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Electro-Surgery Practices and Complications in Laparoscopy

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1. Introduction

Operative laparoscopy is widely accepted as an efficacious technique in the treatment of gynecologic lesions. The patients, as well as the surgeons, may enthusiastically accept these new minimally invasive techniques in treating gynecologic as well as surgical diseases [1]. Since the introduction of the small medical video camera in the mid-1980s, the advent of laparoscopic surgery has brought a revolution in surgical techniques with shorter hospitalization and convalescence [2],[3]. However, surgeons who are well trained in open techniques do not automatically have that same status in laparoscopic cases. Therefore, surgeons who are skilled in open techniques may still require further training to become adapted with laparoscopic techniques. The required spatial orientation, hand-eye coordination and manipulative skills under laparoscopy are quite different [4]. All surgeons are aware of their own “learning curves”, during which time complication rates may be appreciable [4],[5]. Although the complication rate may decrease when more experience is gained with the laparoscopic procedure, the increasingly advanced and difficult procedures performed by the gynecologists via laparoscopic further potentiates the higher risk of complications [6].

The rapidity of the uptake of these procedures into routine use and numerous adverse outcomes have raised justifiable concern [7],[8]. According to Magrina *et al.* review among 1,549,360 patients, the overall laparoscopic complication rate ranges 0.2-10.3% [6]. An early learning curve with limited cases may account for the high complication rate up to 10.3% (47 of 452 patients) [9, 10]. In a Finnish national-wide study [11], the major complication rate in overall gynecologic laparoscopies was 0.4% (130/ 32,205) among total procedures, and 1.26% (118/ 9,337) in operative laparoscopies. In an American Association Gynecologic Laparoscopy (AAGL) membership survey for laparoscopic-assisted vaginal hysterectomy (LAVH) was 6.59% (983/ 14,911) [12]. In Taiwan, Lee *et al.* reported the major complication rate 1.66% (12/ 722) in LAVHs group [13]; Wu *et al.* reported 1.59% (24/ 1,507) [14] and 0.72% (31/4307) in the follow-up study [15]. Since laparoscopic surgery is highly experience-dependent, follow-up studies in different study periods deserve continuous attentions.

Urinary bladder and bowel injuries comprise the main part of the complications. **Bladder injuries** are relatively common in the gynecologic field, especially in LAVHs. The

complication rate was 2.4% (22/9,337) in Finnish study [11], and 1.08% (161/14,911) in AAGL study [12]. In Taiwan, Lee *et al.* reported 0.8% (6/722) [13]; it was 0.40% (6/1,507) [14] and 0.30% (13/ 4107) in Wu *et al.* follow-up study [15]. **Bowel injuries**, although not common, is one of the most serious complications when not detected and managed promptly. van der Voort *et al.* reported, based on 29 studies, the incidence of laparoscopy-induced gastrointestinal injury was 0.13 % (430/ 329,935) and of bowel perforation 0.22 % (66/ 29,532). The incidence may be under-reported due to retrospective and complication that occurred after leaving hospital being overlooked [16]. The small intestine was most frequently injured 55.8 % (227/ 407), followed by the large intestine 38.6% (157/ 407), and the stomach 3.9 % (16/ 407) [17]. The reported bowel injury rates ranged from 0.16% (15/ 9,337) [11] to 0.62% (93/ 14,911); [12] 0.28% (2/ 722) in Lee *et al.* LAVHs stud; [13] 0.33% (5/ 1,507) in Wu *et al.* study. [14], and 0.16% (7/ 4,107) in the follow-up study [15]. Nevertheless, laparoscopy-induced bowel injury is associated with a high mortality rate of 3.6% [17].

2. Electrosurgery use in laparoscopic surgery

The behavior of electricity in living tissue is generally governed by Ohm's law:

$$\text{Voltage (V)} = \text{current (I)} \times \text{resistance (R)}$$

Electrical current flows through a continuous circuit. Voltage is the necessary electromotive force that mediates or drives this electron movement through the circuit. Heat is produced when electrons encounter resistance [18]. The electricity has the following characteristics, which how it works and how it associates complications: i.e. (i) electricity takes the path of least resistance, (ii) seeks ground, and (iii) must have a complete circuit to do work [18]. Understanding the electrosurgical principles is essential for using appropriate currents and techniques to achieve the desired tissue effect and to avoid complication [19].

Electrosurgical units (ESUs) are the most common piece of electrical equipment in the operating room. The constant presence of the ESU in the operating room assists surgeon to achieve desired tissue effect, but also increases the potential for electrosurgical injury [20]. With electrosurgery, we can achieve tissue effects such as cutting (also called vaporization), fulguration (also called superficial coagulation, or spray coagulation), and desiccation (also called deep coagulation) [20],[21],[22]. Primary factors that determine tissue effects of electrosurgery include energy modality (monopolar or bipolar), generator power output (watts), the alternating current waveform, the current density, and surgical techniques.

1. **Energy modality**, i.e., monopolar and bipolar. In monopolar electrosurgery, the current flows starts with the active electrode, through the patient and the return electrode for the completion of the circuit [21]. With monopolar current, the instrument tip is one pole, whereas the second pole is the grounding pad. In bipolar electrosurgery, both active and return electrodes are located at the surgical field, typically within the instrument tip [21]. The electrodes are only millimeters apart, therefore relatively low power of bipolar systems are needed to desiccate the tissue [23]. The power output of bipolar instruments is one-third to one-tenth that of monopolar systems.
2. **Generator power output** is most often indicated via a digital readout on the face of the generator. Others may have a logarithmic scale from 1 (lowest) to 10 (highest), making exact settings and adjustments more difficult [20],[18],[23]. Surgeons should understand what kind of generator they use and in what scale the power is presented.

3. **Alternating current waveforms** include cut waveform (continuous, non-modulated, undamped), blended waveform (different percentage duty cycle), and coagulation waveform (interrupted, modulated, damped), which are used for different surgical aims [20],[18],[23]. However, these labels are misleading because they do not necessarily produce the tissue effects that are associated with the terms “cut” and “coagulation” [23]. In fact, “cut” waveform can coagulate, and “coagulation” waveform can cut. Moreover, “cut” waveform is often the most appropriate current to use for tissue coagulation [23]. A cut waveform incorporates higher current but lower voltage than coagulation waveforms at the same power setting. As contrast, coagulation waveform has higher voltage and lower current than a cut waveform of the same power setting [18]. Therefore, with the same wattage, coagulation waveform has a much higher voltage than cut current. Higher voltages are more likely to produce unwanted effects and injuries than lower voltages. In more simple terms, for the same power levels, cut waveform produce less charring and tissue damage [23].
4. **Current density** depends on the area of surface contact, and the shape or size of the electrode [20],[18],[23]. Current density can affect the tissue effect as well as the heat production. The greater the current that passes through an area, the greater the effect will be on the tissue. Also, the greater the amount of heat that is produced by the current, the greater the thermal damage on tissue [18]. Heat generated at the tissue is inversely proportional to the surface area of the electrode. Smaller electrodes provide a higher current density and result in a concentrated heating effect at the site of tissue contact [18]. When the contact area is decreased by a factor of 10 (e.g. 2.5 cm² to 0.25 cm²), the current density increases by a factor of 100 (e.g. 0.01 amp/cm² to 1 amp/cm²), and the resulting final temperature increases from 37oC to 77oC. Thus, a small contact area produces high enough temperatures to cut [24],[22].
5. **Surgical techniques** include hand-eye coordination, speed of procedure, proximity between the electrode and the tissue, and dwell time [20],[18],[23]. During the learning curve, hand-eye coordination difficulties may be encountered involve working in a two-dimension environment with their hands generally disassociated from their eyes, esp. in radically new operative skills [25]. The speed of procedure will result in either less or more coagulation and thermal spread [18]. Proximity between the electrode and the tissue can determine contact (e.g. desiccation effect) or non-contact tissue effect, e.g. fulguration effect [23]. The dwell time determines the amount of tissue effect. Too long activation will produce wider and deeper tissue damage more than the anticipated desired tissue effect [18].

3. Mechanisms of injury

The majority of laparoscopic complications happen subsequent to the followings: the entry to the peritoneal cavity, the delivery of energy to the surgical site (e.g. electrosurgery) and specific high-risk procedures [26]. A trocar or Veress needle caused the most bowel injuries 41.8% (114/ 273), followed by a coagulator or laser 25.6% (70/ 273). In 68.9 % of instances of bowel injury, adhesions or a previous laparotomy were noted [17]. Injuries during laparoscopic electrosurgical procedures can be attributed to misidentification of anatomic structures, mechanical trauma, and electro-thermal complications [12]. Misidentification and mechanical trauma can occur laparoscopically, just like that in laparotomy [27]. Moreover, surgical skills become more difficult when the surgeon's spatial orientation and hand-eye coordination have not been well established.

Electro-thermal injury may result from the following situations: direct application, insulation failure, direct coupling, capacitive coupling, etc.

1. **Direct application.** Electrosurgical injury may happen via direct application similar to open laparotomy. It may be due to unintended activation of the electrosurgical probe, e.g. moving from the intended operating area to an iliac artery or vein on the pelvic sidewall, or operating on a moving ovarian cyst [28].
2. **Insulation failure-induced stray current** occurs when damage occurs to the covering of the active electrode, allowing the current to contact non-target tissue, which is often out of view of the surgical team members. Pre-operative careful inspection of the equipment before and after use is the best means of identifying defective insulation [20]. 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 [21]. Breaks in the insulation create alternate pathways for current to flow. With a high enough concentration of current, injury to adjacent organs is possible. This occurs primarily when a coagulation waveform is used due to its high voltage output [21]. A common equipment defect is a break in insulation. The risk of a break may be increased when using a 5-mm insulated instrument through a 10-mm sleeve, or by repeated use of disposable equipment [20]. Extensive burns and operating room fires can occur from these current leaks with temperatures measured to be as high as 700 °C [29].
3. **Coupling. Direct coupling** occurs when the electrosurgical unit is accidentally activated while the active electrode is in close proximity to another metal instrument e.g. laparoscope, metal grasper forceps, within the abdomen [21]. Current from the active electrode flows through the secondary instrument through the pathway of least resistance, and potentially damages adjacent structures or organs in direct contact with the secondary instrument. Direct coupling 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 [20]. Ito *et al.* reported a small bowel perforation after a thermal burn caused by contact with the end of the laparoscope during gynecologic laparoscopy [30]. The preventive maneuver is to activate the electrode only when it is fully visible and in contact with the target tissue [30]. However, one must keep in mind that the depth of penetration of thermal energy goes beyond that seen by the naked eye; therefore, unrecognized injuries can present later after progression of the damaged tissue [20].

Capacitive coupling occurs when two conductive elements or instruments are separated by an insulator and form stored energy. An electrostatic field is created between the two conductors such that current through one conductor is transmitted to the second conductor once the net charge exceeds the insulator's capacity [21]. The electric current is transferred from one conductor (the active electrode), through intact insulation, into adjacent conductive materials (e.g. bowel, etc) without direct contact. For example, in a hybrid trocar sleeve, i.e. a nonconductive (plastic) locking anchor is placed over a conductive (metal) sleeve, the plastic anchor will stop the transmission into the abdominal wall over a large surface. This results in capacitive coupling. It happens to adjacent bowel, and results in bowel burns. Although the most common example of a capacitor being created is the placement of an active electrode, surrounded by its insulation, down a metal trocar, this can also occur with plastic trocars [27],[29]. Capacitor coupling may be minimized by activating the active electrode only when it is in contact with target tissues, limiting the amount of time that the coagulation setting (with its high-voltage peaks) is used, and by using metal cannulas that allow stray current to be dispersed through the patient's abdominal wall, not internal tissues [18],[23].

4. **Return electrode burns.** The primary purpose of the grounding (dispersive) pad is to provide the path of least resistance from the patient back to the generator and to ensure an area of low current density [31],[32]. To complete current circuit, the return electrode must be of low resistance with a large enough surface area to disperse the electrical current without generating heat. If the patient's return electrode not completely in contact with the patient's skin, or is not able to disperse the current safely, then the current exiting the body can have a high enough density to produce an unintended burn [21]. The quality of contact between the return electrode and the patient's skin can be compromised by excessive hair, adipose, bony prominences, presence of fluid, or scar tissue. It is important to have good contact between the patient and a dispersive pad [20]. No other object, including hair, clothes, gauzes, and so on, should be between the patient and the grounding pad
5. **Alternative site burn** can happen if the dispersive (ground) pad is not well attached to the patient's skin [20]. When the dispersive pad is compromised in the quantity or quality of the pad/patient interface, electrical circuit can be completed by some small grounded contact points, thus producing high current densities and causing a burn. Examples of such contact points include electrocardiogram (EKG) leads, towel clip, intravenous stand or stirrup, and neurosurgical head frames [31],[32]. The stray current could be intensified if the return electrode was distant from the operating site or if the grounded sites occurred in the path between the active and return electrode. In the case of ground-referenced electrosurgical units, even if the return electrode was disconnected, electrosurgery would continue with current finding alternative pathways to return to the ground. Electrocution of the patient under these circumstances was possible [21].

4. Preventive and adjuvant protective maneuvers

4.1 Pre-operative phase

1. **Knowledge of electrosurgical biophysics.** A thorough understanding of the biophysical principles of radio-frequency electrical energy is of supreme importance [20],[18],[23]. For example, when the generator output cannot accomplish tissue effects as expected, it should be suspected first that there is a defect in the ground plate or its connection, or that an alternative pathway for the current has been instituted [32].
2. **Bowel preparation** is important if it is anticipated that the large bowel is at risk [28]. It facilitates operative maneuvers by increasing intra-peritoneal free space and reducing inadvertent bowel trauma [33]. Additionally, bowel preparation reduces the severity of complications which may occur after bowel perforation. Also, the use of naso-gastric tube is recommended, esp. after several trials of endotracheal intubation, to diminish the possibility of a trocar entry into the stomach [15].
3. **To choose proper current waveform mode.** In monopolar electrosurgery, both "cut" or "coagulation" waveform can be used for either cutting effect or fulguration effect. A cutting current power setting must be between 50 and 80W to be effective. Typically, the coagulation current is effective with the power setting in the range of 30–50W. Although it is possible to cut tissue using coagulation currents at high power, the end result is greater charring and tissue damage [18]. Use bipolar instruments whenever possible [33].
4. **To improve dexterity and hand-eye coordination** through sequential phases of training, i.e. didactic phase, laboratory experience, observation and/or assistance, and

preceptorship [25]. The chances of direct trauma are greater during laparoscopic surgery because the surgeon is limited to visualize in only two-dimensions, with surgeon's hands generally dissociated from their eyes, esp. when operating on mobile organs [28],[34].

5. **Team resource management (TRM).** It is important to organize a laparoscopic team, including biomedical engineer, perioperative nurses and other operation room personnel, and promote extended education activities and participation in medical conferences. When adapting the wisdom of crew resource management (CRM) from aviation to medicine, there still some challenges. Surgical team also needs to improve team communication and coordination [35].

4.2 Intra-operative phase

1. **Safe pneumo-peritonization and entry.** The site of primary entry is usually the umbilicus, but there is a high risk of subumbilical adhesions that may contain bowel in patients with a history of previous laparotomy [26]. There is therefore a risk of injury to the bowel regardless of the entry method, and in these cases, consideration should be given to the use of an alternative site such as left upper quadrant, i.e. Palmer's point [36]. Te Palmer's entry is safe with a lower failure rate in the patients with risks of underlying adhesions and more appropriate in the presence of a large pelvic mass or a nearby hernia [36]. Contraindications to the use of this site, such as hypersplenism or a distended stomach, should be excluded before entry [26].

The blind insertion of a Veress needle or first trocar to create the pneumoperitoneum has been shown to cause vascular and visceral injuries. No single insertion technique is universally safe and divorced from complications in establishing pneumoperitoneum. The use of the open laparoscopy method introduced by Hasson may reduce the likelihood of bowel injury in patients who are likely to have anterior wall adhesions [37]. Other techniques include a well-executed open technique with employment of digital pressure to and local adhesiolysis [38], and/or adjuvant instruments, e.g. optic access trocar [39],[40] can be offered as suggestion for reducing injuries. In addition, the radially expandable sleeve with a tapered blunt dilator and cannula has been proposed to a potential safer laparoscopic trocar access [41]. The radially expanding access system (STEP) trocar entry had less trocar site bleeding when compared with standard trocar entry [42]. The trocar-cannula systems with safety apparatus do not necessarily guarantee the safety during entrance of the abdominal wall, because the relatively thick plastic shields need extra effort push the shield through the transversalis fascia and peritoneum [31],[43].

2. **To identify individual anatomic variation.** Left and right pelvic anatomic locations are not necessarily mirror images, laparoscopically. The course of the inferior epigastric vessels can be more difficult to identify in overweight patients. The proximity of the ureter to the uterosacral and infundibulopelvic ligaments reaffirms the need to identify them before dissection [44].
3. **The adequate electrosurgical techniques,** e.g. do not activate electrode in the air, converting to laparotomy when indicted. Activating the electrode in the air, when not in use, will create an 'open circuit', which can result in a capacitive current effect, too. Capacitive coupling is increased by open circuits, use of 5-mm cannulas (versus 10 mm), and higher generator voltages [45]. This situation can be avoided by using multiple, short activation time that allows normal tissue to remain cool [27].

Meanwhile, do not activate the instrument in close proximity or direct contact with another instrument [21]. Activate the electrode only when whole tissue is in the field of vision, to minimize the chances of direct trauma. After the use of electrosurgery, keep it in view until it has cooled or removed from the body [33]. Meanwhile, surgeons should learn to operate via traditional laparotomy before progressing to laparoscopy. In order to minimize complications, trainees need to become proficient at converting to laparotomy when the procedure cannot be completed laparoscopically [25],[28].

4. **The adequate use of current waveform and advanced bipolar facility.** By lowering the concentration of the current used, coagulating with a cutting current, and using an active electrode monitoring system, the risk of accidental burns caused by insulation failure can be reduced [21]. Advanced bipolar facility include: Ligasure (Valley Lab Covidien, Boulder, CO, U.S.A), Gyrusw Olympus Gyrus ACMI (Maple Grove, MN, U.S.A), EnSeal (Ethicon Endo-Surgery, Cincinnati, OH, U.S.A). Ligasure combined the technology of pressure and bipolar energy; Gyrus used pulsed bipolar energy; EnSeal combined high levels of pressure and temperature sensitive electrodes [46].
5. **To use electrosurgical accessory safety equipment** when possible. A **return electrode monitoring system (REM)** is a dual-padded patient return electrode system designed to monitor irregular separation of the ground pad. It can actively monitor tissue impedance (resistance) at the contact between the patient's body and the patient return electrode, and interrupts the power if the quality and/or quantity are compromised. REM can monitor and assist to avoid return electrode burn. This system inactivates the generator if a condition develops at the patient return electrode site that could result in a burn [20]. **Active electrode monitoring (AEM)** e.g. Encision, Inc, (Boulder, CO, U.S.A), was developed to minimize the risks of insulation failure and capacitive coupling, active electrode monitoring systems now exist [21]. When interfaced with electrosurgical units, these systems continuously monitor and shield against the occurrence of stray electrosurgical currents. Critical to the success of these systems are the integrated laparoscopic instruments which have a secondary conductor within the shaft that provides coaxial shielding [21]. If any stray energy is sensed, the radiofrequency generator shuts down before a burn can occur [46]. The use of an active electrode monitoring system and limiting the amount of time that a high voltage setting is used can also eliminate concerns about capacitive coupling [20].

Tissue response technology (TRT) uses a computer-controlled tissue feedback system that automatically senses resistance of the tissue and adjusts the output voltage to maintain a consistent effect across different tissue density, to achieve a consistent tissue effect. Newer generator constantly monitor impedance to maintain the preset wattage over a broad range of impedance, avoiding unnecessary higher wattage with potential hazards [28]. Improved performance can now be achieved at lower electrosurgical settings [47]. **Vessel sealing technology**, which combines with bipolar electrosurgery with tissue response generators and optimal mechanical pressure, can seal and fuse vessel walls up to 7 mm in diameter [21]. This technology delivers high current and low voltage to the targeted tissue and denatures the vessel wall protein; the mechanical pressure allows the denatured protein to form a coagulum [48]. Thermal spread appears to be reduced when compared to traditional bipolar electrosurgical systems. Valleylab, Gyrus ACMI, and SurgRx, Inc. are three companies which have developed devices for both open and laparoscopic applications

[48],[49],[50]. **Smoke evacuation scavenger system** can improve the operation field from smoggy atmosphere. It also protects patients, as well as surgical staffs, from the exposure of smoke and the byproducts during laparoscopic procedures [51].

6. **To use adjuvant protective procedure.** Some adjuvant protective procedures were suggested during laparoscopic surgeries. In addition to these preventive maneuvers, Wu *et al.* inserted a bladder retractor via urethral meatus into the bladder cavity to identify the utero-vesical space, especially in cases with dense fibrotic adhesion (Fig. 1). The bladder retractor with oval-shaped tip can mobilize the bladder and counter-act with the uterine mobilizer to expose vesico-uterine space at an adequate distance, which was not achieved easily with standard laparoscopic techniques [52]. Lin and Chou conducted a modified procedure of Laparoscopic assisted vaginal hysterectomy (LAVH) by preligating the uterine arteries, in which a pair of polydioxanone (PDS) clips were placed at the uterine artery located between the ureter and the bifurcation of the hypogastric artery before the uterine vessels were desiccated [53]. Chang *et al.* use the retrograde umbilical ligament tracking method for uterine artery ligation to prevent excessive bleeding from uterine vessels and ureteral thermal injury, especially in huge uterine size [54]. The adjuvant protective procedures may account, at least in part, for the lower ureteral injury rate [15]. A high index of suspicion and prior visualization and/or retroperitoneal dissection of the ureter, will be helpful in decreasing ureteral injury [55].

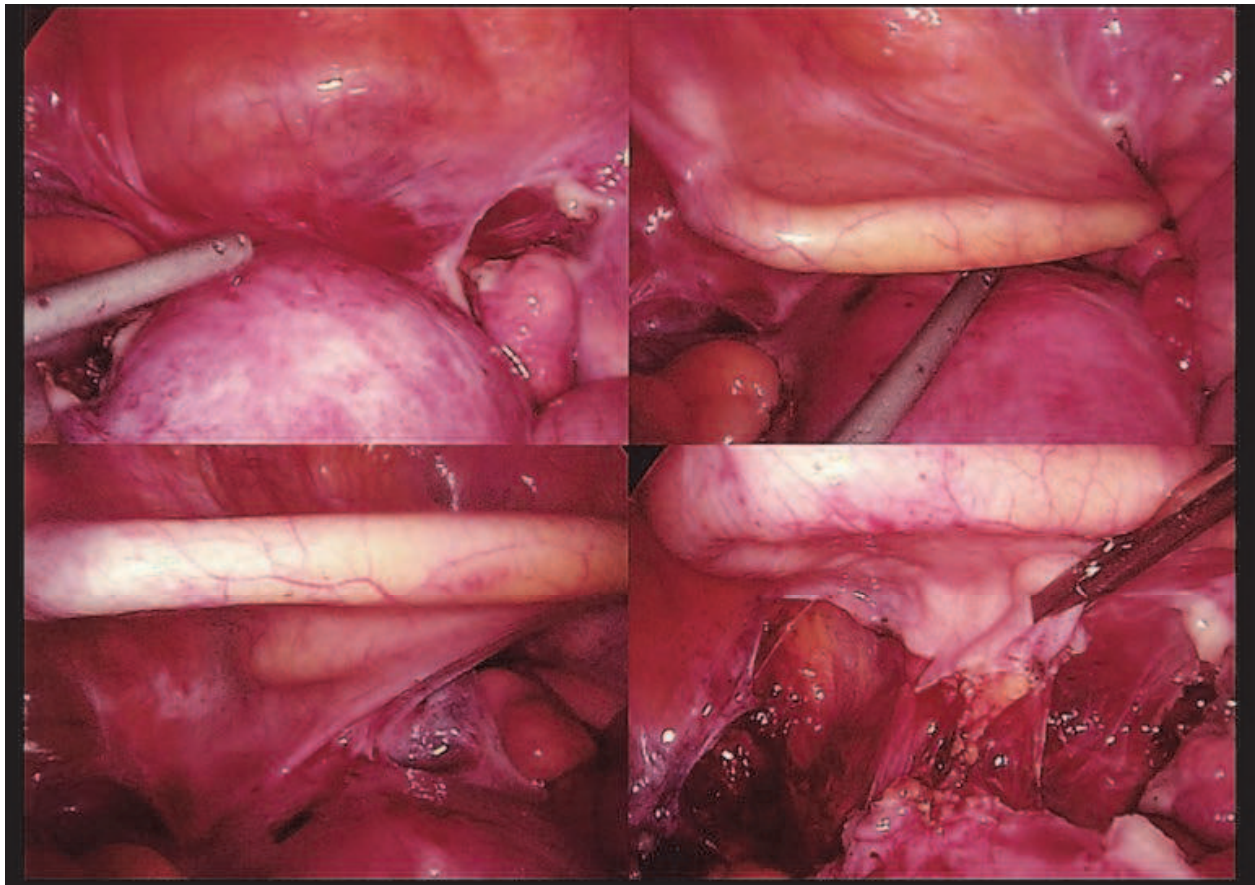


Fig. 1. A bladder retractor via urethral meatus into the bladder cavity to identify the utero-vesical space in cases with dense fibrotic adhesion.

5. Recognition of complication and salvage procedures

5.1 Intra-operative phase

1. **Entry (Veress- or trocar-) related.** The treatment of bowel injuries depends upon the extent of damage. If the Veress needle has been inserted into a hollow viscus without tearing, no further therapy is indicated, since its small diameter leaves no defect; and the muscular wall will close over this puncture spontaneously [33]. However, when the insertion of the trocar into a small intestine, leaves a large defect, e.g. one-half the diameter of the lumen, a segment resection and anastomosis should be performed through laparotomy. If the perforation has occurred, it may be beneficial to leave the trocar in situ to serve to identify the site of laceration [56].
2. **Urinary tract injury. Bladder injury** can be detected by direct visualization of either bladder mucosa or Foley balloon (Fig. 2). If a bladder injury at laparoscopy is suspected but not immediately identified, diluted methylene blue should be instilled into the bladder via a Foley catheter. The bladder will be seen to fill and the dye will leak out through any lacerations [26]. To observe the gas leakage into the urine bag intra-operatively is another detection methods [15]. When bladder injury was recognized intra-operatively, it can be repaired vaginally, laparoscopically or by laparotomy without incident (Fig. 3). Early recognition with immediate salvage procedure could overcome further sequelae [57]. The extended use of an indwelling catheter should be considered.

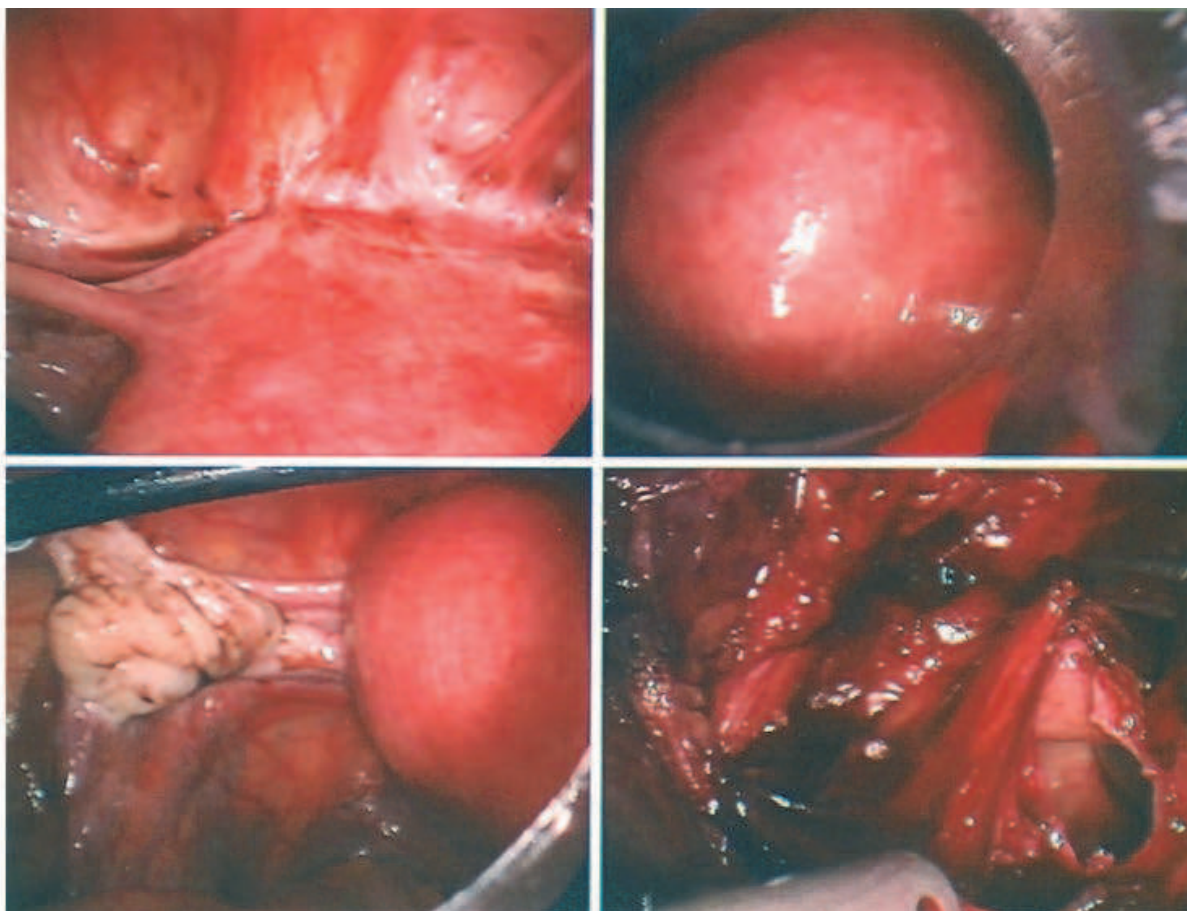


Fig. 2. Bladder injury detected by direct visualization of bladder mucosa and Foley balloon.

Ureteral injuries in gynecologic laparoscopy usually are not recognized intraoperatively, only those patients with persistent abdominal and/or flank pain, abdominal distention, and fever may raise the cautions during post-operative phase [55]. Those intra-operative recognized ureteral injuries can be solved by direct laparoscopic end-to-end reanastomosis (Fig. 4). It can be also resolved by double-J ureteral stent with or without the assistance of ureteroscopy (Fig. 5). If the initial salvage procedure fails, percutaneous nephrostomy and antegrade ureteral double-J stent is a backup procedure to avoid the subsequent ureteral fistula.

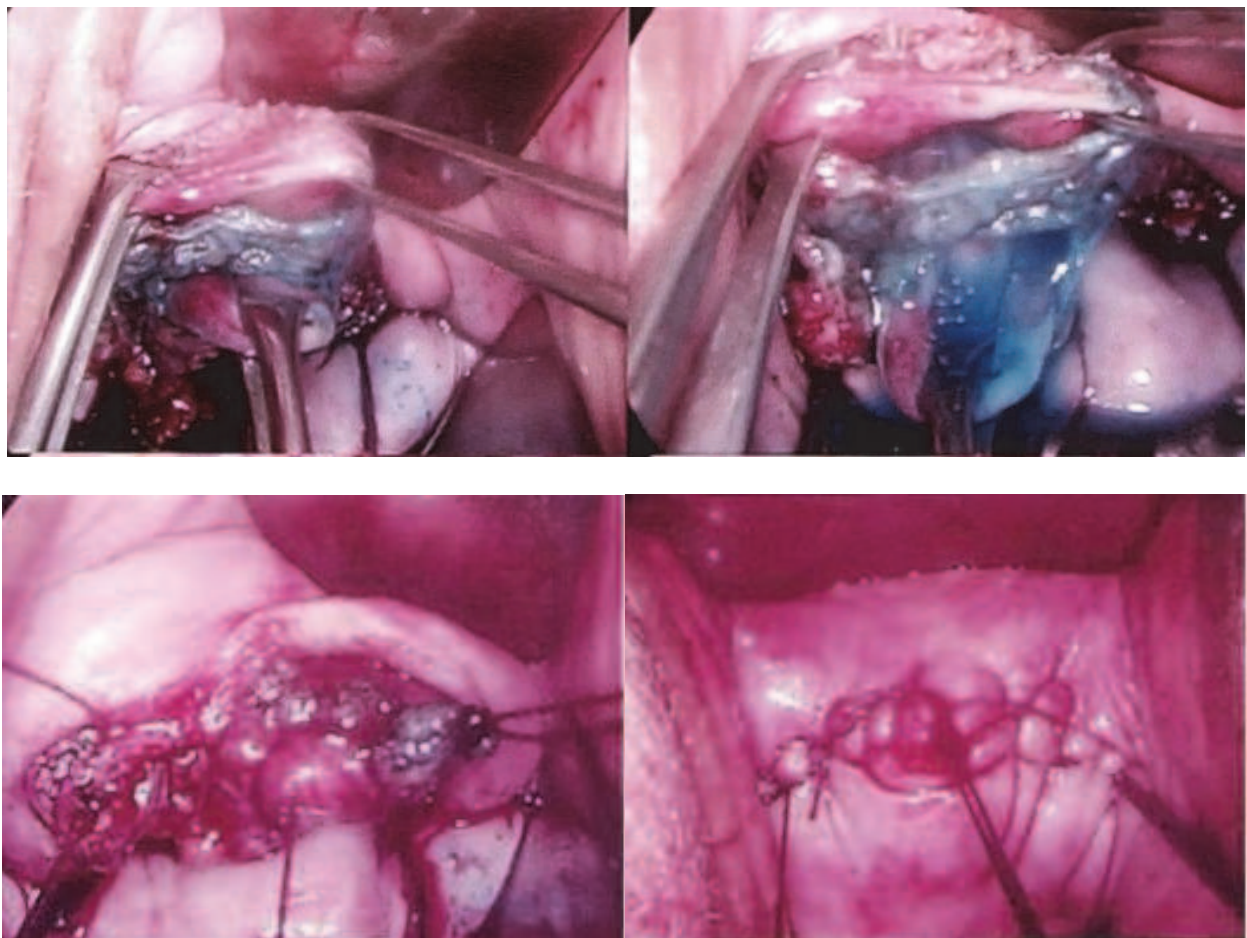


Fig. 3. Bladder injury was recognized intra-operatively, and was repaired vaginally.

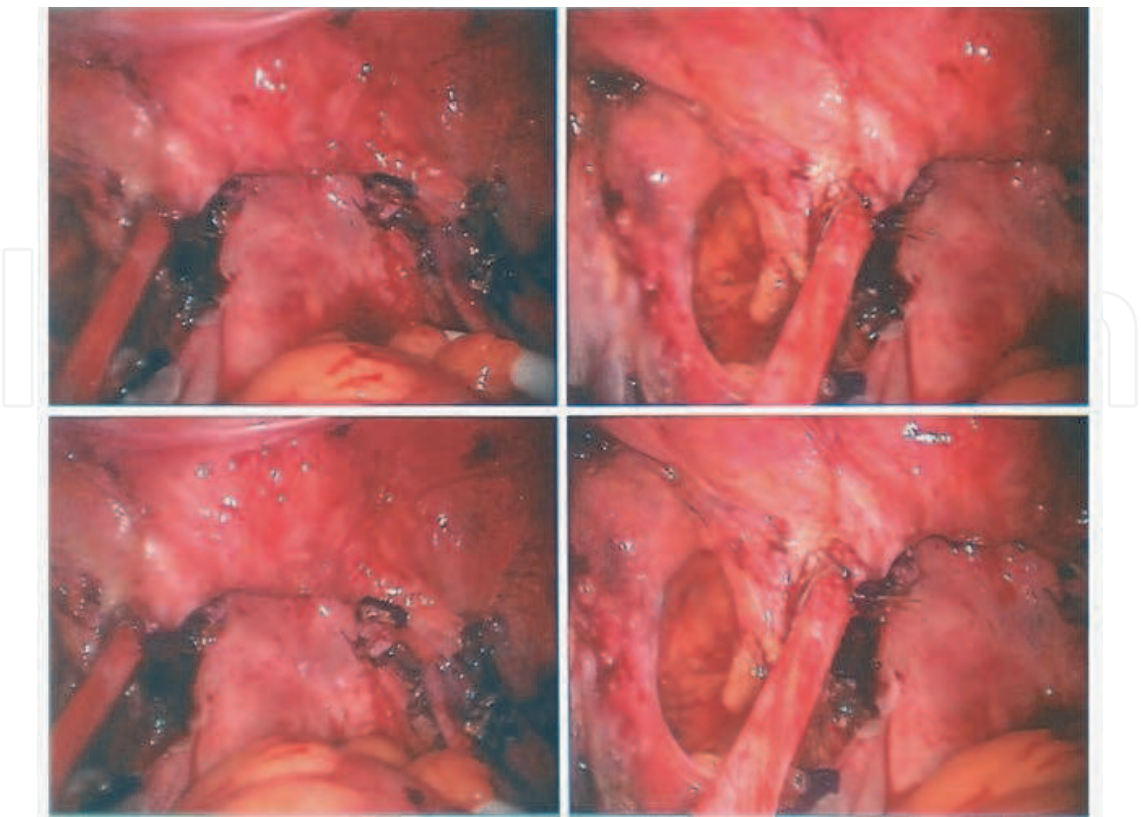


Fig. 4. Ureteral injuries recognized intraoperatively and was repaired by laparoscopic end-to-end reanastomosis.

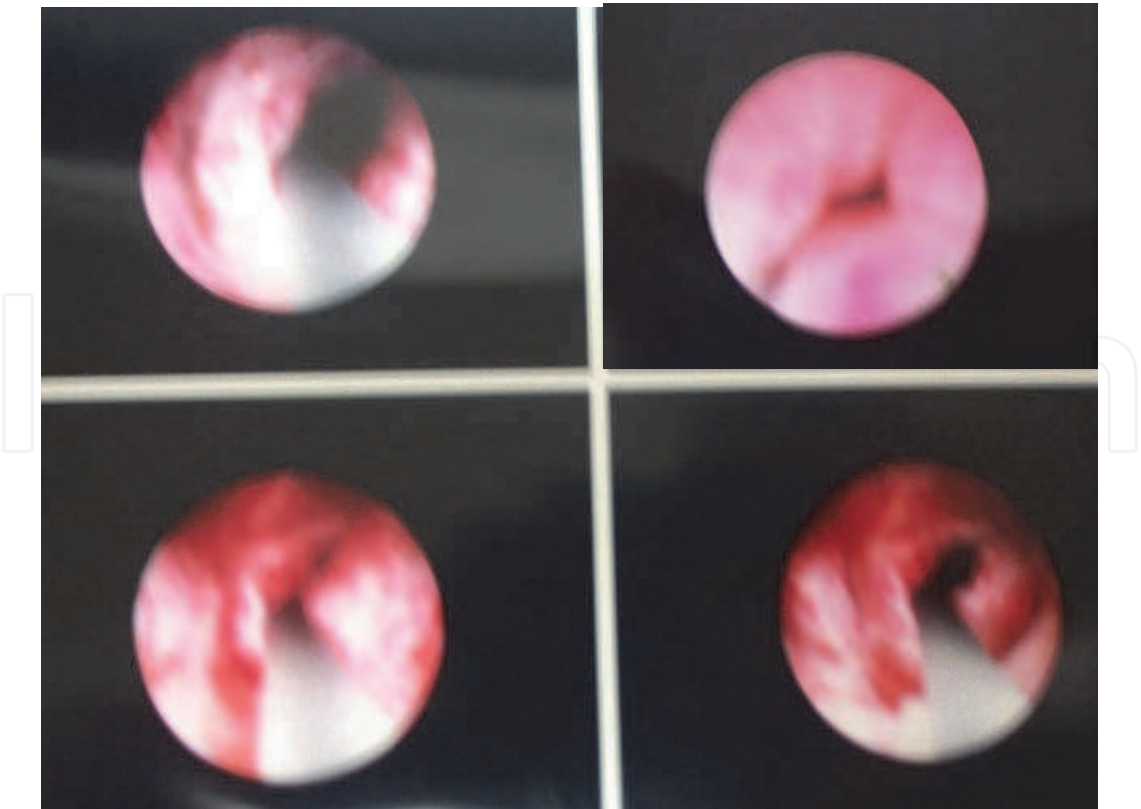


Fig. 5. Ureteral injuries recognized intraoperatively with the assistance of ureteroscopy.

3. **Bowel injury.** The time of diagnosis was reported 61.6% (154/ 250) recognized during surgery; 5.2% (13/ 250) recognized early post-operative phase within the next 48 hours; 10.4% (26/ 250) bowel injuries diagnosed late, at least on the third postoperative day or later. Another 22.8% (57/250) diagnosed after the conclusion of surgery, the number of hours elapsed was not reported [17]. A laparotomy was most frequently performed to manage the laparoscopy-induced bowel injury (78.6%). Conservative (7.0%) and laparoscopic (7.5%) treatment were used considerably less often [58],[17].

Stomach injury is a rare complication, it may be encountered after several trials of endotracheal intubations (Fig. 6). The inadvertent endotracheal intubation can cause excess gas inflated into the stomach and displaced the hyperinflated stomach as low as the periumbilical area [15]. Naso-gastric intubation for decompression is helpful to prevent gastric injury for those cases with distended stomach. **Injury to small bowel** or prepped colon, primary closure in two layers under laparoscopic guidance is recommended [33]. In selected cases with trocar-induced penetrating injuries of the bowel, institution of drainage and antibiotics can allow possible medical management of the problem, and thereby preclude conversion to laparotomy [59]. Conservative management comprised percutaneous drainage of abscesses, antibiotics or expectant treatment [17].

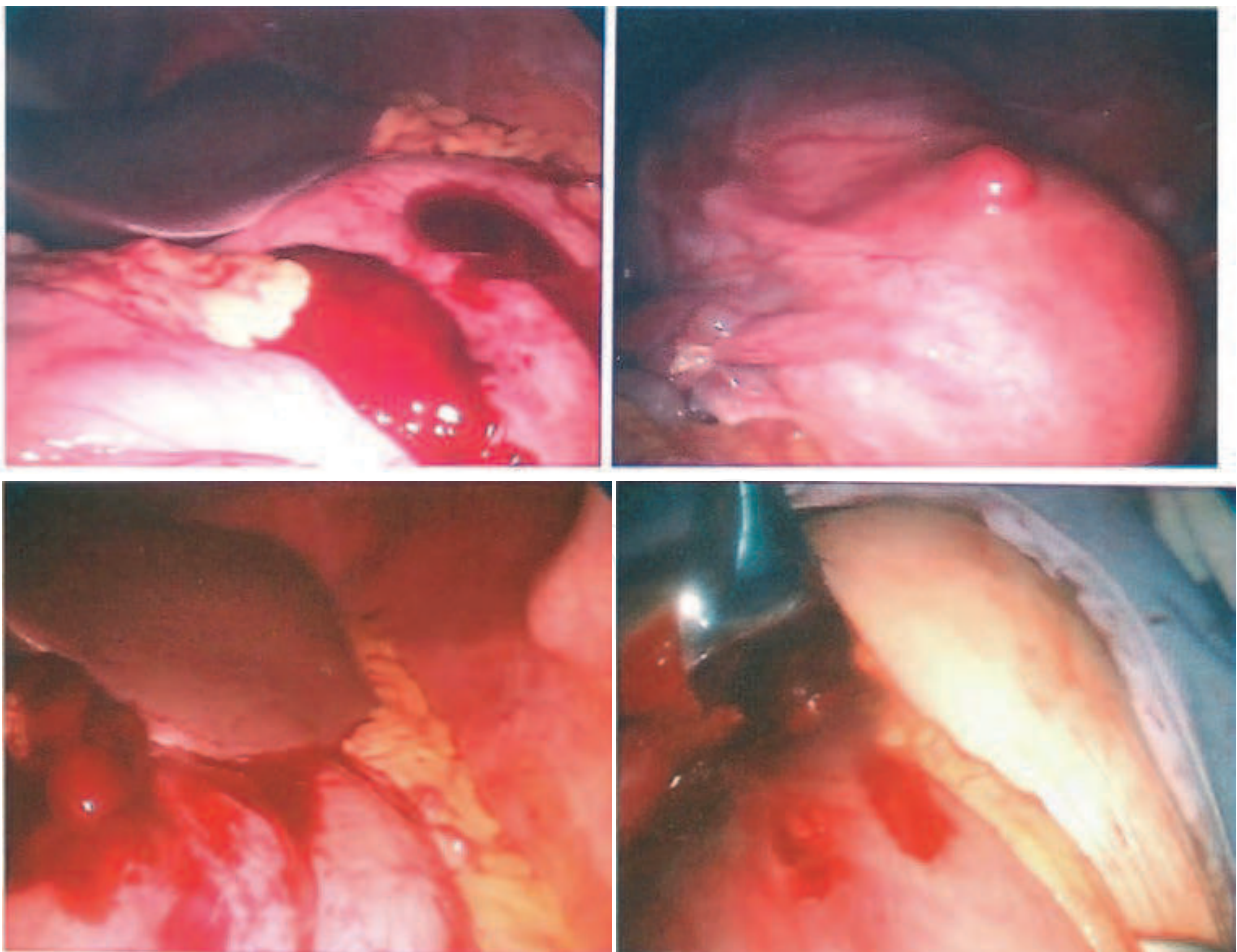


Fig. 6. Stomach injury by the introduction of primary trocar after several trials of endotracheal intubations.

When a large bowel injury is identified at the time of surgery, it is appropriate to repair this immediately, usually with the direct involvement of colorectal surgical colleagues [26]. The exact technique of repair will depend on the size of the injury, the exact site, and whether bowel preparation has been performed before surgery. As for colon injury, the transverse colon and sigmoid colon are most commonly traumatized by the trocar insertion. The spillage of foul-smelling gas through the insufflation needle is a helpful diagnostic sign [56]. The treatment options include primary repair, colostomy or segmental resection [33]. Superficial lesions can be treated with a laparoscopic purse-string suture placed beyond the margins of the thermally affected tissue or by postoperative observation alone [28]. Defects involving the full thickness of the bowel wall require direct surgical repair via laparoscopy or open laparotomy [56]. A suture to oversew a lesion was performed mainly for serosal damage or burn sites, and for perforations that were discovered immediately [17]. Primary closure of the perforation trauma was reported to be a safe method, with a failure rate varying from 1.2% to 2.4 %, as an alternative to traditional colostomy if the absence of contraindication. The contraindication included more than two associated injuries, the need for blood transfusion over 4 units, significant contamination, increasing colon injury severity scores [60]. A laparoscopic suture closure followed by copious irrigation until the effluent becomes clear might be also satisfactory [61]. Suturing was the procedure most often performed at laparotomy, 63% times (61/ 97), followed by bowel resection with reanastomoses 26% (25/ 97). A diverting stoma was required 11 % (11/ 97) [17]. Full-thickness penetration of the rectum can occur during the excision of rectal endometriosis. After excision of the nodule of the recto-sigmoid colon, a single-or double-layered repaired can be done by laparoscopic assisted transvaginal approach or total laparoscopic intracorporeal technique [62]. Concerning the unprepared bowel with a large amount of fecal contamination, laparotomy followed by repair and colostomy should be considered [33].

4. **Electro-thermal effect.** The sigmoid colon is especially vulnerable because of its close proximity to the uterus and ovaries. Colon injury caused by bipolar electrosurgery can be readily identified by viewing the area of blanch on the surface of the colon, as compared with monopolar electrosurgery which is more difficult to detect and evaluate [28]. Superficial thermal injuries to the bowel may be treated prophylactically with a laparoscopic-guided pursestring suture placed beyond the thermally affected tissue [56]. The spread of electro-thermal injuries is greater than the initial area of branching and can create a large area of necrosis; thus the depth of injury is difficult to assess even if they are noticed intraoperatively. The injury of a viscus or bile duct typical occurs only after several days have elapsed [31]. Thermal injury of the bowel necessitates segmental resection with a wide margin around the site of injury because thermal damage may extend for a considerable distance from the site of thermal contact (several centimetres) [33]. Excision of a generous segment up to 5 cm on each side of the margin of the injury site, to include this area of coagulation necrosis, is required to prevent subsequent reperforation. Currently, the best way to treat bowel injury during laparoscopic surgery is by traditional laparotomy. However, as laparoscopists become more experienced in laparoscopic surgery, laparoscopic suture repair will become another choice in the management [13]. The efficiency and accuracy of laparoscopic bowel suturing techniques have been proposed. In Reich's series, there are few indications for colostomy during the repair of bowel injuries noted during the course of a laparoscopic procedure [56].

5.2 Post-operative phase

1. **Being highly alert to postoperative warning signs.** During postoperative observation period, which may last 3 to 5 days, the surgical team should be highly alert to the early manifestations of peritonitis, especially for physicians who are on duty for coverage. Isolated small intestine injuries may not cause clear or rapid symptoms and abnormal laboratory values, while colon injury with or without combined ileal injuries, has grave outcomes. The degree of peritonitis depends on the amount of spillage and length of time between perforation and exploration. However, these warning signs may be insidious, and imply the importance of possible early intervention. For example, persistent excessive external fluid leak from the periumbilical area after laparoscopic surgery with no drainage from other incisional sides may suggest small-bowel injury. Iatrogenic, internal-external canalization between the small intestine and the skin masked clinical symptoms and signs of small-intestinal injury [63].

Abnormal laboratory and imaging tests are helpful in confirming the diagnosis, however, normal test result is not reassuring. Patients who do not void may have early manifestation of bowel injury. Lack of classic symptoms, signs, or changes in pertinent laboratory data did not rule out small-bowel perforation [63].

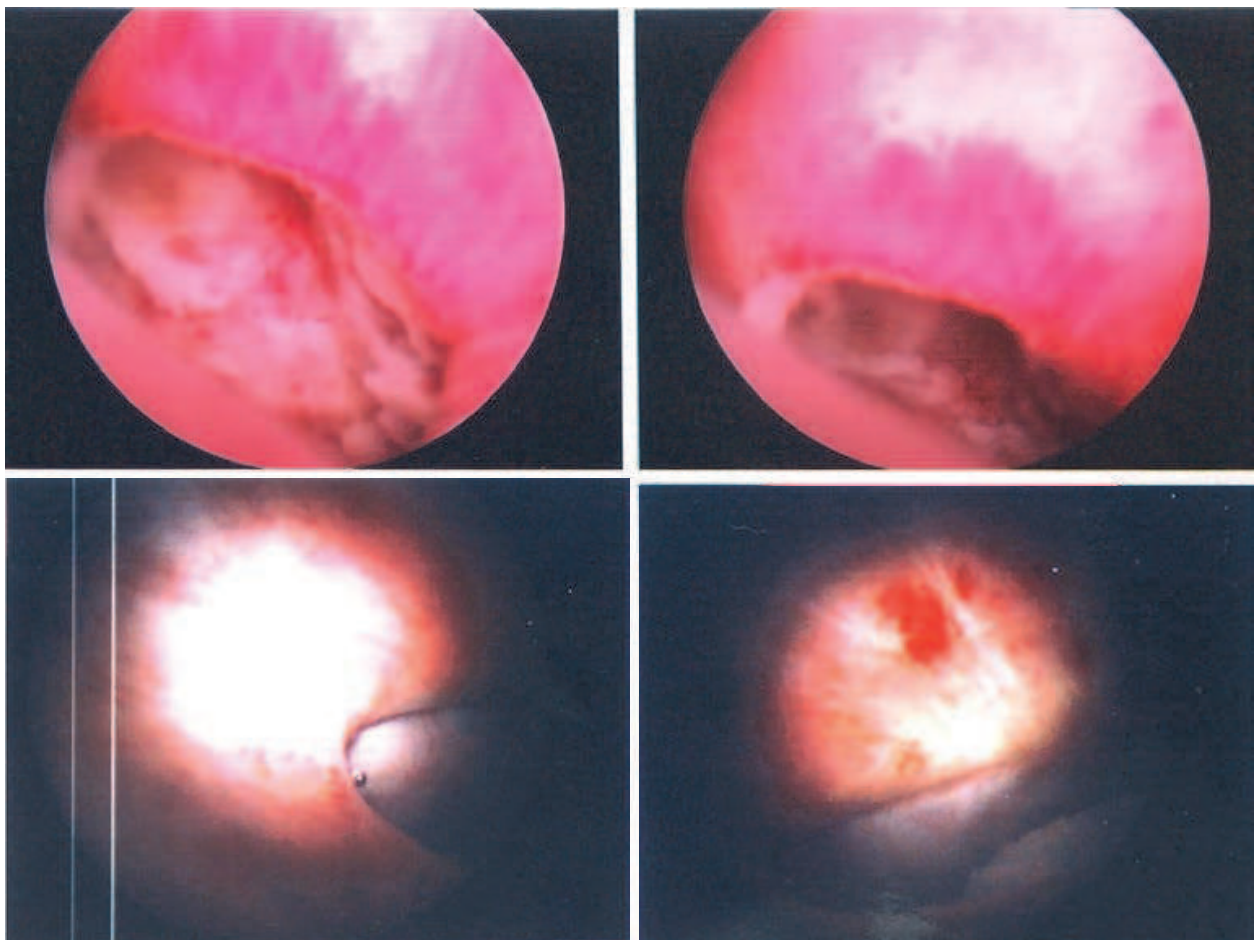


Fig. 7. Vesico-vaginal fistula happened with the delayed detection of bladder injury.

2. **Patient education before discharge.** Bowel injury that is unrecognized at the time of surgery is one of the most dangerous complications of laparoscopic surgery. All

patients undergoing laparoscopy must be advised before discharge that they should feel progressively better, and that any worsening in their condition should prompt them to seek advice [26]. They may well make a reasonable initial recovery and be discharged home. Once at home, they may become unwell, develop pain and fever and start vomiting. On seeking medical help, it is essential that the attending staff have a very high degree of suspicion of bowel injury. In the case of postoperative peritonism or peritonitis, the early use of computed tomography scanning can be very useful in the diagnosis of bowel obstruction secondary to a port site hernia. Increasing abdominal pain after laparoscopic surgery demands an expedient evaluation, even if it requires a repeated laparoscopy with a negative finding [34]. The involvement of general surgeons and early recourse to exploratory surgery is essential to prevent a poor outcome [26].

3. **Delay detection of bladder injury** may result in vesico-vaginal fistula which demand repetitive repair if the first salvage procedure failed (Fig. 7) [15]. If a ureteric injury is suspected but not confirmed at the time of initial surgery, an intravenous pyelogram should be performed. Urological colleagues should be involved in the management of these complication [26]. Once ureteral injury was detected in a late post-operative period after the formation of ureteral fistula, ascites with urine content (urinoma) might complicate the situation. Laparotomy for end-to-end anastomosis is usually necessary in the cases with complete transection, ligation or electro-thermal injury-induced ischemic necrosis [15].

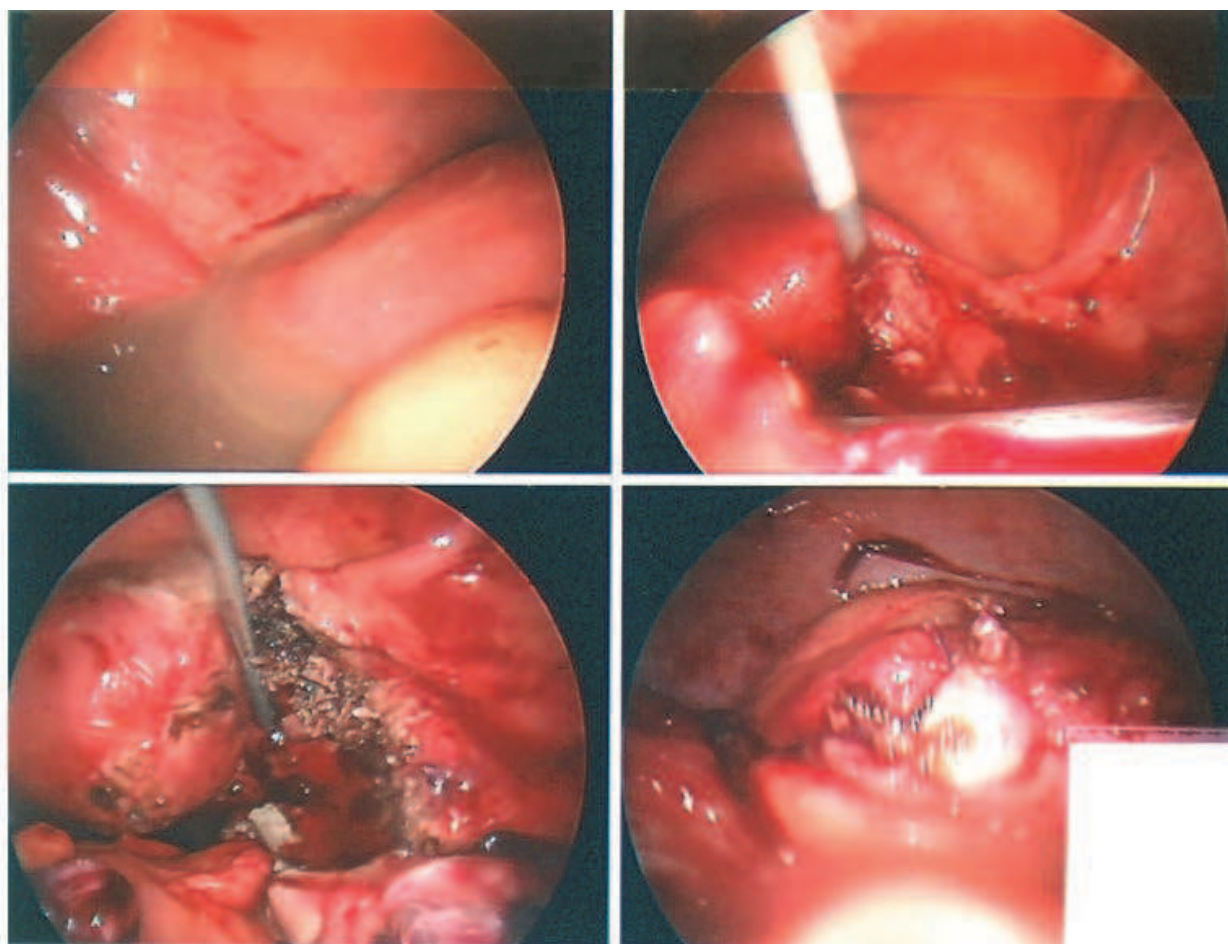


Fig. 8. Tubo-ovarian abscess is a risk factor associated with bowel injuries.

4. **Delay detection of bowel injury** may cause high morbidity and mortality. van der Voort *et al.* reported overall mortality rate associated with bowel injury complication 3.6% (16/ 450) [17]. The clinical picture may be varied. The early manifestation may be non-specific, e.g. vomiting, abdominal pain, distension and malaise; which is followed by additional features, e.g. a localized peritoneal abscess or generalized peritonitis [33]. In this stage, fever, leukocytosis and even septic shock can occur. Bowel injury caused by direct trauma or electrothermal injury has different clinical courses and histo-pathologic findings [64]. Symptoms of bowel perforation after electrical injury usually arise 4 to 10 days after the procedures, whereas symptoms of traumatic perforation usually occur within 12 to 36 hours [56],[65],[34]. Most electro-thermal injuries, more common in large bowel, are unrecognized intraoperatively and lead to long-term sequelae. It may occur insidiously due to stray current, insulation failure or capacitive coupling, in addition to direct, active electrode injury [65]. As for the timing of detection, van der Voort *et al.* reported more than 10% unrecognized until the third post-operative day or later [17]. In Wu *et al.* series, some identifiable risk factors associated with bowel injuries were emergent, non-scheduled surgeries, tubo-ovarian abscess or uncertain preoperative diagnosis (Fig. 8) [15]. The original injury severity, e.g. multiple injuries, happened more commonly in managing tubo-ovarian abscess, especially combined with appendicitis. They had grave outcomes with prolonged hospitalizations and demanded multiple salvage procedures.

6. Conclusions

As complications are an inevitable reality of surgery, we need to be aware of the types of complications in a systematic way, train to respond in an appropriate way, and learn to communicate and deal with complications in laparoscopic surgery [8]. To achieve electrosurgical safety and to prevent potential electrosurgical injury, understanding the biophysics of electrosurgery, characteristics of their own equipment, desired tissue effects, types of injury, and the possible clinical manifestations are very important, as well as the mastering of laparoscopic surgical dexterity. Organizing a team-work including surgeons, perioperative nurses, biomedical engineers, and operation room personnel through team resource management. Intraoperative adjuvant protective maneuvers, early recognition and immediate implementation of salvage procedures will minimize the complications. Risk-averse behaviors include paying particular attentions to placement of the first port, more liberal use of open laparoscopy or other adjuvant instrument, placement of all other ports under direct vision, elimination of intra-operative anatomy uncertainty, programmed inspection of the abdomen before withdrawing the laparoscope [31]. The dexterity improvement with hand-eye coordination and the knowledge of the mechanism of electrosurgical injury is important in recognizing and reducing potential electrosurgical complications [65]. Be highly alertness to postoperative warning signs including obvious signs of peritonitis or abdominal pain, and insidious ones. Patient education before discharge and detection of delay manifestation with salvage maneuver may minimize catastrophic disaster.

7. References

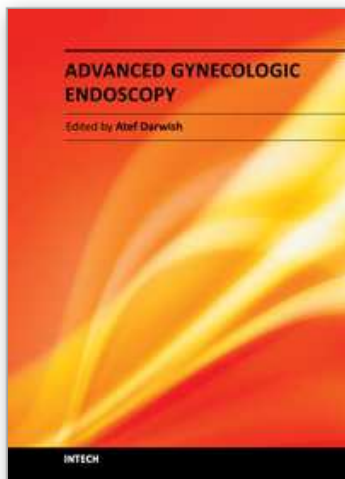
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The main purpose of this book is to address some important issues related to gynecologic laparoscopy. Since the early breakthroughs by its pioneers, laparoscopic gynecologic surgery has gained popularity due to developments in illumination and instrumentation that led to the emergence of laparoscopy in the late 1980's as a credible diagnostic as well as therapeutic intervention. This book is unique in that it will review common, useful information about certain laparoscopic procedures, including technique and instruments, and then discuss common difficulties faced during each operation. We also discuss the uncommon and occasionally even anecdotal cases and the safest ways to deal with them. We are honored to have had a group of world experts in laparoscopic gynecologic surgery valuably contribute to our book.

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