

Anaesthesia for laparoscopic surgery



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Key points

Laparoscopic surgery has many benefits for patients, including reduced postoperative pain and fewer wound-related complications.

Generation of a pneumoperitoneum induces significant physiological changes which must be appreciated, and compensated for, to avoid adverse outcomes.

Specific groups may benefit from laparoscopic techniques such as obese patients or individuals with severe respiratory disease.

Complications may have an insidious onset and all organizations undertaking laparoscopic surgery should have locally devised protocols to ensure staff recognize and rapidly act upon deteriorating patients after operation.

Laparoscopic techniques offer major benefits to the patient such as minimized incision size and trauma with reduced postoperative discomfort, shortened recovery rates, and a lower incidence of postoperative wound infections. These factors all contribute to shorter in-patient stay and reduced perioperative morbidity. Consequently, many major procedures that once required prolonged postoperative recovery such as anterior resection of the rectum or radical cystectomy are now increasingly performed using laparoscopic techniques to improve patient outcomes.¹

However, laparoscopic surgery is not without its own specific risks, either due to the risks associated with individual laparoscopic techniques or due to the physiological changes associated with the creation of a pneumoperitoneum. As a result, anaesthetic techniques for laparoscopic surgery must be refined to anticipate these differences from open surgery.

Benefits of laparoscopic surgery

A major benefit of laparoscopic surgery is the shortened recovery time after major surgery (Table 1). Reasons for this are multi-factorial: the laparoscopic approach reduces manipulation of the bowel and peritoneum, resulting in decreased incidence of postoperative ileus. Therefore, enteral intake can be resumed more rapidly than with open surgical techniques, limiting requirements for i.v. fluid regimes which are associated with tissue oedema, poor wound repair, and prolonged postoperative recovery.

Secondly, because small access points are required for the insertion of laparoscopic trocars, large incisions such as those seen in open procedures are avoided, thereby minimizing complications associated with postoperative pain and wound healing. As laparoscopic techniques have evolved, the number of port sites required has been reduced, with single-port surgery now a viable option. These factors contribute to the reduced incidence of both wound

and systemic infections demonstrated after laparoscopic surgery.²

These benefits are particularly useful in several patient groups. Laparoscopic surgery is useful in obese patients in whom open procedures would be technically very challenging and who are particularly susceptible to wound infections after operation. An example of this is in bariatric surgery where laparoscopic gastric banding has improved short-term mortality rates compared with traditional open techniques.³

Other groups of patients who benefit from a laparoscopic approach include those with severe respiratory disease as the postoperative deterioration in respiratory function that may occur after large incisions with suboptimal analgesia is avoided.

Risks and contraindications for laparoscopic surgery

The risks associated with laparoscopic surgery may be categorized as patient-specific, surgical, positional, or those associated with altered physiology secondary to the generation of pneumoperitoneum.

Laparoscopic surgery should never be dismissed as 'routine' or 'low risk' since complications tend to be more insidious compared with traditional open techniques. A recent National Patient Safety Agency (NPSA) report identified 48 serious incidents after laparoscopic surgery over a 7 yr period, including 11 deaths, and concluded that all organizations undertaking laparoscopic surgery should have local protocols to ensure that staff recognize and rapidly act upon deteriorating patients after operation.⁴

Patient-specific contraindications

Laparoscopic surgery has traditionally been contraindicated in patients with severe ischaemic heart disease, valvular disease, significant renal dysfunction, or end-stage respiratory disease. However, the risk to the individual

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Table 1 Risks and benefits of laparoscopic surgery

Benefits	Risks
Reduced wound infection	Visceral and vascular damage
Faster recovery	Complications associated with extremes of positioning
Reduced morbidity	Acute kidney injury
Reduced pain	Cardiocerebral vascular insufficiency
	Pulmonary atelectasis
	Venous gas embolism
	'Well leg compartment syndrome'

patient must be balanced between the risk of complications due to the position, duration, degree of carbon dioxide (CO₂) absorption, and physiological effects of pneumoperitoneum for a particular laparoscopic procedure vs the shortened postoperative recovery time which may outweigh the increased intraoperative risk. Generally accepted contraindications include pre-existing raised intracranial pressure, severe uncorrected hypovolaemia, and patients with known right-to-left cardiac shunts or patent foramen ovale.

Surgical risks

The insertion of large trocars into the abdominal cavity, frequently without direct vision, carries the potential for damage to solid viscera, bowel, bladder, or blood vessels. Although vascular injury within the pneumoperitoneum is usually apparent immediately, venous tamponade may occur with pneumoperitoneum, masking apparent bleeding. Furthermore, retroperitoneal haematomas are often insidious in nature and diagnosis may be delayed until the postoperative period, allowing significant haemorrhage to occur.

Venous gas embolism can result in catastrophic circulatory collapse and may be caused by direct trocar insertion into a vessel, or inadvertent inflation of a solid organ, and usually occurs as gas insufflation commences. The severity depends on the volume of CO₂ injected, rate of injection, patient position, and type of laparoscopic procedure. Fortunately, compared with venous air embolism, the risks are somewhat lower due to the increased solubility and rapid absorption of CO₂.

Positioning

Patient positioning is determined by the view that the surgeon is trying to optimize, but often involves the extremes of the Trendelenburg or reverse Trendelenburg position with significant physiological effects. Extreme positions place the patient at risk of movement on the table, so meticulous attention must be paid to ensure that the patient is securely positioned with vulnerable pressure points and eyes being protected throughout the procedure.

Prolonged steep Trendelenburg position increases the risk of cerebral oedema, in addition to the risk associated with the pneumoperitoneum (see below), and upper airway oedema which may present with stridor after operation. Functional residual capacity and ventilation and perfusion (V/Q) mismatch are worsened, and

with cephalad movement of the lungs, the tracheal tube may migrate endobronchially.

One rare but devastating complication of prolonged surgery in the steep Trendelenburg position is the onset of 'well leg compartment syndrome' induced by the combination of impaired arterial perfusion to raised lower limbs, compression of venous vessels by lower limbs supports, and reduced femoral venous drainage due to the pneumoperitoneum. The resultant compartment syndrome of the lower limbs presents after operation with disproportionate lower limb pain, rhabdomyolysis, and potentially myoglobin-associated acute renal failure leading to significantly increased morbidity and mortality.

Risk factors include surgery >4 h duration, muscular lower limbs, obesity, peripheral vascular disease, hypotension, and steep Trendelenburg positioning.⁵ Risks may be mitigated by avoiding intermittent compression stockings, moving the patient's legs at regular intervals during surgery, and using heel/ankle supports instead of calf/knee supports (Lloyd–Davies stirrups). For prolonged surgery, at the authors' institution, the patient is returned to the horizontal position at least every 2 h and the lower limbs are massaged for 5–10 min before returning to the Trendelenburg position. A pulse oximeter is also placed on the great toe throughout surgery to assess the adequacy of pulsatile flow to distal areas of the lower limbs.

In the reverse Trendelenburg position, the extreme 'head-up' posture results in reduced venous return, leading to hypotension and potentially myocardial and cerebral ischaemia. Particularly vulnerable are the elderly, hypovolaemic patients, and those with pre-existing ischaemic heart disease or cerebrovascular disease.

Altered physiology of pneumoperitoneum

Intra-abdominal laparoscopic surgery requires the intentional generation of a pneumoperitoneum using insufflated carbon dioxide to enable sufficient visualization for the procedure to be performed. As the volume of the abdomen increases, abdominal wall compliance decreases and intra-abdominal pressure (IAP) climbs. When the IAP exceeds physiological thresholds, individual organ systems become compromised, potentially increasing patient morbidity and mortality, particularly in those patients with relevant co-morbidities.

Cardiovascular effects

As IAP increases, systemic vascular resistance (SVR) is increased due to both mechanical compression of the abdominal aorta and production of neurohumoral factors such as vasopressin and activation of the renin–angiotensin–aldosterone axis. Compression of the inferior vena cava reduces preload and may lead to a decrease in cardiac output and subsequent decrease in arterial pressure, particularly if the patient is hypovolaemic. This may be exacerbated by the cephalad displacement of the diaphragm which raises intra-thoracic pressure with further reduction in blood flow through

the inferior vena cava, and compression of pulmonary parenchyma which increases pulmonary vascular resistance, further reducing cardiac output.

Reverse Trendelenburg positioning may also result in hypotension due to the reduction in preload by venous pooling in the lower limbs and pelvis which in turn is exacerbated by reduced femoral venous flow secondary to raised IAP.

Respiratory effects

Respiratory changes occur due to raised IAP and Trendelenburg positioning. As the abdomen is distended by CO₂, diaphragmatic excursion is limited resulting in raised intra-thoracic pressure, reduced pulmonary compliance, and reduced functional residual capacity which in turn leads to pulmonary atelectasis, altered V/Q relationships, and hypoxaemia. During surgery, insufflated CO₂ is absorbed, causing an increase in P_{CO2} which is further exacerbated by V/Q mismatch.

Splanchnic effects

Blood flow to the kidney and liver is significantly compromised with increasing IAP and this should be an important consideration in patients with existing disease when determining suitability for laparoscopic surgery.

Persistent IAPs over 20 mm Hg will cause a reduction in mesenteric and gastrointestinal mucosal blood flow by up to 40% with progressive tissue acidosis developing as pressure increases.

The renal effects of pneumoperitoneum are significant and raised IAP is recognized as an independent cause of acute kidney injury. An IAP of 20 mm Hg will reduce GFR by ~25%. The mechanism for this is postulated to be an impaired renal perfusion gradient secondary to the combined effect of reduced renal afferent flow due to impaired cardiac output and reduced efferent flow due to raised renal venous pressure.

Neurological effects

An elevated IAP causes an increase in intra-cerebral pressure (ICP) by limiting cerebral venous drainage as a consequence of raised intra-thoracic pressure. While clinical studies have suggested that cerebral perfusion pressure is maintained by the increase in mean arterial pressure that occurs with elevated IAP, the increase in ICP may lead to cerebral oedema. This contributes to the temporary neurological dysfunction that patients often experience on emergence from prolonged laparoscopic procedures, particularly those requiring extended periods of steep Trendelenburg positioning.

Conduct of anaesthesia

All patients for laparoscopic surgery should be fully assessed before operation, particularly those at elevated risk of complications from pneumoperitoneum, and the probability of conversion

to an open procedure considered when choosing the anaesthetic technique.

Perioperative management

Airway

The most common technique for airway management involves placement of a cuffed oral tracheal tube (COTT), neuromuscular relaxation, and positive pressure ventilation. This protects against gastric acid aspiration, allows optimal control of CO₂, and facilitates surgical access. It is recommended that bag and mask ventilation before intubation should be minimized to avoid gastric distension and the insertion of a nasogastric tube may be required to deflate the stomach, not only to improve surgical view but also to avoid gastric injury on trochar insertion.

The use of the laryngeal mask airway (LMA) in laparoscopic surgery remains controversial due to the increased risk of aspiration and difficulties encountered when trying to maintain effective gas transfer while delivering the higher airway pressures required during pneumoperitoneum. Despite these concerns, there have been several randomized controlled trials assessing the use of Proseal LMA (PS-LMA) vs COTT with data advocating the PS-LMA as effective and efficient for pulmonary ventilation in laparoscopic surgery.⁶

Ventilation

Both pneumoperitoneum and steep Trendelenburg positioning inhibit effective ventilation during laparoscopic surgery. Traditional volume control modalities use constant flow to deliver a pre-set tidal volume and ensure an adequate minute volume at the expense of an increased risk of barotrauma and high inflation pressures, particularly in obese patients. The use of pressure-controlled modalities affords higher instantaneous flow peaks, minimizing peak pressures, and have been shown to provide improved alveolar recruitment and oxygenation in laparoscopic surgery for obese patients. The addition of titrated levels of PEEP can be used to minimize alveolar de-recruitment, but this must be used cautiously as increasing PEEP may further compromise cardiac output in addition to the effects of pneumoperitoneum.

Analgesia

A major advantage of laparoscopic surgery is reduced postoperative stay and the need for high-quality analgesia is essential to prevent delayed hospital discharge. By the nature of minimally invasive surgery, the pain is often short, yet intense, and up to 80% of patients will require opioid analgesia at some stage perioperatively. The use of regional techniques such as subdural, epidural, and more recently transversus abdominis plane block, are increasingly utilized as opiate-sparing techniques, particularly in laparoscopic techniques where larger incisions are required.⁷ Wound infiltration with local anaesthetic is useful and reduces postoperative analgesic requirements while intraperitoneal levobupivacaine reduces postoperative pain and opiate requirements.⁸

Dexamethasone has also been suggested before induction to reduce subsequent opiate analgesia requirements in the first 2 h after laparoscopic hysterectomy in addition to its anti-emetic effects.⁹

Antiemetics

Laparoscopic surgery has a high incidence of postoperative nausea and vomiting and this can be very distressing, worsen pain, and extend the period of hospital admission for patients. Therefore, prophylaxis is important, particularly in patients with other risk factors. As with open surgery, multi-modal regimes such as ondansetron, cyclizine, and dexamethasone seem most effective in addition to general measures such as deflating the stomach, avoiding known emetogenic drugs, for example, opiates and ensuring good quality postoperative analgesia.¹⁰

Monitoring

As surgical techniques develop, major procedures are now being performed laparoscopically and may last several hours, with significant physiological disturbances to the patient and limited access once surgery has commenced. The effects of pneumoperitoneum on the respiratory system can be assessed using capnography and pulse oximetry, supported by information available on modern anaesthetic machines such as peak and plateau airway pressures, delivered tidal volumes, and observing dynamic flow-volume loops.

Most anaesthetists advocate the use of invasive arterial monitoring during prolonged surgery, particularly in those patients with cardiovascular co-morbidities. Accurate assessment of preload is particularly challenging, however, due to the effects of raised IAP and subsequently intra-thoracic pressure on cardiac filling pressures. Therefore, pressure-based indices of preload such as central venous pressure may be misleading while commercially available minimally invasive devices such as the oesophageal Doppler monitor (ODM™) or LiDCO™ (lithium dilution cardiac output monitor) may provide more accurate assessments of preload in these circumstances.¹¹ Haemodynamic instability is best treated by optimizing preload with fluid and judicious use of vasoactive drugs. Since SVR is normally raised by the compressive effect of raised IAP on the abdominal aorta, inotropic drugs such as ephedrine are often more effective than vasopressors such as metaraminol.

Postoperative management

Pain will usually be maximal during the first 2 h post-procedure and a prolonged duration of significant discomfort is rare and should raise the possibility of additional complications. Postoperative shoulder-tip pain after laparoscopic surgery is common but may be reduced if the surgeon expels as much gas from the peritoneal cavity as possible.¹²

All patients should receive supplemental oxygen while in recovery to mitigate the effects of pneumoperitoneum on respiratory function. Alveolar recruitment techniques, using short-term continuous positive airway pressure or high flow oxygen delivery systems such as Vapotherm™, are occasionally required after

operation, particularly in patients with existing respiratory disease or those having prolonged surgery.

Conclusion

Over the last 30 yr, anaesthesia for laparoscopic surgery has developed and advanced significantly resulting in a technique that minimizes many of the risks, complications, and prolonged duration of hospital stay of open surgery. The proportion of surgical cases performed laparoscopically will continue to increase and anaesthetists must understand and safely manage the specific physiological alterations, risks, and practical challenges that laparoscopy presents.

Conflict of interest

None declared.

References

1. Veldkamp R, Kuhry E, Hop WC *et al*. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. *Lancet Oncol* 2005; **6**: 477–84
2. Varela JE, Wilson SE, Nguyen NT. Laparoscopic surgery significantly reduces surgical-site infections compared with open surgery. *Surg Endosc* 2010; **24**: 270–6
3. Burns EM, Naseem H, Bottle A *et al*. Introduction of laparoscopic bariatric surgery in England: observational population cohort study. *Br Med J* 2010; **341**: c4296
4. NPSA/2010/RRR016 Laparoscopic surgery: Failure to recognise post-operative deterioration. September 2010. Available from <http://www.nrfs.npsa.nhs.uk/resources/?EntryId45=82748>
5. Simms MS, Terry TR. Well leg compartment syndrome after pelvic and perineal surgery in the lithotomy position. *Postgrad Med J* 2005; **81**: 534–6
6. Lim Y, Goel S. Proseal is effective alternative to laryngoscope guided tracheal intubation. *Anaesth Intensive Care* 2007; **35**: 52–6
7. Conaghan P, Maxwell-Armstrong C, Bedford N *et al*. Efficacy of trans-versus abdominis plane blocks in laparoscopic colorectal resections. *Surg Endosc* 2010; **24**: 2480–4
8. Papadima A, Lagoudianakis EE, Antonakis P *et al*. Repeated intraperitoneal instillation of levobupivacaine for the management of pain after laparoscopic cholecystectomy. *Surgery* 2009; **146**: 475–82
9. Jokela RM. The effective analgesic dose of dexamethasone after laparoscopic hysterectomy. *Anesth Analg* 2009; **109**: 607–15
10. Naguib M, El Bakry AK, Koshim MH *et al*. Prophylactic antiemetic therapy with ondansetron, tropisetron, granisetron and metoclopramide in patients undergoing laparoscopic cholecystectomy; a randomized double blind comparison with placebo. *Can J Anaesth* 1996; **43**: 226–31
11. Koliopoulos A, Zografos G, Skiathitis S *et al*. Esophageal Doppler (ODM II) improves intraoperative hemodynamic monitoring during laparoscopic surgery. *Surg Laparosc Endosc Percutan Tech* 2005; **15**: 332–8
12. Phelps P, Cakmakaya OS, Apfel CC *et al*. A simple clinical maneuver to reduce laparoscopy induced shoulder pain: a randomized controlled trial. *Obstet Gynaecol* 2008; **111**: 1155–60

Please see multiple choice questions 21–24.