures
3. It is relatively easy to learn for a practicing rural surgeon with some exposure to laparoscopic surgery in the past
4. No CO2 related physiological complications
5. Can be used in patients with cardiac and respiratory conditions
6. No loss of space when suction is applied
7. Conventional open surgery instruments can be used
8. Ports are not required. When needed, reusable ports without valves can be used
9. Reduction of aerosolization
10. Sustainable - overall reduction in carbon emission and surgical waste

Randomized control trials and meta-analyses showed no significant difference between GILLS and conventional techniques. The outcomes for GILLS were better when compared to open abdominal surgeries. Moreover, single incision laparoscopic surgeries are more straightforward and less expensive with GILLS.

GILLS creates space for surgery by lifting half of the abdominal wall with a specially designed ring inserted through the umbilical incision. The patient is positioned so that the intestines move away from the operating field due to gravity. For example, a steep lithotomy position is used for pelvic surgeries along with a shoulder brace that prevents the patient from sliding down.

An umbilical incision is used to insert the ring and to pass the laparoscope and instruments. If necessary, additional ports can be placed at convenient places. A combination of laparoscopic and long conventional open surgery instruments can be used.

Exposure to current devices (STAAN and RAIS devices) is the same as conventional laparoscopic surgeries for patients with BMI less than 28. Large open suctions, gauze pieces for retraction and mopping, and other open methods could be comfortably used during GILLS, without loss of exposure due to collapse of

pneumoperitoneum that occurs with conventional laparoscopic surgeries.

We will be describing two different devices used based on the author's experience. The first one is the STAAN (name of the manufacturer) device which has been used for the last 5 years. We will briefly describe this device, to introduce the concept.

The second device is the latest version of the gasless lift device – RAIS (Retractor for Abdominal Insufflation-Less Surgery.) The steps of gasless laparoscopic surgery will be illustrated by Dr. Biju Islary in detail using this device.

STAAN Device:

This device has three main components: The part that attaches to the operating table, the vertical component that holds the ring in place, and the ring itself:

The STAAN Device, with all three parts.

Part that attaches to the Operating Table. There is a "V" shaped cut that allows the clamp to attach to any operating table, and the screws fix it tight. The vertical portion should start low so that once the lift is set up, it can be rotated.

Vertical component that supports the ring. There are two ball and socket joints that allow movement to any desired position and can be fixed quickly with two-click locks.

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The spiral ring that goes inside the abdomen

The ring is the part that goes inside the abdomen and lifts the anterior abdominal wall. The spiral shape of the ring allows it to lift the abdominal wall to a dome shape, similar to the way gases would raise the wall in conventional laparoscopic surgery. The failure to lift in this dome shape was the drawback of many earlier devices. The flatter lifting devices allowed for surgeries like cholecystectomies because the rib cage provided the lift on one side. However, for pelvic surgeries, the dome shape is essential.

Operative setup of STAAN Device

<u>RAIS Device:</u>

The next generation RAIS device (Retractor for Abdominal Insufflation-less Surgery) lift can be used to provide minimally invasive surgery in low resource settings. The RAIS device was designed to provide a retraction system for GILLS which meets current medical device standards (e.g. a modular system which can be readily cleaned and is compatible with auto-clave steam sterilisation,) is robust to transport and can be readily maintained without specialist intervention.

Retractor for Abdominal Insufflation-Less Surgery (RAIS) device

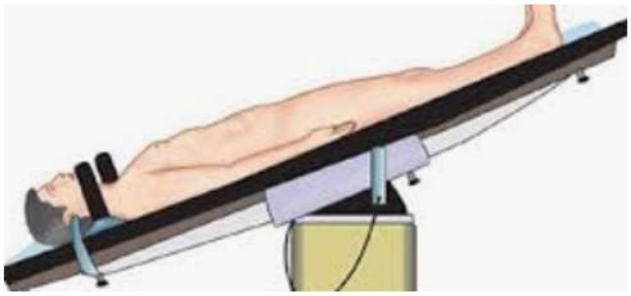
Setup and placement of the RAIS device proceeds in the following steps:

- Positioning of the patient, including retention devices
- Abdominal entry by open technique
- Insertion and positioning of the ring
- Docking of the ring to the device
- Surgical intervention
- Removal of the device and closure of the wounds

Steps:

1. With conventional laparoscopy, the gases move the intestines away from the surgery site, whereas, with gasless laparoscopic surgery, it is

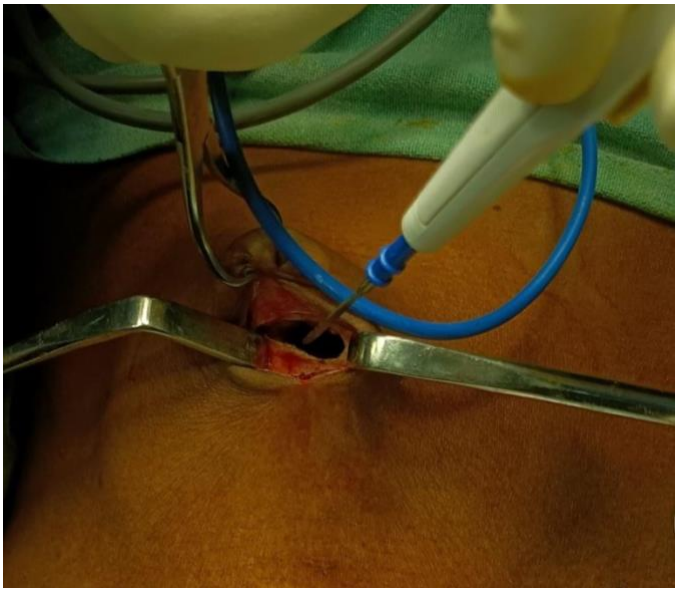
gravity that does the job. Hence positioning is crucial, and so is the shoulder brace that prevents slipping of the patient during surgery.



In order to retract intestines and other viscera away from the operative site, the patient will need to be tilted into extreme positions. Make sure they are secured well to the bed, including shoulder brace, arms well secured, and stirrups.

2. The opening in the abdomen is made and the technique is like the mini laparotomy described by Hasson. (See Principles of Laparoscopy Part 1 for further instructions.) Once the patient is cleaned and draped the lift apparatus is placed in the required position. The Incision is made a centimetre above or below the umbilicus. The lower edges are held up with the towel clips and a No. 15 blade is used to cut from the middle of the umbilicus. 'S' shaped retractors are used to expose and cut the rectus transversely. An artery clamp is used to check if the peritoneal cavity is entered.

Making the periumbilical skin incision



Incision of the Linea alba to safely enter the peritoneal cavity

3. While maintaining anterior retraction on the abdominal wall with a penetrating towel clip, the index finger is passed into the peritoneal cavity. Check for any omental adhesions or trapped intestine between the ring and abdominal wall. At this point, the appropriate size ring is selected. The diameter of the ring should be 2-3 cm smaller than the distance from the umbilicus to the edge of the desired quadrant. For example, for cholecystectomy, use the distance from the umbilicus to the tip of 10th costal cartilage in this calculation.

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Finger sweep maneuver to check for adhesions, attached bowel, omentum, or any other organs.

4. Insert the ring while retracting the abdominal wall anteriorly

Ready to insert the ring.

Insertion of the spiral ring while lifting the abdominal wall

5. Rotate the ring within the abdominal cavity to the quadrant of planned surgery.

Positioning the ring in the required quadrant of the abdomen, in this case the left upper quadrant.

6. Dock the ring to the RAIS Device and adjust the height of the ring.

Adjust the RAIS device to the required position to ease the docking of the ring

Maintaining the lift and ready to dock the ring to the RAIS device.

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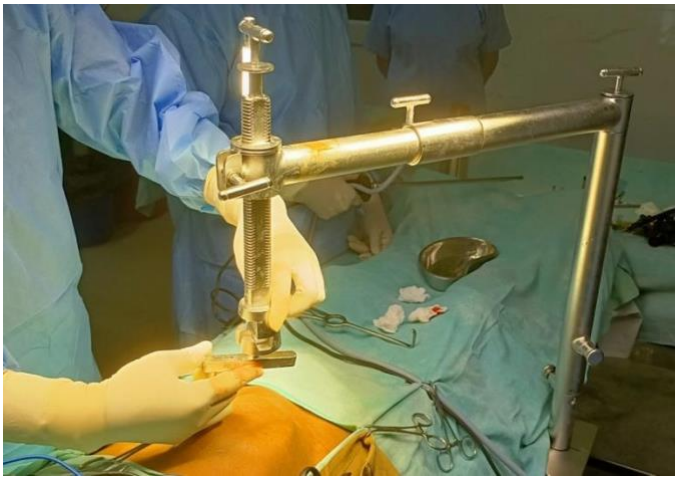
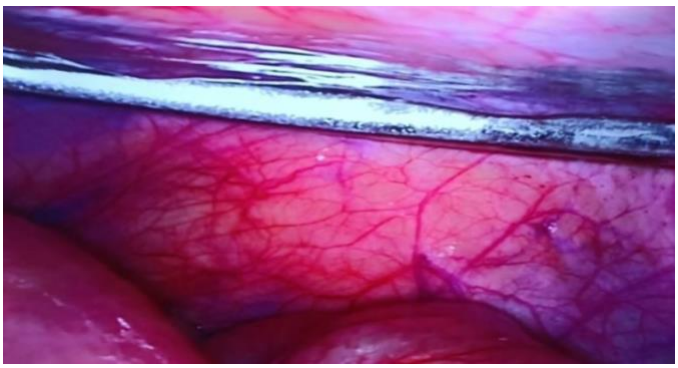


Docking the ring to the device

Rotate the rotating screw handle in a clockwise manner to lift the abdominal wall to a desired height

7. Insert the laparoscope and check that the ring is properly positioned and does not entrap any adjacent organs.

Initial laparoscopy to confirm the location of the position of the ring.



Normal ring appearance in the peritoneal cavity

8. Proceed with surgery. Note that single-incision surgery is much easier using this device than with conventional laparoscopic surgery. The telescope can be passed at the 12 o'clock position of the ring and other instruments inserted below it. If needed, a uterine manipulator could be used to move the uterus and achieve a clear view of the pelvic organs.

Now that the RAIS system has been positioned and the abdominal wall lifted, the surgical procedure can proceed

Safely tilt and position the patient as required

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As there is no need to use a port or to prevent gas leak, several instruments can be inserted through the same incision site.

9. Remove the instruments and close any incisions made. For any instrument site larger than 10mm, including the initial one, the fascia must be closed to prevent incisional hernia.

Skin incisions following multi-port gasless laparoscopy

Pitfalls

- Gasless laparoscopy is limited to selective abdominal procedures (including those described below) and can be challenging in patients with high BMI and in those who have had previous abdominal wall surgery.
- Less compliant abdominal wall: GILLS relies on retraction of the abdominal wall to create surgical working space. This might not be very effective where the abdominal wall is rigid and non-compliant. Patients should be selected carefully, and the below points should be considered:
    - High BMI: This factor may limit the extent of abdominal wall retraction. Caution is advised for BMI >28, especially in the early part of the learning curve.
    - Abdominal wall thickness: wall thickness of more than 5cm has been found to increase difficulty levels and reduce surgeon satisfaction scores.
    - Abdominal wall scarring due to previous surgery or trauma also reduces the compliance of the abdomen, thus making surgery difficult.
    - A muscular abdominal wall increases the stiffness and thus reduces the working space, mainly if muscle relaxants are not used. It can be overcome by using general anaesthesia and muscle relaxants.
- Multi-Compartment surgery: GILLS relies on external retraction; hence shifting to other abdominal quadrants may be cumbersome. This makes surgeries requiring work in more than one quadrant difficult with GILLS. However, newer devices like RAIS allow working in multiple quadrants without difficulty as the ring can easily be rotated without needing to shift the external lift.
- Patient Positioning: GILLS effectively uses gravity to shift other abdominal viscera away from the working field. The patient is generally placed in steep positions like Trendelenburg, reverse Trendelenburg, and lateral positions. Proper support, bracing, and padding should be ensured to avoid any patient harm.
- Electrosurgery: GILLS rings placed inside the abdominal cavity may cause passage of current to the abdominal wall. The ring design is such that the contact area to the abdominal wall is always high, thus making the chance of electrical injury negligible. However, caution is needed to avoid contact with the live electrode. Insulation of working instruments must be checked before use. All principles of safe electro-surgery must always be followed.
- Injury to the abdominal wall: the GILLS ring may cause damage and stretch to the abdominal

wall muscle leading to hematomas, weakening, chronic pain etc. It is essential to carefully decide the extent of wall retraction suitable enough to ensure adequate working space while avoiding unnecessary stretch to the abdomen.

- Size of ring: The GILLS ring size must be selected appropriately according to the patient's build. A too-small ring will be ineffective in creating a good dome-shaped space. A too-large ring will also be ineffective as the ribs and other structures might not allow the retraction. A simple rule may be followed: The diameter of the ring should 2-3 cm smaller than the distance from the umbilicus to the bony parts in the desired quadrant. For example, for cholecystectomy, take the distance from the umbilicus to the tip of 10th costal cartilage.

Specific Situations:

Diagnostic Laparoscopy

For the diagnostic laparoscopy, the initial inspection should be possible with the ring alone after making the umbilical incision. Then, it could be held in various quadrants by assistants and the operating table tilted to view the entire abdominal cavity.

The indications for diagnostic laparoscopy could be broadly classified into

1. Acute Abdominal conditions: appendicitis, diverticulitis, duodenal ulcer perforations, adhesions, Meckel's diverticulitis, intestinal perforations, torsion of abdominal testis, cholecystitis, and abdominal abscess
2. Gynaecological conditions: ectopic pregnancy, endometriosis, pelvic inflammatory diseases, tubo-ovarian lesions, fibroids, pelvic congestion syndrome and evaluation of infertility
3. Chronic abdominal conditions: Some studies report a high percentage of positive findings in chronic abdominal pain
4. Diagnostic purposes: Biopsies to differentiate malignancies when required for staging, or for diagnosis of tuberculosis.

Appendectomy

For GILLS surgeries, the position of the patient is crucial. The intestines must fall away from the field of interest due to gravity. Hence for appendicectomy, the patient's right side must be rotated up by 25-30 degrees and depending conditions inside the peritoneum, the head needs to go down by up to 15 degrees. Hence it is essential to use the shoulder support or shoulder brace to prevent the patient from slipping down, and to strap the patient sufficiently to avoid rolling off the table. If spinal anaesthesia is used, it is vital to ensure sufficient time for the aesthetic agent to fix.

The GILLS apparatus is fixed using the two quick fix levers after placing it about 6 inches above the umbilicus and 2 inches towards the foot end. The apparatus is placed as mentioned earlier with the ring towards the right iliac fossa. The patient is placed in a head down and right side tilted up position.

It is essential to pass the atraumatic grasper below the telescope (especially if it is an angled telescope) and go towards the caecum. Note: For novice laparoscopic surgeons and those not familiar with GILLS, two further 5mm incisions can be made in the left iliac fossa and suprapubic region to insert instruments. The learning curve is from open, to multiport, and then to single port surgeries. The taenia coli are traced to locate the base of the appendix. The base is near where the three taenia coli meet.

The appendix is then held with either the atraumatic forceps, any special curved forceps that are available, or even a long Kelly clamp. The mesoappendix is then dissected using any available energy source. Sometimes just the dissection near the base should suffice.

Several methods are available for tying the base of the appendix. One such method is the low-cost loop made from polypropylene (Prolene ®) and the pusher used with a double-J ureteric stent. In addition, commercial loops can be used. Both intra – corporeal and extracorporeal knotting methods could also be used.

The incision is closed after the appendix is removed. The rectus fascia sheath (linea alba) is usually closed with PDS sutures, and if subcutaneous

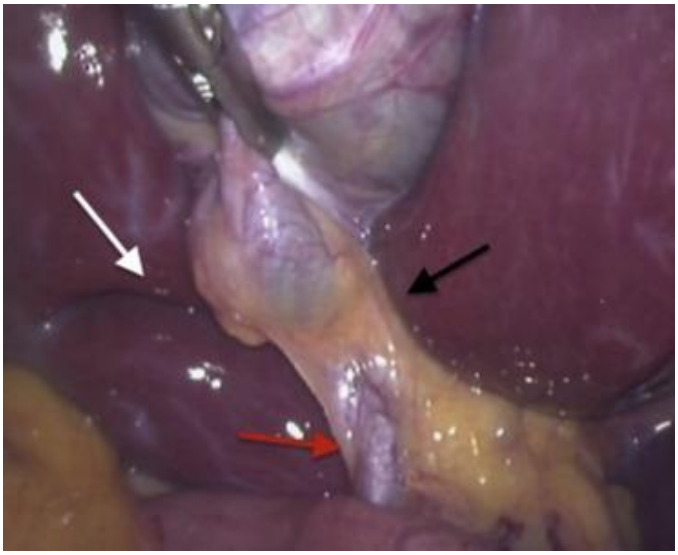
tissue is closed nicely, skin sutures would not be needed. Otherwise, skin sutures may be necessary.

Cholecystectomy

It is important to note that GIILS can be performed even in the presence of few relative contraindications to standard laparoscopic cholecystectomy like pulmonary or cardiac disease. This is because GILLS does not have gas-related complications.

A surgeon needs to know and clearly understand the relevant anatomy in the hepato-cystic triangle. The dissection for cholecystectomy is mainly carried out in an area close to vital structures such as a portal vein, hepatic artery and common bile duct. Any misadventure here can lead the procedure into a significant bile duct or vascular injury. Also, it is essential to be mindful of various anatomical distortions due to pathological processes (i.e. acute. cholecystitis) or the anomalies of the hepatobiliary system. Important landmarks to be understood are

- Hepatocytic triangle
- Cystic plate
- Segment IV of the Liver
- Umbilical fissure
- Rouviere's sulcus



Rouviere's sulcus (White arrow) is a naturally occurring cleft in the right lobe of the liver that points the surgeon to the level of Calot's triangle (Black arrow) and helps orient and avoid injury to the common bile duct (Red arrow.) Source: Stuart Lockhar, Gurpreet Singh-Ranger: Rouviere's sulcus—Aspects of incorporating this valuable sign for laparoscopic cholecystectomy. Asian Journal of Surgery 41(1) 2018

Though lower abdominal GILLS can be performed under spinal anaesthesia, cholecystectomy needs general anaesthesia. However, in rural areas where facilities for General anaesthesia are not available, experienced anaesthesiologists help perform under high spinal anaesthesia. Studies have shown that regular laparoscopic cholecystectomies are possible and safe with low carbon dioxide pressures. GILLS cholecystectomies are regularly carried out in many rural hospitals.

For standard position with the American approach, the patient is supine with arms out, and the surgeon stands on the patient's left side. Alternatively, the patient can be placed in a split leg position (French approach) with the surgeon standing between the legs. The latter is preferred when a single incision approach is used. The position is the same as for classically described single-incision cholecystectomy, but there is no help from the gas in keeping the operative field clear of contents. It is, therefore, helpful to elevate the head as high as possible to let gravity take away contents from the operative field. The ring is placed towards the right hypochondrium.

GILLS cholecystectomy can be done by single incision, 3 ports (3/4 instrument) or even 4 ports. The author uses 4 instruments through 3 incisions.

1. 1.5 cm Sub - umbilical incision, which accommodates the retraction ring, camera, and left-hand instrument
2. 0.5 cm epigastric incision for right-hand instrument
3. 0.5 cm in the right anterior axillary line at the level of the umbilicus for assistant retraction instrument.

Another option is a single port approach, using a single 1.5-2 cm sub-umbilical incision is made, which provides entry to the telescope and two working instruments.

Steps of laparoscopic cholecystectomy

1. Abdominal cavity access through umbilicus
2. Application of abdominal wall device and creating space.

3. Port placement and a quick look around the abdomen
4. Initial dissection of the peritoneum.
5. Dissection of the hepato-cystic triangle
6. Dissection of gallbladder off bottom one-third of the cystic plate
7. Confirmation of the Critical View of Safety
8. Ligation and division of cystic duct and cystic artery
9. Dissection of gallbladder off the remainder of the cystic plate
10. Gallbladder extraction and port closure

Pelvic Surgery

Next, the patient is placed in a lithotomy position at the start and a uterine manipulator is inserted. Then, the patient is placed in a steep Trendelenburg (head downwards) position, so it is essential to have shoulder support to prevent the patient from slipping.

If single incisions are used, it is essential to remember that the camera goes at the 12 o'clock position and the other instruments below it so that the instruments do not clash.

A simple uterine manipulator is used for diagnostic laparoscopy procedures. The complex manipulators are necessary for totally laparoscopic hysterectomy, while the simple ones are sufficient for laparoscopic-assisted vaginal hysterectomy. If none of these is available, cervical (Hegar's) dilators can be used. Rubin's cannula is used to inject methylene blue. Leaving some solution in the pelvis to cool the ovaries is better than aspirating the fluid before closing. Vessel sealing instruments are handy for pelvic surgeries, and often the ovaries need to be preserved, so marsupialization is carried out. The posterior fornix can be used to retrieve large, resected lesions.

The ureteroscope can be used for hydrosufflation and cannulation of the Fallopian tubes. The resectoscope could be used for treating uterine lesions like polyps, Asherman's syndrome etc. The GILLS surgeries have the advantage that the larger open suction cannula can be used, and gauze pieces can be inserted without the problem of the collapse of pneumoperitoneum. As mentioned earlier, urology instruments help in many infertility investigations and treatments.

An advantage of GILLS is that urologic instruments, such as a rigid ureteroscope (top) or operative cystoscope (bottom) can be used intra-abdominally.

GILLS is a valuable technique for evaluating and treating infertility in women, as it is possible under spinal anaesthesia. It can be done with a single cosmetic incision and is relatively inexpensive. In addition, urology instruments offer an additional low-cost advantage.

Hysterectomy

Patients are advised to hydrate and eat lightly for 24 hours before the surgical procedure after optimizing their medical conditions. Prophylactic antibiotics are essential as some parts of the equipment, like the optics, are not sterile. The patient is placed in a lithotomy position with the free arm tucked in and shoulder braces to prevent slipping in the steep Trendelenburg position. Both the perineum and abdomen are prepared and draped.

The double-bladed vaginal (Sims) speculum is used to visualize the cervix, which is held with a vulsellum forceps. Then, dilatation of the cervix is carried out to pass the uterine manipulator comfortably. Several types are available. A simple one can be made by lengthening a cervical (Hegar) dilator. The manipulators used for total laparoscopic

hysterectomies differ from those used for laparoscopic-assisted vaginal hysterectomy.

Starting the lifting process with the lifting part at the lowest position is paramount. After making the connections and tightening them, the apparatus is lifted under vision so that there is no omentum or bowel caught in the intra – abdominal portion of the apparatus. Surgeries are usually possible with single incisions, especially while using a vessel sealing device

Staying close to the uterus, the tubo-ovarian ligaments and the round ligaments are divided. Modern tools like vessel sealing systems, harmonic shears or regular mono-polar or bipolar energy sources could be used. Once well coagulated, the tissues appear white and sufficient stretch offered by the uterine manipulator is essential. The uterine manipulator holds the uterus pushed in superior / anterior direction and to the opposite side of the vessels that are being divided. The broad ligaments are then dealt with by coagulating and dividing. Then the bladder is dissected off the uterus by holding it with an atraumatic forceps and holding the uterus down and pushed in with the manipulator. Then the posterior fornix can be entered by cutting over a large Hegar dilator pushed from below in the posterior fornix. Finally, the uterine manipulator holds the uterus anteverted.

Skeletonizing the broad ligament leads to the uterine vessels. They could be tied using multiple trocars or sealed using the vessel sealing systems. Staying close to the uterus avoids injury to the ureters and bladder. The cervicovaginal junction can be identified using the delineator portion of the uterine manipulator or, if such instruments are not available, using Hegar's dilator in the anterior fornix. The division can be carried out using a hook electrode. Suturing the vaginal walls is easy with Lift laparoscopy and using the regular long needle holders. Doing this operation through a single incision requires a little practice.

A circumferential incision is made using the coagulating current with monopolar cautery and 4 retractors are used for good exposure. Ellis's forceps is used to hold the vaginal wall and dissect the bladder off the uterus. The earlier dissection of the bladder from above helps in finding the correct planes for dissection. Once the anterior and posterior fornixes are dissected, the lateral ligaments can be divided using vessel sealing equipment having the finger then a Kelly clamp to isolate the lateral ligaments. These lateral ligaments can be tied together later to offer support, and the vagina is closed below it.

A recent advance is the use of robotic surgery for hysterectomy. The advantage is that it would be advisable in COVID 19 setting with minimal staff in the operating room or doing the surgeries remotely. However, the technology is costly and unsuitable for low-resource settings.

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