

Energy System and Endosuturing in Single Incision Laparoscopy Surgery

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ABSTRACT

Background: SILS is a newer laparoscopic technique emerging in this era. So this article aims to provide an overview on safer surgical skills by understanding basic principles and proper application of energy source and endosuturing techniques.

Materials and methods: Articles of relevant studies are explored from Google, HighWire Press, PubMed, SpringerLink using keywords—single incision laparoscopy surgery (SILS), energy source in SILS, suturing in SILS.

Aim: The main aim is to evaluate the best energy source which can be used in SILS with better ergonomics and to define the good suturing technique in single port laparoscopic surgery.

Results: Most of the studies show that newer energy devices, such as LigaSure, harmonic and EnSeal, are being used with advantage of less smoke, less operative time, very minimal blood loss, less drop in hemoglobin value postoperatively, and reduced duration of hospital stay. Endosuturing using rotulators, Endo-stitch is easier, though intracorporeal and extracorporeal knotting can also be performed same like conventional laparoscopy.

Conclusion: LigaSure, harmonic and EnSeal can be safely used as multifunctional devices in the available space in SILS without changing the instruments frequently as in conventional laparoscopy. Both intracorporeal and extracorporeal knot can be put by practice and with aid of newer suturing devices.

Keywords: Energy system and SILS, Harmonic, LigaSure and SILS, Suturing in SILS.

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INTRODUCTION

Minimally invasive surgery is one of the most significant surgical advances of the 21st century and has become the standard treatment for many gynecological pathologies. In the last decade, numerous studies have demonstrated that laparoscopic approach for various gynecologic benign and malignant diseases is feasible and results in shorter hospital stay, improved quality of life, shorter operating time and decreased perioperative complications when compared to open procedures.

Single incision laparoscopic tubal ligations have been performed for more than 30 years after the innovation of the single-port laparoscopic tubal ligation by gynecologist Dr Clifford Wheelless.¹ Reports of performing more advanced laparoscopic procedures using single-port surgery

came years later, with the first single-port laparoscopic hysterectomy reported in 1991 by Pelosi et al.² Today, the trend in gynecological laparoscopic procedures changes to 'single incision laparoscopic surgery' (SILS). Single incision (or port) laparoscopic surgery (SILS) has emerged in an attempt to further reduce morbidity and enhance the cosmetic benefits of conventional laparoscopic surgery.

The scope of electrosurgery extends beyond tubal ligation; now tools enable us to perform many procedures and manage anatomic difficulties with increased patient safety. Many new instruments and methods have been developed for suturing and knot tying in SILS to overcome these difficulties.

AIM

The main aim is to evaluate the best energy source which can be used in SILS with better ergonomics and to define the good suturing technique in single-port laparoscopic surgery.

MATERIALS AND METHODS

A literature review was performed using SpringerLink, HighWire press, Journal of MAS and major search engines like Google, Yahoo, MSN, PubMed, etc. The search terms were energy system and SILS, harmonic, LigaSure and SILS, suturing in SILS. The articles were selected based on the type of energy system used, special instruments used for energy and suturing and its safety and reliability in SILS.

PRINCIPLES OF ENERGY SYSTEMS

A surgeon must understand the fundamental principles of energy-based surgery and the relative strength and weakness of any device in this context and take the device to a higher level of performance, achieving otherwise impossible tissue effects.³⁻⁵

Bipolar Electrosurgery

A high frequency alternating current applied to living tissue by an active electrode, flow through the tissue by pathways offering the least resistance and return to an opposing electrode. The flow of electrons or electric current (I) is set in motion and sustained by electromotive force termed voltage (V) to complete the circuit across the differences in electrical potential between the two electrodes. Greater voltage produces greater thermal necrosis.

Thermal injury correlates to the maximum tissue temperature, total volume of heated tissue, rate of temperature rise and duration of temperature elevation. If living tissue is heated to above 50°C for a sufficient duration of time, irreversible damage occurs; cellular water evaporates at 90°C (desiccation); cell walls rupture at 100°C (vaporization) and tissue begins to carbonize and char at 250°C. The temporal relationship between tissue temperature and thermal injury is nonlinear owing to the complex effects of conduction and convection on the entire process.

Practically, thermal effects can be moderated by altering the power setting, the type of output current (cut vs blend vs coagulation), the electrode dwell time, the proximity of the tissue to the active electrode and the current density (i.e. electrode surface area). The behavior of electricity in living tissue is generally governed by Ohm's law $V = I \times R$. Derivatively, current is directly proportional to voltage and inversely proportional to resistance (R). To complete a circuit, force or voltage must increase as resistance increases.

Power is keyed into an electrosurgical generator as watt (W), corresponding to the rate of work being performed. The relationship between voltage and resistance. The relationship between voltage and resistance is restated by the derivation of power, $W = I^2/R$ and $W = V^2/R$; at any particular power setting (W) using a conventional electrosurgery generator, higher R as with desiccation, fat or char will drive higher output V to maintain the desired tissue end point.

Ultrasonic Surgery

This type of surgery owes its efficacy to the fact that ultrasound travels easily through water, which makes up roughly 80% of all soft tissue. High intensity focussed ultrasound transfers a significant amount of energy to the targeted tissue, causing a rise in temperature.

Coagulation with ultrasound requires coaptation of blood vessels; H⁺ bonds are broken, and protein in the cells is denatured. Denatured protein forms a sticky coagulum. Internal tissue heat generated from friction then seal or weld vessel walls. Simultaneous cutting and coagulation takes place at a lower temperature than in electrosurgery with minimal lateral thermal spread.

New Energy Devices

Evaluation of newer energy systems should be based on the following characteristics:⁵

- Reliability
- Efficiency
- Ergonomics

- Handedness
- Response to variable tissue content
- Smoke production
- Capacity to dissect
- Tissue sticking
- Tissue color
- Cost
- Degree of innovation

Instrumentation to expand Surgical Options

One of the disadvantages of SPLS has been the restriction of movement that arises because of the close proximity of instruments and instrument handles. The latest designs have made articulation possible for tissue graspers, scissors, vessel sealers and scopes. The value of articulation is apparent inside the abdomen, where it allows perfect positioning of the area of dissection. Outside the abdomen, the handles can be arranged in an angled pattern to allow the surgeon and assistant to operate comfortably. The latest instruments are designed to dissect, cauterize and cut, thereby decreasing the number of instrument exchanges necessary.^{6,7} New bipolar technology seals blood vessels to withstand high systolic pressure.

There are three bipolar platforms that utilizes low constant voltage, pulsed current and impedance feedback along with a paired ligating cutting device.^{4,5} This intricate combination complete the sealing. Consequently, there is minimal plume, carbon formation and tissue sticking:

LigaSure vessel sealing device (Covidien, Boulder, CO) applies a high coaptive pressure during the generation of tissue temperature under 100°C hydrogen cross-links that are first ruptured and then renatured, resulting in a vascular seal that has high tensile strength.

The second instrument, the PlasmaKinetic cutting forceps (Gyrus/ACMI/Olympus), lacks the compressive pressure needed to create a true vessel seal but provides efficient coagulation with visibly pulsed energy that is moderated by impedance feedback.

The third device, the EnSeal laparoscopic vessel fusion system (EES, Cincinnati, OH) utilizes temperature-sensitive polymeric material (PTC) embedded with nanometer-sized spheres of carbon that automatically controls a locally regulated current, regulating temperature at about 100°C. Desiccation with this device is facilitated by advancing an innovative 'I-blade' that provides extremely high pressure along the length of the jaw to both cut and squeeze the tissue bundle, eliminating tissue water and steam. So when we 'follow the bubble', tissue becomes easier to cut which can be achieved by advancing I-blade at a rate of 1 mm/sec. It produces only 1 mm of spread, used for transecting larger vessels. In EnSeal, there are two ways to deliver energy,

single tap and double tap. Single Tap is a 15 seconds cycle which will tell us when the tissue has reached 450 Ohm or complete coagulation has been reached. Double tip is a 2 minutes cycle, which does not confirm this tissue impedance.

- **Harmonic device:** Using the dynamic tissue effects of mechanical energy, ultrasonic blades and shears, tissue effects from ultrasonic energy using the harmonic scalpel (EES, Cincinnati, OH) are actuated by a titanium blade of variable excursion that vibrates nearly 55,500 Hz/sec from an in-line piezoelectric crystals housed in the hand piece of the device. It is not regulated through impedance. The high frequency vibration in tissue causes a low temperature protein denaturation by rupturing the hydrogen bonds of tissue proteins. Tissue cutting from cavitation fragmentation naturally evolves from the mechanical vibration and percussive effects of steam that emanates through the tissue parenchyma. Differing from the volumetric thermal tissue effects during electrosurgery, lateral thermal damage with ultrasonic energy is limited by the linear nature of energy propagation through the tip of the blade.

Properties of laparoscopic vessel sealing devices:⁸

Devices	Mean burst pressure (mm Hg)	Mean seal time (sec)
LigaSure V	386	10
Gyrus PK	290	11.1
Harmonic scalpel	204	14.3
EnSeal PTC	255	19.2

Evaluation conducted on 5 mm bovine arteries

Thunderbeat™ (TB)(Olympus, Japan): It simultaneously delivers ultrasonically generated frictional heat energy and electrically generated bipolar energy. TB has a higher versatility compared with the other instruments like: Harmonic® ACE, LigaSure™ V and EnSeal tested with faster dissection speed, similar bursting pressure and acceptable thermal spread. This new energy device is an appealing, safe alternative for cutting, coagulation and tissue dissection during surgery and should decrease time and increase versatility during surgical procedures.⁹

APPLICATION OF ENERGY SYSTEM IN SIL SURGERIES

Harmonic energy: Harmonic ACE can be used for peritoneal separation, to amputate the cervix, coagulating and cutting across the infundibulopelvic ligament, ovarian ligament/pedicle, colpotomy, excision of endometriosis, to release adhesions and distortion, appendectomy and myomectomy. Near the vital structures, like ureter, bladder or bowel, harmonic will be the option.^{5,10,11} In one case report,¹² the ovarian cyst wall was cut with harmonic scalpel on coagulation mode and the epithelial lining in the residual

cyst was removed by electrocauterizing with a monopolar cautery hook. Ismail H et al¹³ reported that harmonic ACE can be used safely for Nissen fundoplication. Harmonic is also one of the choice for colectomy in colon cancer which was shown by Egi et al¹⁴ study where 20 patients were operated with 10 cases each with SIL and conventional laparoscopic colectomy. They have shown less operative time, less blood loss and conversion rate.

LigaSure: The LigaSure has 5 mm blunt tip laparoscopic sealer, 37 cm long shaft and is capable of sealing and dividing vessels up to 7 mm in diameter. The 44 cm instrument allow to access difficult to reach areas, such as those near the spleen, hilum or gastroesophageal junction. A 20 cm shaft can be used in pediatric age group.¹⁵ Parag WD et al describes in his techniques that LigaSure tissue fusion technique, LigaSure advance and Valleylab are ideal hemostatic tool for minimal access surgery. Ultrasonic devices, like harmonic, AutoSonix (Autosuture) and SonosurgX (Olympus), have been well established. Ogura et al report the development of a new compact articulating ultrasonically activated device (USAD) prototype in 5 and 10 mm size with a bendable tip that offers coagulating dissection performance.¹⁶

Ligasure gives a promising results in SIL hysterectomy with excellent tissue dissection, less operative time, less blood loss and reduced duration of hospital stay.¹⁷⁻²⁰ Young et al²⁰ performed SIL-LAVH on 100 patients wherein he used LigaSure system (Valleylab) for all patients.

Mathew et al conducted animal study (N = 45) and concluded that the acute *ex vivo* study demonstrated a significant difference in the cystic duct bursting pressure between surgical clips and ultrasonic coagulating shears and between electrothermal bipolar vessel sealer and ultrasonic coagulating shears. The ultrasonic coagulating shears and electrothermal bipolar vessel sealer failed to maintain seal integrity in the *in vivo* animal study. Given the failure of the ultrasonic coagulating shears and electrothermal bipolar vessel sealer in the animal model, these energy sources should not be used for transection of the cystic duct or major hepatic ducts during hepatobiliary surgery.²¹ In one of the case report published by Ondrer S, it is mentioned that, for vessel sealing, the shaft of LigaSure is parallel to uterine artery instead of perpendicular to their axis. They had used LigaSure, harmonic scalpel for adnexal dissection, bipolar cautery (for hemostasis at cut surface of cervix). Cervix was transected with lap unipolar scissor. For sacrocolpopexy-bladder was retracted away from vagina and vesicovaginal space by fine dissection using 5 mm harmonic scalpel.²² Exploring the safer techniques of SILS surgery in children Joshi M et al says that SIL splenectomy can be performed utilizing combination of harmonic scalpel and LigaSure.²³



Combination of energy sources can also be used in hysterectomy as mentioned in few searched articles;^{24,25} in their study, IP was sealed and cut with 10 mm LigaSure. The bladder peritoneum was dissected with 5 mm Harmonic ACE uterine artery which was skeletonized and dissected by 10 mm LigaSure™. Anterior and posterior colpotomies were performed with Harmonic ACE®. In another study, colpotomy was performed using monopolar hook or scissor.

EnSeal: EnSeal device comes either as a round tipped 5 mm device or as a curved 3 mm device that looks like a curved surgical clamp. It is effective for large vascular bundles and for separating the leaves of broad ligament or opening the bladder flap. It can be used for adnexal dissection.^{5,26} EnSeal can also be used for splenectomy, studies have stated that blood loss was <10 ml.²⁷

PKS (Gyrus): It was applied in 30 cases—10 mono/bilateral adnexectomies and 20 cystectomies. They used PKS as it was multifunctional with comparable results to LigaSure/Harmonic.²⁸ Mean blood loss was 10 ml, overall operative time was 39.5 minutes. Hospital stay was for 1.3 days and no postoperative complication was done.

Bipolar forceps/scissors: Maxime M et al did salpingectomy in 37 patients using bipolar forceps/scissor. Operative time was longer (50 minutes) but duration of hospital stay was shorter (1.5 days).²⁹

SUTURING IN SILS

Among searched articles, only few mentioned about the correct endosuturing methods in SILS. Suturing through a single port can be a challenge. When endoscopic suturing is required, standard suturing using both intracorporeal and extracorporeal methods is possible. Suturing aids, such as the Endo Stitch (Covidien) or LapraTy (Ethicon), Roticulator, are helpful. One author recommends Quill bidirectional, self-retaining suture with barbs (Angiotech) to avoid the need for knot-tying. The MiniLap (Stryker) is a 2.3 mm grasper that is inserted percutaneously directly through the abdominal wall without an incision. It can be used to set the needle on the needle driver or manipulate tissue while suturing. The resulting skin incision is barely visible and does not require closure.⁶

Toshiaki E have devised a remarkably simple knot-tying technique that can be applied during SILS with a SILS port with a Roticulator and a straight-type needle driver. We determined that, after transfixing the needle, the long tail of the thread should be grasped at around 90° relative to the long axis of tip of the Roticulator, which is articulated at 80°. This automatically forms an ideal C-loop because of gravitation. The needle attached to the long tail should face

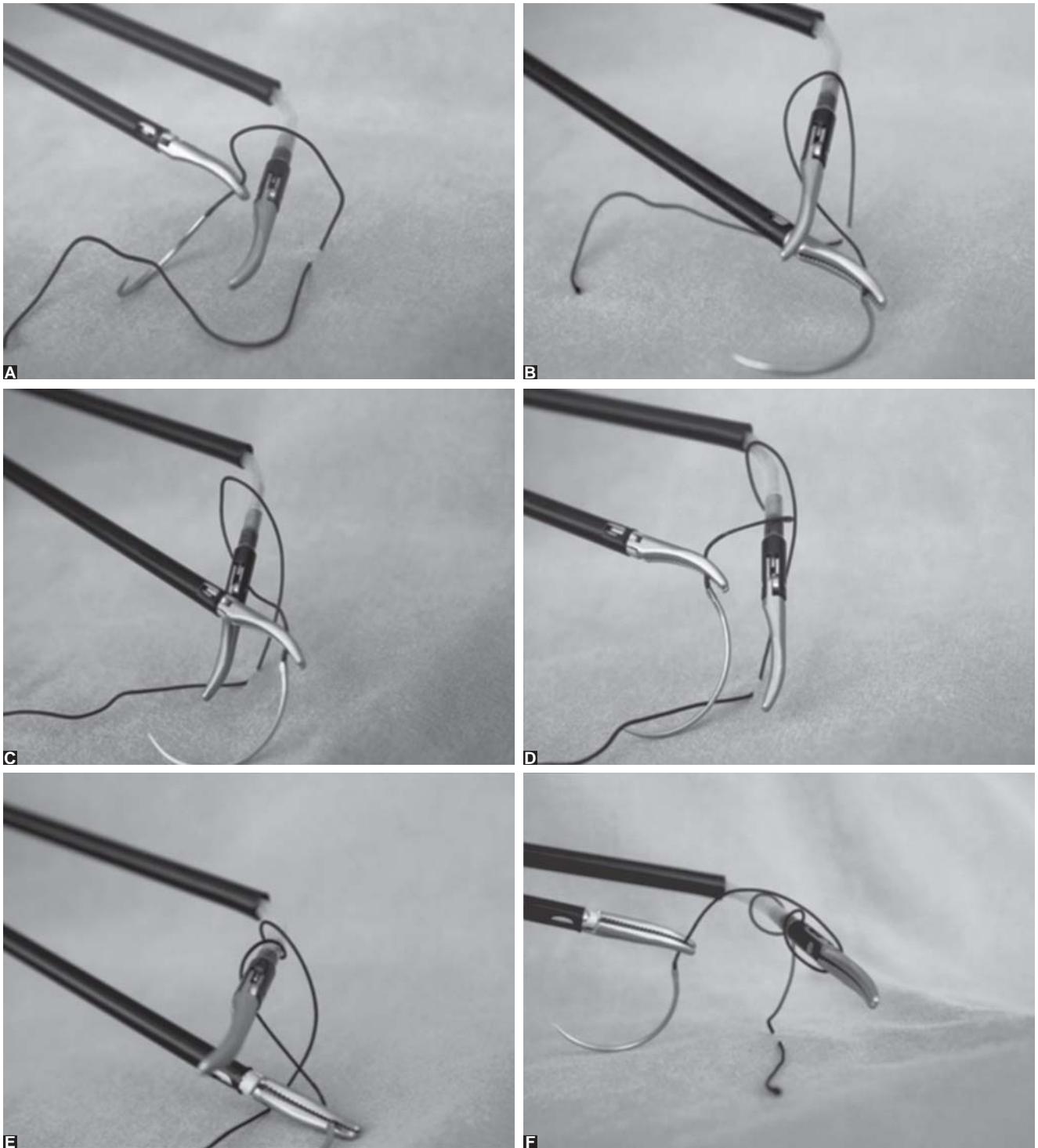
the distal side from the tip of Roticulator (from the surgeon's perspective). The apex of the C-loop is then toward the proximal side from the tip of the Roticulator (from the perspective of the surgeon). This thread position is important during the knot-tying process. The upper arm of the C-loop should then be entwined by applying a series of axial spinning movements to the rod of the needle driver. At this time, the jaws of the needle driver should be kept open so the thread does not slip off of the rod. The benefit of this technique is that it does not require any special skills; any surgeon able to perform intracorporeal suturing should also be able to easily tie knots during SILS.³⁰

Another method noted in literature for suturing in SILS:³¹ In the first step, the Roticulator Endo Grasp is opened in the knotting area, and the suture is wound around twice (Figs 1A to F). The suture is grasped with the Roticulator instrument at a point a few centimeters distal to the exit of the suture from the tissue (Fig. 2). The reef knot is converted into a slip knot by applying distracting forces on the suture material at the two opposite points (Fig. 3). After the first knot has been tightened, the instrument is removed, and the procedure is repeated until the desired number of knots has been made. Finally, after the knot has been tightened, the suture is cut (Figs 1A to F, 2 and 3).

The majority of these methods required special, often disposable, devices that were expensive (i.e. Endo Stitch).¹² The 'side winding' technique makes laparoscopic suturing feasible, especially when the angle between the hand instruments is not ideal and the working space is limited. With this simple technique, the disadvantages of the single incision are overcome with the aid of flexible instruments. It is also helpful when the length of the suture is short. With this technique, laparoscopic suturing may be performed by using routine instruments, thus providing cost-effectiveness, feasibility and minimal instrument transfer. Moreover, with this technique, the instruments are pulled away from the tissue during knotting, so it is safer than the conventional approach. It reduces the possibility of inadvertently catching the organs in the suture.

In gynecology, hysterectomy is the most common surgery done. So in modern day, we should be thorough with SILS hysterectomy whether it is supracervical or LAVH or total. In hysterectomy, endosuturing of vaginal cuff can be closed with either intracorporeal or extracorporeal separate sutures. Extracorporeal sutures were performed by using a Clarke-Reich knot pusher, same as in conventional laparoscopic cuff closure^{24,22} (Figs 4A and B).

Bidirectional barbed sutures reduce the difficulty of technique intracorporeally knotting compared with



Figs 1A to F: The Roticulator Endo Grasp is opened on the knotting area, and the suture is wrapped around twice

traditional sutures, the benefits of the bidirectional self-retaining sutures with tissue retainers (barbs) include speed and economy of suture placement.²⁶

The flexible endostapler (Endo GIA Roticulator™, Autosuture; Covidien Norwalk, CT, USA) and the Endostitch™ suture system (Autosuture; Covidien, Norwalk, CT, USA) introduced through a Quadport™ or Triport (advanced surgical concepts) to fashion the enterocolonic anastomosis with extracorporeal knot tying after the initial

holding stitch. Use of a 10 mm endoscopic suturing device (SILS™ Stitch, Covidien, Norwalk, CT, USA) has been described for MISS Nissen's fundoplication.¹⁶

The feasibility of linear salpingotomy with suturing for ampullary tubal pregnancy via single incision laparoscopic surgery (SILS) was studied in three patients with ampullary tubal pregnancy. The linearly incised fallopian tube was intracorporeally sutured using an articulating suturing device dedicated to SILS. The mean surgical duration was



Fig. 2: The suture is grasped with the Roticulator instrument at a point that is a few centimeters distal to the exit of the suture from the tissue

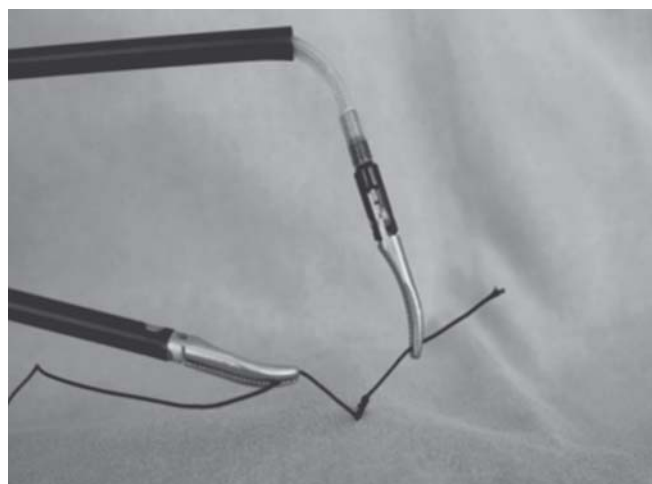
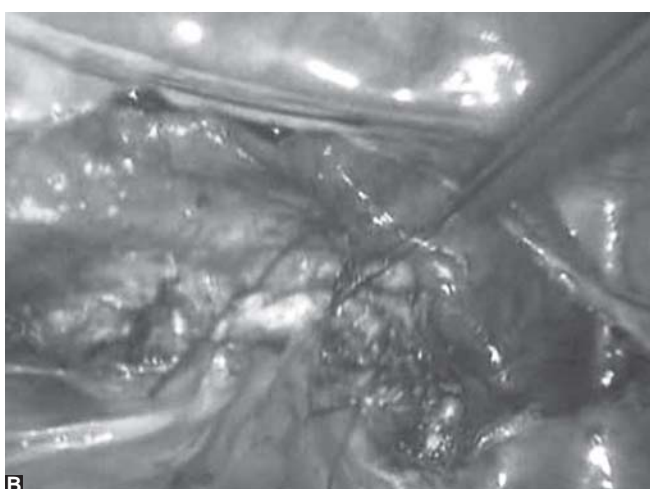
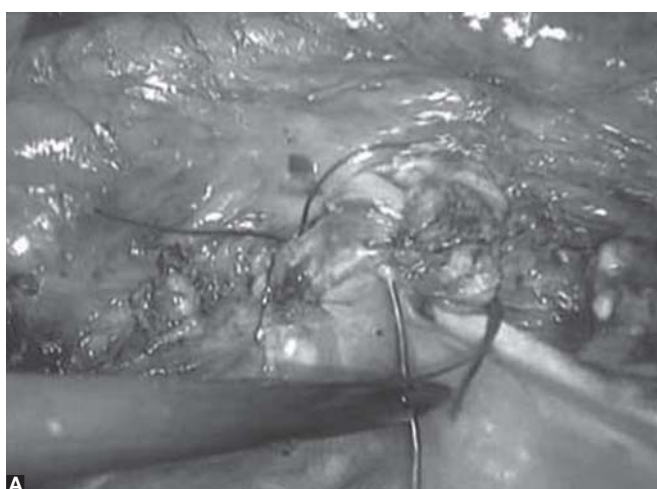


Fig. 3: The reef knot is converted into a slip knot by applying distracting forces on the suture material at the two opposite points



Figs 4A and B: (A) Flattened needle was used during vaginal cuff suturing using Vicryl 0, (B) extracorporeal sutures were performed by using a Clarke-Reich knot pusher

54 minutes. Tubal preservation by linear salpingotomy was accomplished for all patients without up-conversion to conventional laparoscopy.³²

CONCLUSION

The days of clamp-cut-tie or desiccate-cut are gone. Gaining control over the energy and moderating tissue effects is the key. Assess new energy based device not just for thermal characteristics, but for use-ability to lift, grasp and dissect tissue and its performance in heterogenous desiccated, fatty or vascular tissue. Evaluate its ergonomics and its cost and, most importantly, whether it is safer than other devices. LigaSure, Harmonic and EnSeal can be safely used as multifunctional devices in the available space in SILS without changing the instruments frequently as in conventional laparoscopy.

SILS is a new and promising technique, but suturing is more difficult in this procedure due to the port position and

the angle of the hand instruments. It is particularly challenging to form a loop around the hand instrument when there is limited working space. Both intracorporeal and extracorporeal knot can be put by practice and with aid of newer suturing devices.

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