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REVIEW

Prevention and Treatment of Intraoperative Complications During Gynecological Laparoscopic Surgery: Practical Tips and Tricks—A Narrative Review

Matteo Giorgi · Giorgia Schettini · Luca La banca · Alberto Cannoni · Alessandro Ginetti · Irene Colombi · Nassir Habib · Ramon Rovira · Francesco Martire · Lucia Lazzeri · Errico Zupi · Gabriele Centini

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ABSTRACT

Several complications can occur during laparoscopic gynecological surgery. The insertion of trocars and the induction of pneumoperitoneum are essential steps, but they can still pose potential risks during laparoscopic surgery. Bowel injuries are the most common during gynecological procedures as a result of thermal damage and trocar placement, while vessel injuries may carry a high mortality rate. Gynecologic surgeons should be aware of the risks associated with laparoscopic procedures and be able to prevent and treat potential complications. We conducted a literature search using three electronic databases (Pubmed/MEDLINE, Google Scholar, Embase) from inception to May 2024 to identify the most common intraoperative gynecological laparoscopic complications, including those related to trocar insertion, bowel, urinary, and vessel injury. The aim of this narrative review is to describe the most common complications during gynecological laparoscopic surgery and to outline the safety rules and techniques necessary for their prevention and treatment.

M. Giorgi · L. La banca
Obstetrics and Gynecology Unit, Valdarno Hospital, Montevarchi, 52025 Arezzo, Italy
e-mail: matteogiorgi@hotmail.it

L. La banca
e-mail: lucalabanca@gmail.com

G. Schettini · A. Cannoni · A. Ginetti · I. Colombi · F. Martire · L. Lazzeri · E. Zupi · G. Centini (✉)
Department of Molecular and Developmental Medicine, Obstetrics, Gynecological Clinic University of Siena, 51300 Siena, Italy
e-mail: centini.gabriele@gmail.com

G. Schettini
e-mail: giorgiaschettini@gmail.com

A. Cannoni
e-mail: albertoacannoni@gmail.com

A. Ginetti
e-mail: ginettialessandro14@gmail.com

I. Colombi
e-mail: colombi.irene1@gmail.com

F. Martire
e-mail: francescogmartire@libero.it

L. Lazzeri
e-mail: lucialazzeri79@gmail.com

E. Zupi
e-mail: errico.zupi@unisi.it

N. Habib
Department of Obstetrics and Gynecology, Francois Quesnay Hospital, 78201 Mantes-la-Jolie, France
e-mail: dr.nassirhabib@gmail.com

R. Rovira
Department of Gynecology and Obstetrics, Hospital de la Santa Creu i de Sant Pau, C/Sant Quintí 89, 08041 Barcelona, Spain
e-mail: ramonroviran@gmail.com

PLAIN LANGUAGE SUMMARY

Laparoscopic surgery, or keyhole surgery, is a common technique used in gynecology to treat various conditions. While effective, it can sometimes lead to complications. These complications often occur during two important steps: inserting the surgical instruments (trocars) and creating space in the abdomen with gas (pneumoperitoneum). The most frequent problems include injuries to the bowel, urinary system, or blood vessels. Among these, bowel injuries are the most common and are often caused by heat from surgical instruments or improper placement of trocars. Blood vessel injuries, though less common, can be very serious and even life-threatening. It is crucial for gynecologic surgeons to know how to prevent these risks and manage complications if they occur. In this review, we examined studies on these complications, using trusted sources like PubMed, Google Scholar, and Embase. Our goal was to identify the most common complications and provide guidance on how to prevent and treat them. This review highlights the importance of proper surgical techniques and adherence to safety protocols to reduce risks during gynecological laparoscopic surgery. By improving awareness and training, healthcare professionals can make this minimally invasive procedure safer for patients.

Keywords: Laparoscopy; Complication; Safety rules; Injury; Gynecological surgery

Key Summary Points

Laparoscopic gynecological surgery carries specific risks, including injuries related to trocar insertion, bowel damage, and vessel trauma, which can have serious implications for patient safety.

This narrative review identifies and describes the most common intraoperative complications of laparoscopic gynecological surgeries, emphasizing the risks and prevention strategies for trocar, bowel, urinary, and vessel injuries.

The findings highlight the importance of implementing safety protocols and refined techniques to reduce complication rates and improve surgical outcomes.

Enhancing surgeon training and adopting advanced technologies may further minimize risks and advance the safety of laparoscopic gynecological procedures.

INTRODUCTION

Laparoscopy has revolutionized gynecological surgery, becoming the gold standard in many surgical procedures owing to its advantages, including lower surgical invasiveness, reduced trauma and postoperative pain, shorter hospital stays, faster recovery, and better cosmetic results [1, 2]. However, like any surgical technique, laparoscopy carries risks of complications that the surgeons must be skilled in recognizing and managing. Complications can vary from those specific to laparoscopy, such as trocar insertion and limited vision, to more general issues common in laparotomy, such as electrical complications. The literature has proposed several safety rules to approach laparoscopy [3].

Chapron et al. (1998) reported an overall gynecological laparoscopic complication rate of 4.64 per 1000 cases [4]. A more recent retrospective analysis estimated this rate to range from 0.69% to 6.22%, with major complications occurring in about 2.84% of cases [1].

Common intraoperative complications include hemorrhage (1.1%), bowel (0.5%) and urinary tract injury (0.7%); hemorrhage (1.1%), wound infection (0.5%), and pelvic abscess (0.4%) often occur in the postoperative period [5]. Risk factors for intraoperative injuries include age > 38 years, surgery duration > 99 min, and adnexal findings. Postoperative complications are linked to surgery duration > 94 min, hemoglobin drop > 2 g/dl, and American Society of Anesthesiologists (ASA) status III [6].

Complications are influenced by surgeon experience, with longer and more complex surgeries correlating with higher risks. According to Buhur and Unal, complications increased significantly when surgery exceeds 110 min [2]. Deep infiltrating endometriosis and the so-called frozen pelvis are among the riskiest conditions, with complication rates ranging from 2% to 24%, often due to bowel involvement [7] and loss of pelvis landmarks. Expertise in pelvic anatomy and surgical techniques is essential for minimizing complications, as is knowledge of urological and general surgery.

Surgical proficiency, gained through both theoretical knowledge and practical experience, reduces complications over time. Wattiez et al. reported a 4.3% reduction in complications after 6 years [8], while Brummer et al. found a decrease from 1.8% to 1% over 13 years [9]. Skills training, including live surgery, video tutorials, and practice on artificial or animal models, further enhances proficiency [10]. A step-by-step approach, combining simulation and live surgery, accelerates the learning process. Agha et al. [11] found that virtual reality (VR) simulators help trainees develop technical skills before performing real procedures, reducing errors. Combining simulation with hands-on practice shortens learning time and improves performance [12]. Ting and Lau [13] emphasized the importance of competency-based training with milestone assessments and targeted feedback to enhance both technical and clinical decision-making skills. Similarly, Seymour [14] demonstrated that regular virtual simulations reduce anxiety and improve precision, further highlighting the role of VR in enhancing surgical competence. Table 1 summarizes the common complications during gynecological laparoscopic surgery and their cause/risk factors, prevention strategies, and treatments.

Key Facts:

- Laparoscopy offers reduced invasiveness, faster recovery, and better outcomes.
- Complication rates range from 0.69% to 6.22%, with major complications in ~2.84% of cases.
- Common intraoperative complications include hemorrhage (1.1%), bowel (0.5%), and urinary tract injuries (0.7%).
- The learning curve in laparoscopic surgery significantly impacts complication rates.
- Training methods like virtual reality simulation, live surgery, and milestone assessments enhance surgical proficiency.
- Risk factors for intraoperative complications include age > 38 years, surgery duration > 99 min, and adnexal pathology.
- Postoperative complications correlate with surgery duration > 94 min, hemoglobin drop > 2 g/dL, and high ASA status.

METHODS

This study is a narrative review aimed at providing an overview of the most common intraoperative complications in gynecological laparoscopic surgery, including trocar insertion, bowel, urinary, and vessel injuries. To identify relevant literature, we employed a structured search across PubMed/MEDLINE, Google Scholar, and Embase, covering publications from inception to May 2024. The search considered a wide range of study types, including clinical trials, observational studies, reviews, and case reports. Titles and abstracts were screened for relevance to the research question, and reference lists of selected articles were manually reviewed to identify additional studies.

Specific inclusion and exclusion criteria were applied to select articles for the review. Studies were included if they (1) focused on gynecological laparoscopic complications or safety measures; (2) provided clinical data relevant to the prevention, recognition, or management of these complications; and (3) were published in English. Priority was given to systematic reviews, meta-analyses, and high-quality observational studies. Historically significant studies were also included for context. Articles lacking sufficient methodological detail,

Table 1 Common complications during gynecological laparoscopic surgery with cause/risk factors, prevention strategies, and treatments

Gynecological laparoscopic complication	Overall rate 0.69–6.22%	Timing	Cause/risk factor	Prevention strategy	Treatment option
Bowel injury	0.36%	Intraoperative	Surgeon's low experience Longer and complex surgery (adhesions for deep infiltrating endometriosis, frozen pelvis, previous surgery or pelvic inflammatory disease) Veress needle insertion Trocar misplacement Thermal damage Cold dissection Tissue mobilization	Accurate trocar placement Careful use of energy devices	Immediate laparoscopic or open repair
Vascular injury	0.04–0.5%	Intraoperative	Surgeon's low experience Longer and complex surgery Injury during trocar insertion or adhesiolysis	Visual confirmation before trocar entry Preoperative imaging Trendelenburg position and stretched legs after the first trocar insertion (minimizing distance and vessel exposure)	Immediate control of bleeding Suturing
Urinary tract injury	0.7%	Intraoperative	Surgeon's low experience Longer and complex surgery Close proximity to the operative field	Preoperative stenting (high-risk cases) Inserting a Foley catheter before surgery (reducing bladder volume and sliding it retropubically)	Repair via laparoscopic or open technique
Trocar site complications	0.4%	Intraoperative	Surgeon's low experience Previous surgery Inadequate insertion technique Obesity Multiple trocar use	Training on insertion techniques	Suture fascial defects Manage infections

with small sample sizes, or limited relevance to the topic were excluded.

Three independent reviewers (G.S., M.G., and G.C.) rigorously evaluated the identified articles for relevance and scientific quality. Discrepancies were resolved through consensus. This narrative review synthesizes current evidence to offer practical guidance on managing laparoscopic complications but does not provide a systematic analysis.

Potential biases, such as variability in surgical expertise, differences in institutional practices, and geographic variations, were considered in interpreting the findings. These biases, along with others, are discussed further in Sect. "Study Biases and Limitations".

This article is based on previously published studies and does not involve new studies with human or animals participants performed by the authors.

Bullet points are provided at the end of each section, in order to enhance clarity and ensure further comprehension of the most important topics for the reader.

Ethical Approval

This narrative review article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

ENTRY COMPLICATIONS

Entry complications, which occur before surgery or during trocar insertion and pneumoperitoneum establishment, are common even in simple laparoscopic procedures. Although the absolute rate is low (0.2–0.4 cases per 1000 procedures), entry complications account for over 50% of all laparoscopic complications [15–17]. They are the Achilles' heel of laparoscopic surgery, as trocar insertion is blind and may pose unrecognized risks at the time of injury [18]. Laparoscopic complications are categorized as major and minor. Minor complications, often resulting from incorrect placement, include omental damage, mild bleeding, postoperative infection, subcutaneous emphysema, nerve injury, abdominal wall hematoma, failed port insertion, and extraperitoneal gas insufflation [1]. Major injures, requiring additional laparoscopic or laparotomic intervention, occur in 0.4–0.9 cases per 1000 procedures [19] and include bowel, bladder, ureter and blood vessel injuries, significant bleeding (>600 mL within 24 h postoperatively), severe infections, and pulmonary edema, although data is limited [18–20]. Bowel and large vessels are the most common sites of injury, with the latter potentially being severe and even lethal.

The debate over the safest technique for trocar insertion is ongoing [21, 22]. The literature does not unanimously support a single procedure, and international guidelines do not recommend one method over others [15, 23–25], so surgeons must choose the technique they are most familiar with [26]. Table 2 summarizes laparoscopic complications according to severity.

Key Facts:

- 50% of laparoscopic complications occur during trocar insertion and pneumoperitoneum establishment.
- Major complications (0.4–0.9 per 1000 cases) include bowel, bladder, ureter, and vascular injuries.
- Bowel and vascular injuries are the most severe trocar-related complications.
- Preoperative imaging and patient history are crucial to assess risks of adhesions and determine safer entry sites.
- The umbilicus remains the preferred entry site owing to its predictable anatomy and reduced tissue variability.

Comparing the Techniques

Since the first report on laparoscopic entry complications over 30 years ago [27], significant progress has been made in safety improvements. Optical trocars, radially expanding trocars or retractable-blade trocars are just a few examples of how laparoscopy has evolved during this time frame.

Currently, three main methods are used for inserting the trocar into the abdominal cavity:

the conventional closed-entry technique (Veress needle with CO_2 pre-insufflation), Hasson's non-insufflated open entry technique, and the direct trocar or optical entry method [28]. The optical trocar (direct vision) entry, consisting in accessing the peritoneal cavity directly, under monitor guidance without prior umbilical pneumoperitoneum, will not be the subject of our analysis [29].

Below is a brief description of these trocar entry techniques (Table 3).

The Veress Needle Technique

The Veress needle, designed to prevent organ perforations, features a sharp flute-like outer tip and a retractable inner cannula, retracting to safely engage tissues as it passes through the abdominal wall. Once reaching the peritoneum, a spring mechanism pushes the blunt end beyond the outer cannula tip, protecting internal organs. Typically inserted at the umbilical scar, it can also be placed along the midline (between the umbilicus and a point 5 cm cranially to the pubic symphysis) or at the lateral margin of the rectus abdominis muscle (at McBurney's point). However, insufflation at these sites can lead to preperitoneal insufflation, as the peritoneum does not perfectly adhere to the abdominal wall. Insufflation through the Veress needle creates a gas cushion above the intestinal loops, facilitating the safe insertion of the first trocar and induction of pneumoperitoneum for surgery [30, 31].

Table 2 Laparoscopic complications: major and minor injures

	Laparoscopic complications
Major complications	Bowel, urinary bladder, ureter, or major blood vessel injury, significant bleeding exceeding 600 mL within perioperative 24 h, severe infective complications, and pulmonary edema
Minor complications	Omental damage, mild bleeding or postoperative infection, subcutaneous emphysema, nerve injury, abdominal wall hematoma, unsuccessful port insertion, and extraperitoneal gas insufflation

The Open Entry Technique

The Hasson technique (non-insufflated open entry) uses a small infraumbilical incision to access and directly open the peritoneum, reducing the risks of blind instrument insertion. A 3-cm vertical incision is made, preperitoneal adipose tissue is dissected and the fascia is incised transversely, with two sutures piercing the fascial margins to anchor the Hasson trocar. Pneumoperitoneum is then induced. Although it reduces the risk of retroperitoneal vessel injury, intestinal perforation remains a concern. The most common complication is intestinal injury during fascial incision [30].

Direct Entry Technique

A 1–1.5-cm umbilical incision allows perpendicular insertion of the first trocar into the muscular fascia. Subsequently, the abdominal wall is elevated below the umbilical scar, creating a tent-like space between the parietal peritoneum and the internal structures. The trocar is advanced at a 45° angle towards the pelvis until the security system clicks, indicating blade retraction due to pressure changes. Correct trocar positioning within the abdominal cavity is confirmed by the 0° optic [32].

Accessory Trocars

Accessory trocars are placed under direct laparoscopic guidance, with positioning based on pelvic anatomy and surgical needs. Ideally, trocars are inserted at a 90° angle, forming an equilateral triangle. Access points are performed in the avascular lower abdomen, 3 cm medial to the anterior superior iliac spine, for insertion of 5-mm trocars. For additional access, a third 5-mm trocar is inserted on the patient's left side, approximately 12 cm above the umbilicus [32, 33]. Lateral trocar placement increases the risk of injuring the inferior and superficial epigastric arteries, which run cranially and laterally to the pubic symphysis. Transillumination assists in precisely locating the superficial epigastric artery, to prevent vascular injuries during trocar insertion. Laparoscopic

Table 3 Trocar entry techniques

Entry technique	Advantages	Disadvantages	Risks	Safety rules
Veress needle with CO_2 pre-insufflation or closed entry	Designed to prevent organ perforations Insufflation creates a gas cushion for organ protection at the insertion of the first trocar Insertion at Palmer's point if necessary Widely used in the past	Risk of preperitoneal insufflation Requires expertise for proper placement	Organ and vascular injury Extraperitoneal insufflation Multiple attempts Failed entry	Correct manipulation and mid-level grip Insert at a 45° angle toward the pelvis, with the skin stretched Pressure, aspiration, and injection tests to verify the correct positioning of the needle
Non-insufflated open entry (Hasson)	Direct visualization of the peritoneum Reduces risk of retroperitoneal vascular injury	Slower technique Risk of bowel injury during fascial incision	Bowel injury during fascial incision Risk of infection at the incision site	Make a 3-cm infraumbilical vertical incision Stretch the abdominal wall to increase the distance from underlying vessels Anchor the trocar to fascial edges with sutures
Direct entry	Faster entry Lower risk of visceral and vascular injuries Reduced failure rate Widely used	Higher technical demand Risk of incorrect angle during insertion	Misalignment causing injuries Potential bleeding at the site	Ensure incision matches trocar size Handling the trocar with the palm of the hand, positioning the index finger towards the instrument's tip and gently rotating it while entering at a 45° angle towards the pelvis Insert the first trocar perpendicular to the muscular fascia Confirm entry by monitoring loss of resistance and optic visualization

Table 3 continued

Entry technique	Advantages	Disadvantages	Risks	Safety rules
Radially expanding trocars (RET)	Less trocar-site bleeding Decreased visceral and vascular injuries Reduced adhesions	Requires more force to insert Risk of uncontrolled entry if resistance is suddenly lost	Uncontrolled abdominal entry Fascial defects	Use the index finger to guide the device and control insertion Confirm safety using optic feedback and slow, steady advancement

identification of these arteries relies on their anatomical course [30].

Entry Trocar Techniques: Which One Should We Prefer?

Direct entry trocar has recently overtaken the traditional Veress needle and open methods owing to its lower complication risks; previously, the Veress needle was utilized in 90% of cases, compared to 5% for the open technique and just 1% for direct entry [19, 20, 26, 34]. This shift is driven by fewer major and minor complications, including reduced visceral injuries and trocar-site infections [8–10]; moreover, direct trocar entry is faster (while the open method is the slowest) [26] and more efficient, minimizing the failure entry rate associated with multiple attempts, extraperitoneal gas insufflation, and omental damage are characteristic of the Veress technique more than the direct entry technique [19, 20]. In clinical practice, and according to our experience, the most frequently used technique is direct entry, with the Veress needle inserted at Palmer's point representing a preferred option in cases of prior median laparotomic incision, as a result of fewer adhesions encountered in this area [35].

With no consensus on the safest technique, surgeons should use their preferred method [34], while remaining adaptable to alternatives in case of failure.

Radially Expanding Trocars (RET)

The 2019 Cochrane review does not favor any technique [20] but suggests radially expanding trocars (RET) may be safer. RET begins with Veress needle entry, encased in a polymer sleeve, followed by a blunt obturator inserted with a twisting motion. Compared to traditional blunt trocars, RET reduces trocar site bleeding, visceral and vascular injures, postoperative adhesions [36] and pain, while causing a smaller fascial defect due to a narrower incision [37]. However, it requires greater force to insert, leading some authors to recommend

using the index finger to prevent uncontrolled entry from sudden resistance loss.

Key Facts:

- No single trocar insertion method is universally superior. Surgeons should use the technique they are most proficient in.
- Veress needle technique: Creates a protective gas cushion before trocar insertion but carries a risk of preperitoneal insufflation and failed entry if mispositioned. Its insertion at Palmer's point is a safer alternative in high-risk cases.
- Open entry (Hasson technique): Reduces retroperitoneal vascular injury, but is slower and increases the risk of bowel perforation during fascial incision.
- Direct entry technique: Faster and associated with lower failure rate and lower risk of visceral injury, but may have a higher risk of vascular injury.
- Radially expanding trocars (RET): Minimize tissue trauma, bleeding, and adhesion formation, but require greater insertion force and can be harder to control.
- Accessory trocars: Allow flexible placement based on anatomy. Improper positioning increases the risk of injuring epigastric vessels.

General Safety Rules

Bowel and vascular injuries are the most common trocar-related complications, followed by bladder damage. Adhesions from previous surgeries, particularly transverse (6.87%) or longitudinal (31.46%) laparotomy incisions [38], significantly increase bowel injuries risk, though even patients without prior surgery face a 0.68% risk [39]. Therefore, a detailed medical history and preoperative imaging in high-risk patients help identify adhesions and determine safer entry points, such as Palmer's point when umbilical access is unsuitable.

Gentle lifting of the abdominal wall during Veress needle or trocar insertion reduces bowel perforation risk, while optical trocars provide direct visualization to minimize blind injuries. In complex cases, a rectal probe can help delineate anatomical planes during dissection and prevent inadvertent injuries.

Timely detection of bowel perforation significantly reduces morbidity and mortality. Standardized safety checks, including thorough inspection of the bowel and dissection sites at the end of the surgery, are recommended.

Vascular injuries, particularly to the iliac vessels, aorta, vena cava, and aortic bifurcation, are critical because of their proximity to the umbilicus. The umbilical site remains the preferred entry point due to its consistent anatomy and predictable distance from major vessels. Here, the abdominal wall tissues are fused, and thickness remains constant across patients, including those with obesity. The iliac vessels and aorta are positioned at a fixed proportion (one-third of the total abdominal thickness) providing a stable and safe zone for trocar insertion. However, Trendelenburg positioning and leg stretching should be applied only after the first trocar is placed to minimize vessel exposure (Fig. 1). Similarly, a Foley catheter inserted preoperatively reduces bladder volume, positioning it retropubically to lower the risk of injury.

To prevent stomach damage, a nasogastric tube should be placed before pneumoperitoneum induction.

Tips and Tricks

- Use preoperative imaging and patient history to assess adhesion risk and determine the safest entry site (e.g., Palmer's point in case of prior midline incisions).
- Trendelenburg positioning should be avoided before first trocar placement to reduce vascular exposure.
- Employ gentle lifting of the abdominal wall during Veress needle or trocar insertion to minimize bowel perforation risk.
- Prefer optical trocars to enhance visualization and minimize blind entry risks.
- Insert a Foley catheter and a nasogastric tube before insufflation to reduce bladder and gastric injury risks.

– Postpone Trendelenburg positioning and leg extension until after the first trocar is inserted to minimize vascular exposure.
– Conduct standardized safety checks at the end of surgery to ensure no undetected injuries remain.

Safety Rules: Veress Needle

Proper technique reduces risks. A stable mid-level grip prevents unintended movements during insertion. The needle, held like a pen, should be inserted at a 45° with stretched skin, directed towards the pelvis for safety, ensuring airflow moves away from the bowel. A 90° angle is recommended [40] for greater vascular clearance and improved port insertion, especially in patients with obesity [41].

Intra-abdominal placement is confirmed using standardized tests. The pressure test is the most reliable method (Azevedo et al.) [42]: intra-abdominal pressure < 10 mmHg within 10 s of insufflation (1.2 L/min) confirms correct positioning. Alternative tests include air aspiration—rather than blood, feces, or other biological fluids or tissue—(aspiration test), and 5 mL saline injection (injection test), where moderate fluid resistance excludes ectopic needle entry. Moreover, the double-click of the valve as the needle passes through layers, along with recovery tests, confirms intraperitoneal entry.

Tips and Tricks

– Use a 45° angle with stretched skin for standard insertion or 90° for patients with obesity to enhance vascular clearance.
– Confirm intraperitoneal entry with standardized tests:
  - Pressure test: Intra-abdominal pressure < 10 mmHg within 10 s.
  - Aspiration test: Air aspiration confirms correct placement.
  - Injection test: Moderate resistance during saline injection excludes ectopic entry.
– Listen for the double-click of the needle's valve passing abdominal layers.
– Avoid excessive needle manipulation to reduce bowel and vascular injury risks.
– Be cautious of preperitoneal insufflation, which can lead to failed trocar entry and misplacement.

Safety Rules: Inserting the First Trocar

In direct entry, the skin incision should match trocar size to avoid excessive traction and complication risks. Extending the incision when necessary is advisable.

A palm-grip on the trocar, guided by the index finger and gently rotated during insertion, ensures proper alignment (Fig. 2).

Conversely, in the open technique, the trocar is inserted perpendicularly to the muscular fascia, while stretching the abdominal wall to increase vessels clearance. Loss of resistance confirms successful entry.

Tips and Tricks

– Ensure the skin incision matches the trocar size; extend it if necessary to avoid excessive traction and tissue damage.
– For direct entry:
  - Handle the trocar with the palm grip, using the index finger at the tip for controlled insertion.
  - Rotate gently to ensure proper alignment.
– For open entry:
  - Insert the trocar perpendicular to the fascia, stretching the abdominal wall to increase vessel clearance.
  - Loss of resistance signals successful entry into the peritoneal cavity.
– Place lateral trocars in the "safety zone" (2–3 cm above the superior iliac spine) to prevent epigastric vessel injury.

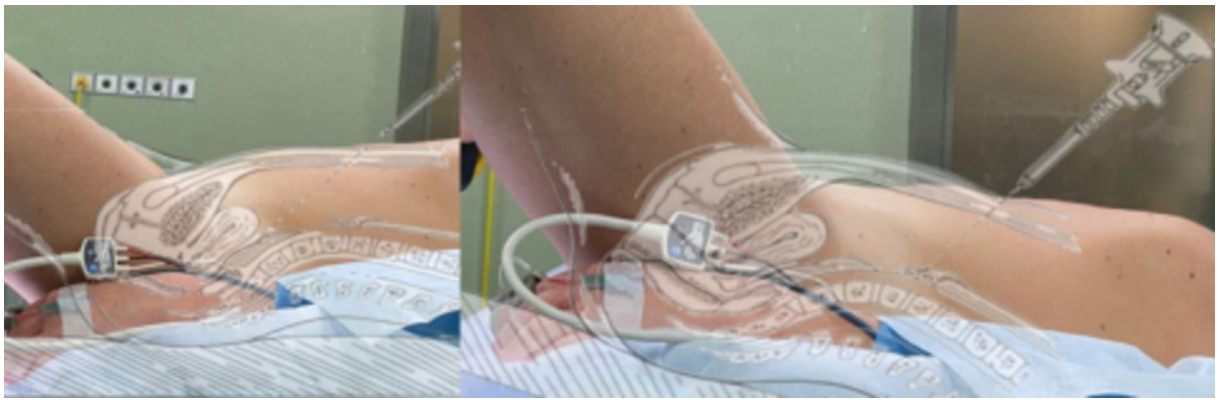

Fig. 1 Patient position. The picture shows the relationship between the umbilical trocar and the sacrum in a 0° position (left-side) and in Trendelenburg (right-side). The comparison shows that a Trendelenburg position exposes the promontorium and the aortic bifurcation increasing the risk of vascular injuries

– Opt for conical or radially expanding trocars (RET) to minimize fascial trauma and reduce adhesion formation.

BOWEL COMPLICATIONS

Bowel and vascular injuries account for 70% of laparoscopic complications. Bowel injury occurs in 0.36% of cases, affecting the sigmoid, rectum, and small bowel (55%), mainly as a result of Veress needle insertion (41%), thermal effects (25%), cold dissection, and tissue mobilization. Peritoneal adhesions or prior open surgery (68.9%) increase bowel injury risk [43], as adhesions and fibrosis distort anatomy and thereby increase surgical complexity [4].

Early complications stem from trocar insertion and bowel mobilization; late ones include thermal damage, bowel occlusion, and anastomotic leakage. Misdiagnosis is frequent, with 15–50% of bowel injuries undetected within 24 h, raising mortality to 3.6% [44]. Table 4 summarizes bowel complications and their management and safety rules (Fig. 3).

Safety Rules and Management of Bowel Complications

Safety Rules

Basic safety rules reduce bowel injury risk, though entry complications remain challenging to prevent. Familiarity with laparoscopic instruments and anatomy helps prevent tissue mobilization issues.

Bowel graspers minimize pressure and maximize surface contact when handling delicate intestinal loops. Laparoscopic graspers provide less tactile feedback than laparotomic ones. While rarely causing severe damage, laparoscopic graspers may lead to mesenteric tearing. A rectal probe helps better define the cleavage plane during dissection, reducing injury risk, especially in complex cases. This approach enhances the visualization of anatomical planes, minimizing the chance of accidental injury.

Furthermore, electrical injuries occur in 0.2–0.5% of cases, with a 0.6–3/1000 perforation rate. Direct coupling effect, accidental circuit activation, or grasper isolation malfunctioning are common causes [45]. Magnified imaging in laparoscopy, reducing peripheral vision, increases the risk of coupling effect injuries. Lateral tissue electrical conduction may sometimes occur, with an increased

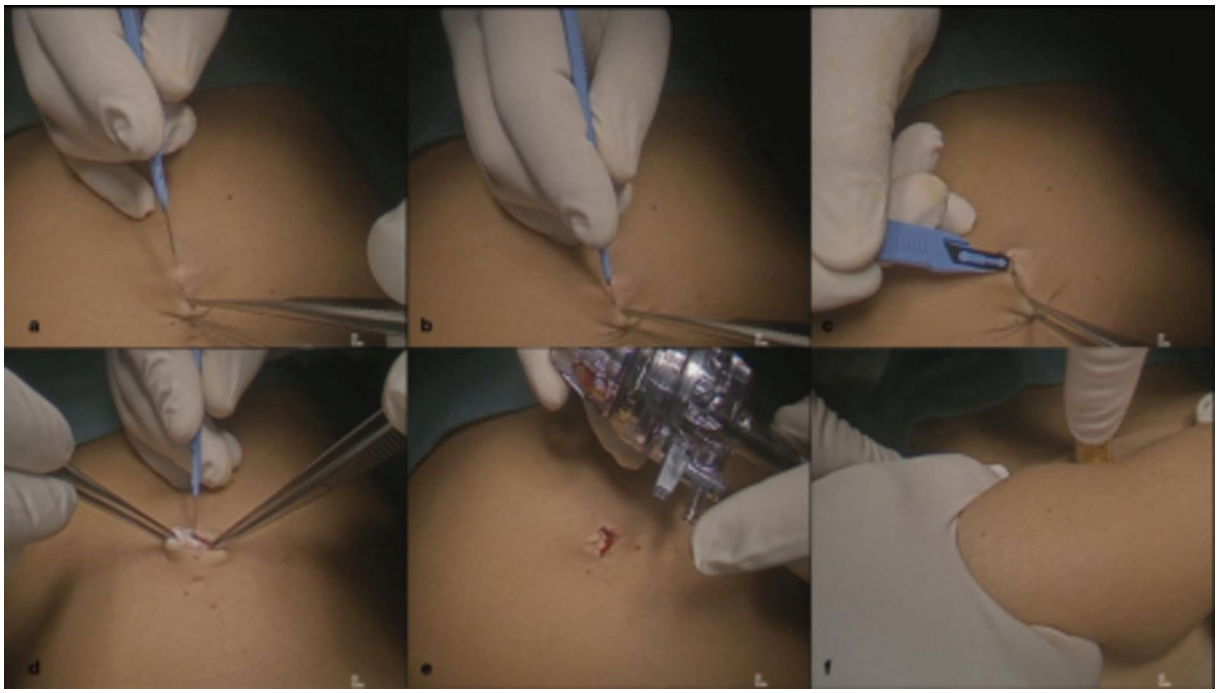

Fig. 2 Introduction of the first trocar. **a** The surgeon lifts up the inferior margin of the umbilical cushion; **b** The umbilical skin incision is performed caudocranially starting at the inferior margin on the left side; **c** Once the skin has been incised the scalpel is moved parallel to the skin plane proceeding on the left side of the scar; **d** The fusion of the abdominal fascias is then exposed by the assistant and released; **e** Prior to the insertion of the trocar the air valve should be opened; **f** The trocar is laid on the fascia, then the surgeons lift up the abdominal wall and the trocar is inserted perpendicular to the fascia. The index finger should be placed along the trocar to avoid sudden uncontrolled trocar entry

risk related to the use of metal instruments. Thermal damage depends on energy type and duration; bipolar energy peaks at 100 °C, while ultrasound energy reaches even higher and requires longer cooling. Consequently, after using ultrasound devices, avoid bowel mobilization briefly to prevent thermal injury.

Tips and Tricks: Safety Rules

- Use bowel graspers to reduce pressure and maximize surface contact, minimizing mesenteric tearing.
- Employ a rectal probe during dissection to highlight anatomical planes and prevent inadvertent injury.
- Avoid prolonged tissue contact with energy devices:
  - Bipolar energy peaks at 100 °C; limit application time.
  - Ultrasound devices require cooling time before bowel manipulation to prevent thermal injury.
- Always inspect the bowel carefully after using energy devices to detect any unintentional injury.
- Be cautious of direct coupling effects and magnified imaging limitations that can obscure lateral tissue damage.
- Early detection is critical—15–50% of bowel injuries are misdiagnosed in the first 24 h.

Management

Only 35% of bowel injuries are diagnosed intraoperatively; 48% appear within 7 days [46], with early detection improving outcomes.

Symptoms—abdominal pain, nausea, vomiting, paralytic or mechanic ileus, tachycardia, fever, or diffuse guarding—can appear up to 3 weeks post surgery. Mechanical-related symptoms appear earlier than thermal ones (1.7 vs 4.8 days) [47]. Final abdominal cavity inspection is recommended, especially in patients with adhesions. Gas tests and methylene blue injection aid perforation diagnosis. In the gas test, the pelvis is filled with irrigation fluid, intestinal loops are submerged, and 60 ml of gas is injected into the anal canal while the sigmoid is occluded with a grasper. Bubbling indicates rectal perforation. Methylene

Table 4 Bowel complications, management, and safety rules

Aspect	Details
Incidence	Overall incidence: 0.36% of cases (70% of all laparoscopic complications) Sigmoid and rectum are most commonly injured, followed by the small bowel (55%)
Causes	Veress needle insertion (41%) Thermal (25%) and electrical effects Cold dissection and tissue mobilization Peritoneal adhesions or prior open surgery history (68.9%)
Timing	*Early complications*: occur during trocar insertion or bowel mobilization *Late complications*: caused by thermal damage, bowel occlusion, or anastomosis leakage
Diagnosis challenges	15–50% of injuries are undetected within the first 24 h Late detection increases mortality risk to 3.6%
Management	**Details**
Intraoperative diagnosis	Visual inspection: often missed (just 35% intraoperative diagnosis) Gas or methylene blue test to detect perforations
Postoperative diagnosis	Symptoms: abdominal pain, nausea, vomiting, ileus, tachycardia, fever, or guarding (up to 3 weeks post surgery) Imaging: CT scans, direct abdominal X-ray, or exploratory surgery if needed
Treatment	*Small injuries (< 1 cm)*: repair with single suture (3/0 absorbable monofilament) *Larger injuries*: require double-layer sutures General surgeon consultation is recommended
Antibiotic therapy	Indicated when perforation is confirmed to prevent secondary infections
Safety measure	**Rationale**
Use appropriate instruments	Employ specific bowel graspers to minimize pressure and maximize surface contact on loops
Avoid excessive thermal application	Prevent direct coupling and accidental activation of electrical circuits Avoid bowel mobilization for a few seconds after using ultrasound devices to allow cooling
Understand anatomical risks	Prior adhesions or surgical history significantly increase complication risks Inspect peritoneal cavity carefully at the end of surgery

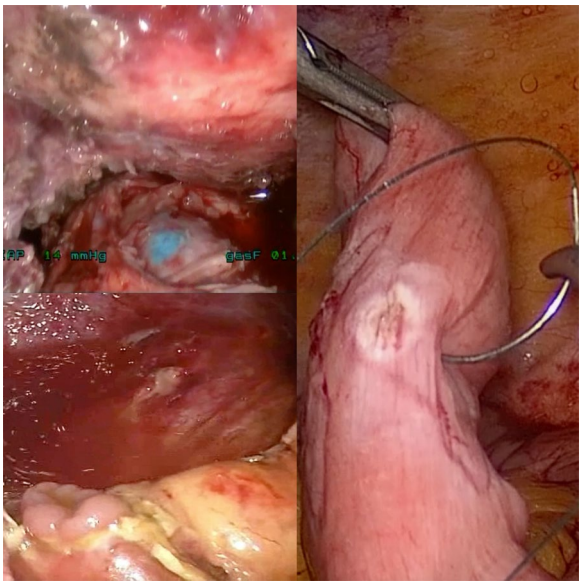

Fig. 3 Bowel complication. **a** Positive methylene blue test for muscular layer injury; **b** mucosa eversion after full-thickness injury; **c** small bowel thermal injury

blue can be used instead of gas. If a perforation is confirmed, antibiotic treatment is recommended [48]. Imaging exams like direct abdominal X-ray (although it could be affected by residual CO_2 in the abdomen) or CT scans may also be useful for perforation, hernias, or abscesses. Ultimately, explorative surgery may be necessary when previous techniques fail.

Bowel injuries < 1 cm or thermal damage require a single 3/0 absorbable monofilament suture; deeper or wider injuries need a double-layer suture, regardless of mucosal involvement. Consulting a general surgeon for advice is good clinical practice, as repairing a bowel injury could have legal implications.

Tips and Tricks: Management

- Carefully inspect the bowel at the end of the procedure, particularly in patients with adhesions or prolonged use of energy devices.
- Use diagnostic tools:
  - Gas insufflation or methylene blue test can help detect small bowel perforations intraoperatively.
  - CT scans for identifying perforations, abscesses, or hernias postoperatively.
- Repair minor bowel injuries (< 1 cm) with a single-layer suture using 3/0 absorbable monofilament.
- For deeper injuries, employ a double-layer suture and consult a general surgeon when needed.
- Early recognition of symptoms (e.g., abdominal pain, ileus, fever) improves outcomes.

BLADDER COMPLICATIONS

Bladder injury, one of the most common visceral organs injuries in laparoscopy [49–51], occurs in 0.03–0.24% of cases (Wong et al.) [52]. Prolonged monopolar energy use, improper uterine manipulator placement, or suprapubic trocar entry may lead to bladder injury [53]. In benign gynecological surgeries, urinary tract complications have decreased to 1–3% in the last decade, with bladder involvement in two-third of cases [54]. Doğanay found similar complication rates in laparoscopic (0.7%), laparotomic (0.7%), and vaginal (0.3%) hysterectomies [55]. While urinary complications are higher during the laparoscopic learning curve, experienced surgeons show comparable or better outcomes than with laparotomy [56].

Complex surgeries with fibrosis or altered anatomy (e.g., prior C-section or deep endometriosis) pose higher risks of bladder lesion. Meticulous dissection of the vesicovaginal space is essential, especially in C-section patients [57]. Deep endometriosis increases bladder injury risk due to lesion removal or nerve damage from extensive dissection, leading to urinary retention or dysfunction [57], which usually resolves spontaneously within 9 months. Nerve damage is more likely with involvement of the pararectal space, where parasympathetic innervation is widely located. The presence of bilateral nodules requires a choice between radical excision or conservative single nodule removal to preserve unilateral parasympathetic innervation.

Vesicovaginal fistula is a rare complication requiring intraoperatively attention to prevent

postoperative fibrosis [57]. Table 5 summarizes bladder complications and their management and safety rules.

Safety Rules and Management of Bladder Complications

Safety Rules

Bladder injuries are rare in lower-risk procedures (e.g., a simple hysterectomy) but more common in complex gynecological surgeries. Key steps include exposing the bladder and identifying the cleavage plane between the bladder and the anterior vaginal wall to facilitate the colpotomy (Fig. 4) [58]. The assistant should pull the bladder cranially to expose the peritoneum and white reflection line between bladder and vagina, to aid dissection. Uterine manipulation improves the surgical field, reducing unintentional damage risk, especially in patients with C-section adhesions. A vaginal valve before colpotomy ensures a 1-cm safe distance, reducing bladder injury and fistulae risk [58]. Preoperative catheterization decompresses the bladder, enhancing visualization and reducing injury risk. Lifting the uterus with manipulators during gynecological procedures also help maintain a clear surgical field and reduce unintentional damage risk.

Tips and Tricks: Safety Rules

- Perform preoperative catheterization to decompress the bladder and enhance visualization.
- Use a vaginal valve before colpotomy to maintain a 1-cm safe distance, minimizing bladder injury risk.
- Identify the cleavage plane between the bladder and the vagina by carefully dissecting the white reflection line.
- Use uterine manipulators to lift the uterus, ensuring a clear surgical field and reducing accidental damage.
- Carefully manipulate the bladder cranially to expose key anatomical landmarks and facilitate precise dissection.

Management

Surgeons handle bladder lesions but consult urologists for intramural ureteral injuries. Ureteral stenting is necessary when suturing the bladder near the ureteral ostium. During extensive bladder dissections, identifying the ureter location is crucial. Bladder wall lesions are sutured with single- or double-layer stitches using 2/0 or 3/0 Vicryl or monofilament sutures, with a catheter left in place for 10–15 days [51, 54, 55]. The bladder heals well; meticulous suturing is key to ensure the integrity of the repair. Proper tests can be done at the end of the procedure: a methylene blue test (≥ 150 ml of fluid via Foley catheter) confirms suture integrity and detects vesicovaginal fistulae, if the blue fluid is visible in the vagina. The catheter remains until the fistula is resolved [59–61]. Inspect the Foley bag for air and check for thermal damage on the bladder (detectable as white spots) before trocar removal, because it can lead to fistulae [62, 63]. If damage occurs, an immediate reinforcement stitch is recommended. Cystoscopy should be performed for suspected injuries near the ureteral ostium. For ureteral injuries, double J ureteral stenting is required for 6–8 weeks [60, 62, 64]. Cystography detects instead altered scarring and associated lesions [59]. Assess bladder functionality after bilateral pararectal space dissection to detect nerve damage with consequent bladder filling capacity injury. Clamping of the Foley catheter and later urine bladder residual of 150 ml or higher can detect an altered nerve functioning [62]. Symptoms typically resolve in a few days.

Tips and Tricks: Management

- Use a methylene blue test (injecting ≥ 150 ml) to verify suture integrity and detect vesicovaginal fistulae.
- Place a Foley catheter for 10–15 days, adjusting duration based on lesion size and inflammation.
- Inspect the bladder for thermal damage (white spots) before removing the trocar to prevent fistula formation and reinforce with an immediate intraoperative stitch if needed.

Table 5 Bladder complications, management, and safety rules

Aspect	Details
Incidence	Rare in low-risk (0.7%) surgeries but more frequent in complex procedures (3%) Postoperative vesicovaginal fistula is uncommon but severe
Causes	Extensive dissection near bladder or ureters Misidentification of the cleavage plane between the bladder and anterior vaginal wall Altered anatomy (previous C-section, deep endometriosis)
Common risks	Bladder dysfunction or urinary retention (resolves in ~ 9 months) Vesicovaginal fistula due to improper closure or thermal damage
Diagnosis	Methylene blue test: Inject 150 mL of dye via Foley catheter; blue fluid in the vagina confirms a fistula Cystography for scarring Cystoscopy for suspected injuries near the ureteral ostium
Management	Details
Small lesions	Repair with a single-layer suture using 3/0 absorbable monofilament Leave Foley catheter for 10–15 days based on lesion size
Vesicovaginal fistula	Immediate reinforcement stitches during surgery Continue catheterization until the fistula heals completely
Involvement of ureters	Perform ureteral stenting for injuries near ureteral ostium
Safety measure	Details
Expose the bladder clearly	Identify the cleavage plane between bladder and vaginal wall Carefully manipulate the bladder by pulling it cranially
Use protective measures	Employ a vaginal valve during colpotomy to maintain a safe distance (at least 1 cm) from the bladder
Intraoperative assessment	Inspect the bladder for thermal damage (white spots) and confirm suture integrity using methylene blue or gas tests

- Perform cystoscopy to evaluate injuries near the ureteral ostium and place a double J stent for 6–8 weeks if ureteral damage is confirmed.
- Assess bladder functionality post pararectal dissection by monitoring urinary output (residual urine > 150 ml indicates parasympathetic nerve damage).
- Confirm ureter location during extensive dissections to prevent inadvertent injury, especially near the bladder.

URETERAL COMPLICATIONS

The ureter's proximity to the uterus and ovaries makes it highly vulnerable in gynecological surgeries, with hysterectomy carrying up to a 50% damage recognition rate [8]. The overall incidence of ureteral injury ranges from 0 to 2.2% [65]. Experienced surgeons—with over 30 hysterectomies performed—show reduced complication rates [8]. Ureteral lesions often occur at the pelvic brim (42%) with injury near the cervix, where the ureter crosses under the uterine artery,

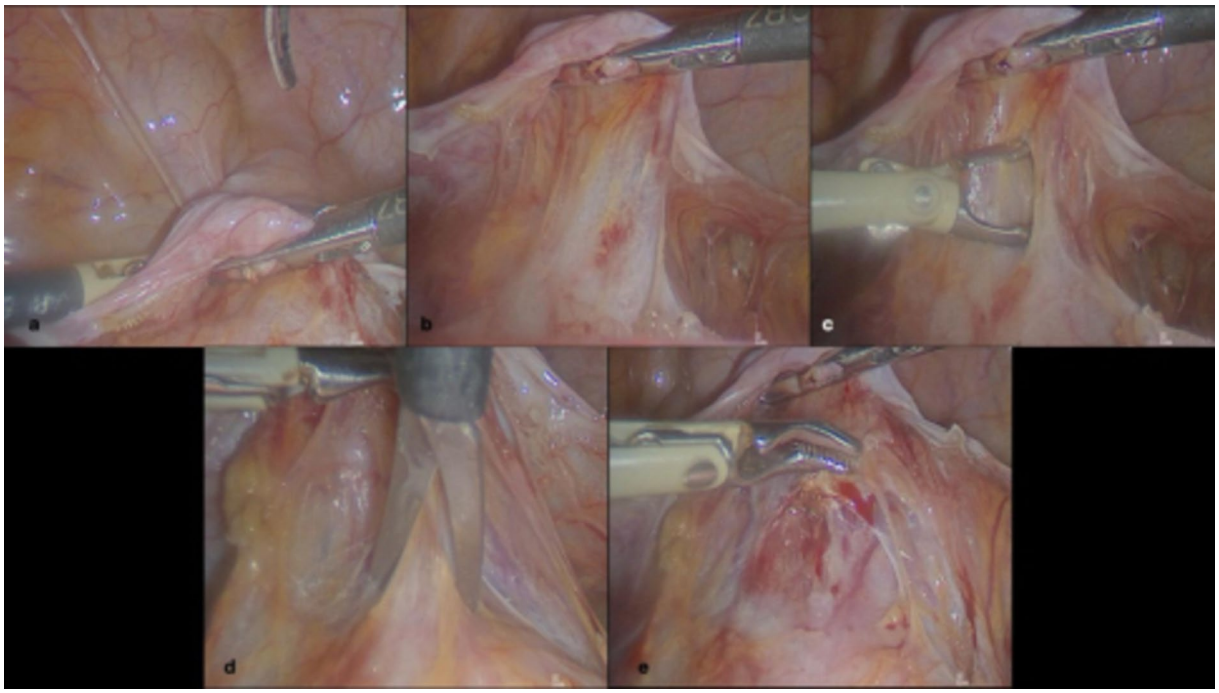

Fig. 4 Safe bladder surgical approach: dissection of the vesicouterine space. **a** The bladder is grasped deeply to open the vesicovaginal space; **b** The exposed gray/white line corresponds to the vesicouterine space and the correct dissection plane; **c**, **d** A smooth dissection is performed inside the avascular vesicouterine space following the champagne effect; **e** A vaginal valve is introduced to expose the anterior vaginal fornix

being the second most common site [66]. Risk factors include deep infiltrating endometriosis, large uteri, hysterectomies, and excessive bleeding [8]. Uterine artery bleeding increases thermal damage risk due to altered suturing or clamping techniques.

Endometriosis correlates with ureteral disease, with a 10% incidence of ureteral endometriosis in women with urinary tract endometriosis. Large nodules (>2 cm) in the rectovaginal space pose a higher risk [67]. Reckless dissection can lead to intraoperative complications such as thermal damage, devascularization with consequent tearing, obstruction, stenosis, and fistula [68]. Table 6 summarizes ureteral complications and their management and safety rules (Fig. 5).

Safety Rules and Management of Ureteral Complications

Safety Rules

Identifying ureters at key landmarks (e.g., pelvic brim) and tracing their course reduces injury risk. The use of advanced imaging techniques, such as indocyanine green fluorescence, can greatly enhance ureter visualization during surgery. These techniques allow for real-time identification of ureteral anatomy and ensure greater precision, particularly in challenging cases involving severe adhesions or endometriosis. This technology reduces unintended ureteral injury. In complex cases, preventive ureteral stenting can facilitate visualization and reduce injury risks. Adherence to strict guidelines aids in prompt identification and treatment of ureteral injuries, decreasing the need for further surgery and mitigating long-term complications

such as urinoma formation or renal function loss [3].

The section of the infundibulopelvic ligament during hysterectomy poses the highest risk for ureteral lesions. Creating a fenestration of the posterior fold of the broad ligament, using the vaginal valve and correct manipulation of the uterus (pushing it cranially after vesicovaginal dissection) help increase safety, isolating the vascular pedicle, providing a clearer view of the nearby structures and increasing the distance between the ureter and the uterine artery right next to the uterus [58]. Additionally, care must be taken to avoid excessive traction near ligaments close to the ureteral pathways, such as the infundibulopelvic ligament and the uterosacral ligament. Gentle handling of tissues minimizes the risk of stretching or compressing the ureter, thereby reducing the likelihood of complications.

Coagulate the uterine artery using the lateral trocar, securing it at a 90° angle with bipolar forceps. In cases of distorted anatomy, accurate dissection of the ureter is necessary, starting more cranially at the entrance of the ureter into the pelvic brim, where the organ is easily recognizable. Identifying the left ureter can be challenging because of the overlying sigmoid. Verification of its course, peristalsis, and integrity is crucial if a lesion is suspected.

Tips and Tricks: Safety Rules

- Identify ureters at key landmarks (e.g., pelvic brim) and trace their course during pelvic surgery to reduce injury risk.
- Use indocyanine green fluorescence imaging for enhanced ureteral visualization, particularly in complex or anatomically distorted surgeries.
- Consider preventive ureteral stenting in high-risk surgeries to aid intraoperative identification.
- During hysterectomy, create a posterior broad ligament fenestration and push the uterus cranially to isolate the vascular pedicle and increase the distance between the ureter and uterine artery.
- Avoid excessive traction near ligaments close to ureteral pathways (infundibulopelvic ligament, uterosacral ligament) to prevent ureteral stretching or injury.
- Coagulate the uterine artery with a lateral trocar, ensuring the bipolar tool is at a 90° angle for precise coagulation.
- Start ureter dissection cranially at the pelvic brim in cases of distorted anatomy to easily recognize its course and verify peristalsis and integrity if injury is suspected.
- Delayed ureteral injuries may present postoperatively with hydronephrosis, flank pain, or urine leakage.

Management

Clamping or thermal damage necessitates ureteric stenting and Foley catheter insertion, with removal after 10–14 days [69]. Extensive devascularization and loss of peristalsis may require ureteral resection.

Reimplantation or anastomosis (with or without stenting) depends on damage extent, proximity to the bladder, and pelvic conditions. If an injury is within 5 cm of the ureteral ostium, ureter reimplantation should be performed [70], with anastomosis secured with a stitch to the psoas muscle to reduce tension [71]. For damage up to 5 cm, use an anastomosis with a stent [72]. Ureter resection is diagonal, followed by reanastomosis at the stent level. According to Sakellariou et al., without other pelvic diseases and damage over 2.5 cm from the bladder, re-anastomosis may not be necessary [69]. Regardless of medicolegal variations, urologist consultation is advisable for ureteral reimplantation. Ureteral reimplantation is a procedure that requires specialized expertise to ensure optimal functional and anatomical outcomes. Collaboration with a urologist not only enhances patient safety but also reduces the likelihood of complications, particularly in cases of extensive damage or anatomical challenges.

Tips and Tricks: Management

- For thermal or clamping injuries, place a ureteral stent and Foley catheter for 10–14 days.

Table 6 Ureteral complications, management, and safety rules

Aspect	Details
Incidence	Overall incidence 0–2.2% Common sites: pelvic brim (42%), near cervix (uterine artery crossing)
Causes	Risk factors: deep endometriosis, large uteri, hysterectomies, excessive bleeding Misidentification of ureter anatomy
Risks	Thermal damage Obstruction or stenosis Ureteral fistula and devascularization
Diagnosis	Use cystoscopy for suspected injuries near ureteral ostium Verify ureteral peristalsis and course intraoperatively
Management	**Details**
Thermal or clamping injuries	Ureteric stenting for 6–8 weeks and catheter insertion for 10–14 days
Extensive injuries	Injury within 5 cm of the ureteral ostium: ureteral resection and reanastomosis to bladder with tension relief Injury up to 5 cm: anastomosis with ureteral stent
Diagnostic tools	Use imaging (CT or cystography) to detect scarring or associated lesions Consider exploratory surgery if noninvasive methods fail
Safety measure	**Details**
Isolate critical structures	Identify the ureter early, especially at the pelvic brim Use fenestration of the broad ligament for better visualization
Precise coagulation	Coagulate the uterine artery at a 90° angle using the lateral trocar to ensure safety
Monitor ureteral course	Check ureteral peristalsis and integrity intraoperatively if lesions are suspected

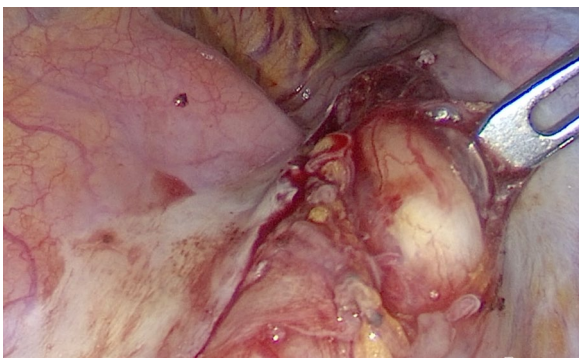

Fig. 5 Ureteral thermal injury. The whitening of the tissue along with the blockage of the vermiculation is pathognomonic and a preventive double J stent insertion is required to avoid subsequent fistula or perforation

- In cases of extensive devascularization or loss of peristalsis, consider ureteral resection or alternative techniques like reimplantation or anastomosis.
- For injuries within 5 cm of the ureteral ostium, perform ureter reimplantation with an anastomosis secured to the psoas muscle to reduce tension.
- When damage is beyond 5 cm from the bladder, opt for diagonal ureter resection and stent-supported anastomosis.
- Tailor the approach based on injury location and the presence of other pelvic diseases to minimize long-term complications.

VASCULAR COMPLICATIONS

Vascular complications (0.04–0.5% incidence) are the leading cause of mortality in laparoscopic surgery. However, their true incidence may be underestimated as a result of unreported non-lethal cases [73].

Johnson et al. [74] and King et al. [75] identify prior abdominal surgery and adhesions as key risk factors for trocar-related injuries to bowel or major vessels (e.g., mesenteric vessels). King's systematic review [75] found the most vascular injury (82%) occurred during abdominal entry, with the right iliac artery particularly vulnerable because of its proximity to the umbilicus [76]. The remaining 18% occur during dissection or accidental perforation [21]. Most major vascular injuries (93%) are recognized intraoperatively, with 55% requiring laparotomic repair. Inferior epigastric vessels are the most injured (48%), followed by iliac vessels (common, external, and internal), inferior vena cava and aorta, the last of which are rarely involved because of their retroperitoneal position [21, 76]. Rare but severe, aortic or common iliac injuries may lead to massive bleeding, hypotension, and hemorrhagic shock (Shaikh et al.) [76].

Mesenteric vessel management is challenging because of rapid retraction post coagulation and fat embedding. Early removal of omental adhesions may help mitigate these risks. Inferior epigastric vessel injuries are common during lateral trocar insertion [77, 78], particularly with pyramidal or cutting trocars, for their width and sharp tip. In a study by Wong et al. [52], 0.44% of vascular injuries involve inferior epigastric vessels and occur during the conversion from laparoscopy to laparotomy. Furthermore, veins, especially the common iliac vein, are more vulnerable because of their thin walls (more than arteries) and position, particularly during lymph node dissection and colposacropexy [21].

While major vessel damage is rare during laparoscopy, it remains a significant concern, underscoring the importance of meticulous technique and awareness of anatomical risks.

Safety Rules and Management of Vascular Complications

Safety Rules

To prevent laparoscopic entry injuries, surgeons must ensure proper intraperitoneal placement of instruments (Veress needle, trocars, etc.). Maintaining 12–14 mmHg intraabdominal pressure and minimizing needle manipulation are essential [79, 80]. Prompt recognition of mesenteric vessel injuries is essential to prevent hematoma formation. Dissection or ligature can be employed to manage these lesions; in any case, hemostasis must preserve bowel vascularization to avoid intestinal ischemia.

Place lateral trocars 2–3 cm above the superior iliac spine (safety zone) to avoid superficial epigastric vessels (visible via transillumination) and deep epigastric arteries (seen with central optics) (Fig. 6). Using conical tip trocars or dilating trocars can reduce the risk of epigastric vessels injury [79].

Blunt-tip trocars reduce but do not eliminate vessel injury risk. The occurrence of vascular complications largely depends on the entry technique rather than the trocar type alone. Proper training in entry techniques and adherence to safety protocols minimize risks. Additionally, careful anatomical assessment, including the use of imaging in high-risk cases, can further reduce the likelihood of vascular injuries during trocar insertion.

Tips and Tricks: Safety Rules

- Ensure proper training in laparoscopic entry techniques to minimize vascular injury risks.
- Maintain an optimal intraabdominal pressure of 12–14 mmHg to reduce vascular exposure.
- Use transillumination to locate superficial epigastric vessels before lateral trocar placement.
- Place lateral trocars in the safety zone (2–3 cm above the superior iliac spine) to avoid superficial epigastric vessels, using transillumination for identification of superficial epigastric vessels and direct visualization for deep epigastric arteries.

– Opt for conical or dilating trocars to minimize vessel trauma. Blunt-tip trocars reduce vessel trauma, but entry technique is more critical than trocar type.
– Promptly recognize mesenteric vessel injuries to prevent hematoma or ischemia, prioritizing hemostasis without compromising bowel vascularization.
– In cases of adhesions, perform early removal of omental or peritoneal adhesions to improve visibility and avoid inadvertent vascular injuries.

Management

For epigastric vessels damage, use laparoscopic upstream and downstream sutures or insert a Foley catheter in the trocar site for mechanical hemostasis (the balloon is filled up with water and is blocked with a laparotomic grasper).

Major vessel damage requires immediate laparotomy for optimal management. Iliac vessel injuries instead can be managed laparoscopically by clamping both tear edges and suturing with 4/0–6/0 non-absorbable thread. In an emergency, hypogastric vessels or uterine arteries may be sacrificed or clamped, while preventive dissection of vital structures (e.g., ureter, uterine artery) reduces bleeding risk. The uterine artery can be identified by ligating the obliterated umbilical artery, which is the first anterior branch of the hypogastric artery. Laparoscopic lateral uterine artery ligation is advised for broad or cardinal ligament bleeding. Table 7 summarizes vascular complications and their management and safety rules.

Tips and Tricks: Management

– Epigastric vessel injury: Manage damage to inferior epigastric vessels by laparoscopically suturing upstream and downstream tears or inserting a Foley catheter into the trocar site to achieve mechanical hemostasis. Inflate the balloon with water and secure it with a laparotomic grasper.
– Convert to laparotomy immediately in cases of major vascular bleeding to ensure optimal hemostasis.
– Recognize iliac vessel injuries early—right iliac artery is the most vulnerable during laparoscopic access.
– For iliac vessel injuries, clamp both ends of the tear and suture laparoscopically with non-absorbable 4/0–6/0 thread.
– Sacrifice minor vascular branches, if necessary, but ensure preservation of critical structures.
– Temporarily clamp or sacrifice hypogastric vessels or uterine arteries in emergencies to control bleeding, while prioritizing patient stability.
– Perform laparoscopic lateral ligation of the uterine artery for bleeding in the broad or cardinal ligament areas.

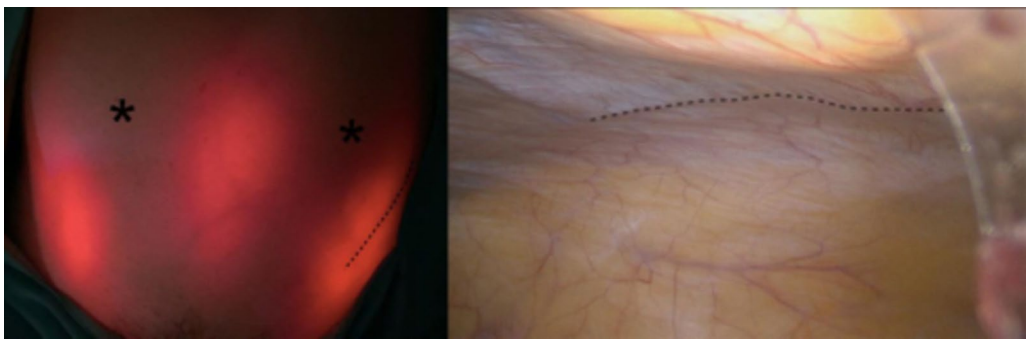

Fig. 6 Abdominal wall vessels. The left-side image shows the transillumination of abdominal wall with recti muscles (*) and the safety zones (lightened area). The right-side image shows the endoabdominal vision. The inferior epigastric artery is marked with the dotted line, the safety zone is the gray avascular zone lateral to the epigastric vessel

Table 7 Vascular complications, management, and safety rules

Aspect	Details
Incidence	0.04–0.5%, potentially underestimated because of unreported non-lethal injuries Major vascular injuries are rare but life-threatening
Causes	*Trocar insertion*: Right iliac artery is highly vulnerable (82% of injuries occur during abdominal entry) *Surgical dissection*: 18% of cases
Common sites	Inferior epigastric vessels (48%) Iliac vessels (common, external, internal) Inferior vena cava and aorta (rare but critical)
Risk factors	Previous abdominal surgeries, adhesions, or anatomical distortion Use of sharp or pyramidal trocars
Type of injury	Management
Minor vessel injuries	Sutures placed upstream and downstream of the injury site Foley catheter balloon inserted into trocar site for mechanical hemostasis
Major vessel injuries	Immediate conversion to laparotomy for better access Clamp both ends of the tear and suture with 4/0–6/0 non-absorbable thread
Mesenteric vessel damage	Prompt dissection or ligation to achieve hemostasis, ensuring bowel vascularization to prevent ischemia
Epigastric vessel injury	Identify vessels via transillumination (superficial) or optic (deep) Use upstream/downstream laparoscopic sutures to stop bleeding
Broad ligament bleeding	Laparoscopic lateral ligation of the uterine artery
Critical artery injuries	Temporary clamping of hypogastric or uterine arteries to control bleeding in emergencies
Safety measures	Rationale
Proper training	Ensure correct use and placement of instruments like Veress needles and trocars
Optimal trocar positioning	Insert lateral trocars 2–3 cm above the superior iliac spine to avoid superficial epigastric vessels (use transillumination for guidance)
Use of safe instruments	Prefer conical-tip or dilating trocars to minimize vessel damage during insertion
Maintain intraabdominal pressure	Keep pressure between 12–14 mmHg to stabilize tissues and prevent inadvertent movements
Key points on recognition and mitigation	
Aspect	Details
Recognition	Mesenteric vessel damage often masked as a result of fat tissue; early removal of omental adhesions aids in visualization
Emergency response	For uncontrolled hemorrhage, rapid laparotomy is critical to prevent shock Identify and isolate critical structures like the uterine artery

Table 7 continued

Preventive measures	Dissect and isolate vital structures (ureters, uterine arteries) before performing high-risk maneuvers

- Dissect vital structures (ureter or uterine artery) in advance to reduce the risk of bleeding during high-risk procedures.
- Identify the uterine artery by locating and ligating the obliterated umbilical artery, which is the first anterior branch of the hypogastric artery.

DISCUSSION

Study Biases and Limitations

The narrative review approach offers flexibility in synthesizing diverse sources but also has limitations, particularly regarding study selection biases and data heterogeneity. To address this, we prioritized high-quality evidence and transparently detailed our selection process. However, future systematic reviews may provide more rigorous validation of these findings.

Study results may be influenced by various biases. Variability in surgical experience among participants, discrepancies in complication reporting and definitions, and geographic or institutional differences in patient populations and surgical techniques can all impact the outcomes. For example, the study by Karaman et al. [58] reflects practices in a single institution, which may not be generalizable, while older studies like Levinson (1974) [27] may not account for advancements in laparoscopic techniques.

Data inconsistencies, particularly regarding trocar insertion techniques and complications, were observed. Studies like Ahmad et al. [20] and Raimondo et al. [26] highlight the lack of consensus on the optimal insertion method, underscoring the need for further research. Finally, differences in findings across regions or healthcare systems further emphasize the need for caution in interpreting the data, as they may reflect variations in patient demographics, healthcare resources, and surgical practices.

Controversies and Debate in Gynecological Surgery Practices

Gynecological laparoscopic surgery has advanced significantly, yet several aspects of intraoperative management remain debated as a result of conflicting evidence on best practices. One key controversy is the choice between the Veress needle and Hasson open entry techniques. The Veress needle allows faster access but carries a higher risk of bowel and vascular injuries, especially in patients with prior abdominal surgery [81]. The Hasson technique reduces these risks but is linked to longer procedural times and port-site hernias [82]. A meta-analysis by Ahmad et al. [20] found no significant difference in major complications, emphasizing the need for patient-specific selection.

The use of Palmer's point for laparoscopic entry in patients with adhesions is another debated topic. While it lowers the risk of bowel and vascular injuries, it presents technical challenges, such as difficult trocar placement. A vacuum-assisted device has been proposed as an alternative, but its efficacy remains under investigation [83]. The choice of entry site depends on surgeon expertise and intraoperative factors.

Prophylactic ureteral stenting is also controversial. While some advocate for routine use to prevent injuries, others highlight increased infection risk and prolonged operative time without significant reduction in injury rates [84]. A retrospective analysis by Wong et al. [85] found no significant difference in ureteral injury rates, supporting a selective approach [52].

Intraoperative bleeding management remains debated. Advanced hemostatic agent (e.g., fibrin sealants) may aid hemostasis, but some studies find traditional methods (bipolar coagulation, suturing) equally effective and more

cost-efficient [86]. The literature provides mixed evidence; therefore case-specific application is recommended [25, 30]. Similarly, advanced bipolar technology is promoted as a safer alternative to traditional electrosurgical devices for reducing thermal damage, but its superiority and cost-effectiveness remain unproven [86]. The role of adhesion barriers is also uncertain. Some studies support their use, particularly in endometriosis surgery, citing reduced postoperative adhesions [87, 88]. However, concerns about cost-effectiveness and potential inflammatory reactions persist [89, 90].

These debates underscore the complexity of optimizing laparoscopic gynecological surgery. A tailored approach, guided by patient-specific factors and robust comparative evidence, is essential. Further large-scale trials are needed to establish best practices and address existing knowledge gaps.

CONCLUSION

Although entry complications in laparoscopic gynecological surgery cannot always be prevented because of the anatomical variations and previous surgeries, adherence to safety rules minimizes risks of injuries. Surgeons should use the trocar insertion technique they are most proficient in. Lateral trocar placement must respect the safety zone to prevent iliac vessels injury, and optical trocar should be directed towards the pelvis to avoid major vessel damage. Bowel injuries, a common occurrence detected during the intervention in approximately one-third of the cases, necessitate thorough abdominal inspection post surgery. Bladder lifting, uterine manipulation, and ureter identification (mostly injured at the pelvic brim) enhance laparoscopic safety.

Future research should address long-term laparoscopic outcomes, particularly in complex cases, and develop predictive models for high-risk patients. Robotic-assisted surgery and advanced imaging show promise in improving precision and safety, requiring further study for routine use. Regular updates to international guidelines and multicenter trials are crucial to validate innovations, ensure reproducibility, and standardize practices, driving the continued advancement of laparoscopic surgery in gynecology.

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Declarations

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Ethical Approval. This narrative review article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

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