

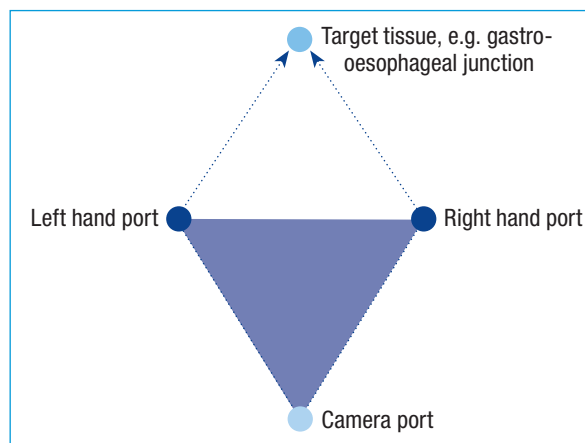
# Anaesthesia for laparoscopic surgery

**Laparoscopic surgery has become increasingly common with reduced postoperative pain and faster recovery. Clinicians managing patients undergoing abdominal laparoscopic surgery should appreciate the physiological changes which mainly arise from patient positioning and the effects of pneumoperitoneum.**

Laparoscopic techniques are increasingly becoming a mainstay of surgical management. The technique consists of a minimal surgical incision to form a camera port, insufflation of the abdomen with carbon dioxide (CO<sub>2</sub>) and the placement of further port sites under direct camera vision to facilitate the entry of laparoscopic instruments (Veitch and Mahendran, 2013) (Figure 1).

Laparoscopic surgery offers numerous benefits to the patient including improved cosmetic results from smaller incisions, improved perioperative morbidity, reduced postoperative pain and faster recovery (Veldkamp et al, 2005). The use of laparoscopic techniques has also been associated with overall shorter inpatient stay and a reduction in health-care costs (Twaij et al, 2014). This review discusses

**Figure 1. Examples of port site positions in laparoscopic abdominal surgery. Adapted from Veitch and Mahendran (2013).**



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the physiological changes and anaesthetic considerations of laparoscopic surgery. These are mainly the result of the effects of patient positioning, pneumoperitoneum and surgical instruments.

## Background

Anaesthetists should be aware that laparoscopic surgery presents a unique set of risks to patients that require a clear understanding of the practical and physiological changes associated with the surgical techniques, patient positioning and induction of pneumoperitoneum involved with laparoscopy. The patient population undergoing various laparoscopic procedures now encompass a range of body mass indices and concurrent comorbidities. Diligence is therefore required to optimize and stabilize patients preoperatively, intraoperatively and postoperatively.

While laparoscopy has many benefits, it is not without risk. The benefits of laparoscopy (Table 1), its smaller incisions and faster recovery need to be balanced against its associated risks, mainly the physiological changes from the changes in patient position and induction of pneumoperitoneum. For certain procedures the benefits of laparoscopy may outweigh the intraoperative risks. Absolute contraindications to laparoscopy are rare but relative contraindications include severe ischaemic or valvular heart disease, raised intracranial pressure and uncorrected hypovolaemia.

## Pneumoperitoneum

In order to facilitate intra-abdominal laparoscopic surgery, a pneumoperitoneum needs to be created.

**Table 1. Benefits of laparoscopic surgery**

|   |
|---|
| Smaller incisions – improved cosmetic results |
| Shortened recovery time                       |
| Reduced postoperative pain                    |
| Reduced perioperative morbidity               |
| Less postoperative wound infection            |
| Shorter in patient stay in hospital           |
| Reduced health-care costs                     |

Pneumoperitoneum is the insufflation of the peritoneal cavity with gas, usually CO<sub>2</sub>, which facilitates surgical visualization within the abdomen. CO<sub>2</sub> is a clear, non-flammable soluble gas. Intra-abdominal pressure is raised by an initial gas flow of 4–6 litres/min; this generates an intra-abdominal pressure of 10–20 mmHg. A gas flow of 200–400 ml/min is continued to maintain the intra-abdominal pressure. The aim is to keep intra-abdominal pressure below 15 mmHg as the clinical consequences of an elevated intra-abdominal pressure, including mild renal and pulmonary derangement, begin to occur at pressures between 15 and 25 mmHg (Nguyen et al, 2001).

The increase in intra-abdominal pressure results in physiological responses that may be undesirable, especially for vulnerable patient groups with limited physiological reserve. However, these changes can be carefully managed so as to reduce patient morbidity during the intraoperative and postoperative phases.

### Patient positioning in laparoscopic surgery

A number of patient positions may be used for laparoscopic surgery. Trendelenburg (head down), reverse Trendelenburg (head up), lithotomy and lateral positions are often used to aid surgical access. Individuals with high body mass index, severe cardiac and respiratory disease, and the elderly may be particularly vulnerable to extreme changes in position and the associated cardiorespiratory physiological changes caused by their already compromised organ function.

#### Trendelenburg position

The Trendelenburg position decreases functional residual capacity. When used in conjunction with a pneumoperitoneum, the Trendelenburg position further decreases the functional residual capacity, possibly to values less than the closing capacity, causes airway collapse and leads to atelectasis. The atelectasis can exacerbate any already existing ventilation–perfusion mismatch. The addition of positive end expiratory pressure during ventilation can help prevent this. Diaphragmatic splinting increases intrathoracic pressure and reduces compliance. Endobronchial intubation or dislodging of the airway may occur with cephalad movement of the lungs, and upper airway oedema may also occur with repeated movement of the endotracheal tube. The Trendelenburg position may also cause increased intracranial pressure, cerebral oedema and sub-conjunctival chemosis, all of which are exacerbated by the hypercapnia from absorption of CO<sub>2</sub> from the pneumoperitoneum.

#### Reverse Trendelenburg position

The Reverse Trendelenburg position may improve ventilation–perfusion mismatch, reduce intracranial pressure and decrease the likelihood for passive regurgitation. However, it can cause a decrease in venous return resulting in hypotension and potentially cerebral and cardiac ischaemia in vulnerable patients, so any pre-existing hypovolaemia should be corrected preoperatively.

“ The increase in intra-abdominal pressure results in physiological responses that may be undesirable, especially for vulnerable patient groups with limited physiological reserve. ”

#### Lithotomy position

Lithotomy positioning in patients undergoing prolonged laparoscopic surgery has been associated with the rare but significant complication ‘well leg compartment syndrome’. This syndrome is associated with high body mass index, significant blood loss, hypotension and peripheral vascular disease. It presents with severe postoperative lower limb pain, rhabdomyolysis and potentially acute kidney injury and myoglobinuria (Hayden and Cowman, 2011).

#### Lateral position

The lateral position has been associated with the highest incidence of ocular complications, including corneal abrasions in both eyes. Care must also be taken to make sure excessive pressure is not applied to the head, neck and axilla to avoid brachial plexus injury (Knight and Mahajan, 2004).

It is vital to ensure that all pressure points are protected and that the eyes are taped closed. Positions may be changed during protracted surgery, especially Trendelenburg and lithotomy. There are further practical considerations for laparoscopic surgery as the patient must be securely positioned on the table to prevent any movement during changes in position to facilitate surgery. This is often done by way of shoulder supports and strapping the patient to the table. The patient’s arms are often secured to the patient’s sides to help secure the patient on the table and avoid any hindrance to the surgeons operating by the arm board supports. This necessitates that all vascular access be confidently secure before the operation as access during the procedure may be difficult. The physiological effects of patient positions are summarized in *Table 2*.

**Table 2. Physiological effects of positioning**

|                                      | Trendelenburg (head down) | Reverse Trendelenburg (head up) |
|--------------------------------------|---------------------------|---------------------------------|
| Venous return                        | ↑                         | ↓                               |
| Cardiac output                       | ↑                         | ↓                               |
| Functional residual capacity         | ↓                         | ↑                               |
| Chest compliance                     | ↓                         | ↑                               |
| Ventilation–perfusion (V/Q) mismatch | ↑                         | ↓                               |
| Atelectasis                          | ↑                         | ↓                               |

### 66 Laparoscopy often causes intraoperative hypertension and the exact aetiology is unclear. 99

#### Anaesthetic considerations of laparoscopic surgery

##### Airway

Traditionally, airway management in laparoscopic surgery is through a cuffed oral endotracheal tube, as this establishes a definitive airway. However, some anaesthetists use supraglottic airway devices as a mode of airway management. It should be noted that the risk of gastric content aspiration is higher with increased intra-abdominal pressure. Aspiration pneumonia carries high morbidity and mortality, and therefore laryngeal mask airways and other supraglottic airway devices have not become routinely accepted as standard airway management in laparoscopic surgery. The authors recommend using an endotracheal tube. However, there is some evidence that the use of a ProSeal laryngeal mask airway rather than a cuffed oral endotracheal tube is linked to a reduction in postoperative nausea and vomiting and throat pain (Hohlrieder et al, 2007). The haemodynamic changes that occur during airway insertion are less with a Proseal laryngeal mask airway which does not require laryngoscopy than with a cuffed oral endotracheal tube (Saraswat et al, 2011).

##### Breathing and ventilation

The pneumoperitoneum used in laparoscopy causes increased intra-abdominal pressure and splinting of the diaphragm; if coupled with Trendelenburg positioning, the abdominal contents are displaced cephalad. Accordingly, there is atelectasis and reduced thoracic compliance with a resultant increase in airway pressure. This may risk barotrauma with positive pressure ventilation

The decrease in functional residual capacity and basal atelectasis leads to further ventilation–perfusion mismatch with hypoxaemia. CO<sub>2</sub> from insufflation of the peritoneum is also absorbed as a result of its relative high blood solubility leading to hypercapnia. This may worsen ventilation–perfusion mismatch as well as increasing pulmonary vascular resistance. There is usually no requirement to adjust tidal volume settings but the minute ventilation may be increased by an increase in respiratory rate to control any significant hypercapnia.

Incorrect positioning of gas insufflation needles or trochars may result in subcutaneous emphysema, pneumomediastinum or a pneumothorax. If CO<sub>2</sub> is insufflated directly into a vessel catastrophic cardiorespiratory collapse can occur from a venous gas embolism. The severity of the hypoxaemia and hypotension depends on the volume and rate of CO<sub>2</sub> injected (Cobb et al, 2005). The physiological effects are less than with air embolism as a result of the greater blood solubility

and absorption of CO<sub>2</sub> (Perrin and Fletcher, 2004). Treatment involves rapid deflation of the abdomen and resuscitation with 100% oxygen and fluids. If severe the patient may need to be placed in the left lateral position and air aspirated via a central line.

Neuromuscular blockade and pressure-controlled ventilation have demonstrated optimal control of ventilation and oxygenation, with lower airway pressures and improved compliance (Cadi et al, 2008). Optimal neuromuscular blockade improves surgical conditions and also allows complete control of ventilation and CO<sub>2</sub>. At the end of the operation, patients must be adequately reversed; a train-of-four stimuli should be used to determine the extent of neuromuscular blockade. Best practice suggests that neostigmine and glycopyrrolate or sugammadex should be used in order to ensure complete reversal of neuromuscular blockade at extubation (Geldner et al, 2012). Maintenance of anaesthesia in laparoscopy comparing sevoflurane *vs* total intravenous anaesthesia (propofol and remifentanyl) has shown that maintenance using sevoflurane improves compliance and airway pressures, most likely through bronchodilating properties (Bang et al, 2014).

##### Cardiovascular changes

Peritoneal stretch at induction of pneumoperitoneum can stimulate a vagally-mediated bradycardia. This can be relieved with release of pressure and ensuring that intra-abdominal pressure does not exceed 16 mmHg. Anticholinergics such as glycopyrrolate may occasionally be necessary to reverse the bradycardia.

CO<sub>2</sub> is insufflated for a pneumoperitoneum with compression of the large intra-abdominal vessels. With an increase in intra-abdominal pressure, venous return initially increases but further rises in intra-abdominal pressure cause a decrease in cardiac output. Compression of the abdominal aorta, production of neurohumoral factors and activation of the renin–angiotensin–aldosterone axis causes a raised systemic vascular resistance and has a depressive effect on myocardial contractility. The rise in systemic vascular resistance is usually greater than the reduction in cardiac output. As a result, mean arterial pressure is usually maintained or even raised but it can be labile, especially in hypovolaemic patients, and put vulnerable patient groups at risk. Also changes in position and the effects of changing position on preload can cause notable variation in mean arterial pressure.

Laparoscopy often causes intraoperative hypertension and the exact aetiology is unclear. It is thought to be either through the activation of a neurohumoral response or as a result of pain from stretching of the peritoneum. The resultant increase in systemic vascular resistance and tachycardias can lead to an increase in myocardial workload and resultant cardiac ischaemia with tachyarrhythmias, especially in patients with a poor cardiac reserve.

Anaesthetists may choose to run an infusion of the short-acting opiate remifentanyl to titrate against the

cardiovascular changes of the pneumoperitoneum. Alternatively giving intravenous magnesium sulphate before pneumoperitoneum has been shown to attenuate increase in arterial pressure during laparoscopic cholecystectomy. This attenuation is apparently related to reductions in the release of catecholamine, vasopressin or both (Jee et al, 2009).

Appropriate administration of intravenous fluid may be difficult to ascertain in view of raised intra-abdominal pressure and resultant raised intrathoracic pressure. This makes interpretation of any central venous monitoring difficult. To improve assessment of filling, volumes may be tailored accordingly through use of cardiac output monitoring devices such as transoesophageal Doppler or LiDCO rapide (lithium dilution cardiac output monitor) (Koliopoulos et al, 2005). Over-administration of fluids can cause oedematous bowel, postoperative ileus and a protracted hospital stay, thus increasing patient morbidity.

Trochars inserted into major abdominal vessels can cause major haemorrhage and cardiovascular collapse. Haemorrhage is not always obvious intraoperatively and hypotension from retroperitoneal haemorrhage or venous bleeding can present insidiously postoperatively, so clinicians should have a high index of suspicion. Thus it is recommended that all patients undergoing laparoscopy should have large intravenous access to allow rapid fluid administration if needed. The authors recommend an intravenous cannula of 18G or greater. This is particularly important in laparoscopy as the patient's arms may not be easily accessible during the operation as a result of the variations in patient position and as the arms are often secured to the patient's sides.

### Renal or splanchnic

There is an increased risk of gastric regurgitation with raised intra-abdominal pressure. The raised intra-abdominal pressure can also lead to a reduction of blood flow to the liver and kidneys which could affect their function. Therefore it is inadvisable to raise pressures to over 16 mmHg for abdominal laparoscopic surgery. A persistently high intra-abdominal pressure can cause a reduction in mesenteric blood flow by up to 40% with ensuing tissue acidosis as well as a reduction in glomerular filtration rate (Hayden and Cowman, 2011).

There is also the risk of visceral damage to the bowel or liver from trochar puncture and both the anaesthetist and surgeon should be wary of this complication perioperatively. *Table 3* outlines the physiological effects of pneumoperitoneum.

### Other postoperative anaesthetic considerations

#### Postoperative analgesia

Laparoscopic surgery is associated with lower analgesic requirements compared to open surgery as a result of smaller incisions and reduction in tissue trauma. Opiates are still usually required perioperatively in laparoscopic surgery, but in smaller amounts. Patient comfort is important

to allow improved and earlier mobility, and adequate respiratory function. The reduced opiate requirement minimizes the associated problems of postoperative nausea and vomiting, and confusion. Smaller incisions reduce the development of respiratory infections that can manifest through basal atelectasis and inability to clear secretions. Shoulder tip pain is not uncommon as a result of referred diaphragmatic pain caused by pneumoperitoneum; this can be ameliorated through ensuring complete expulsion of gas from the abdomen at the end of surgery. Regional anaesthetic techniques including transversus abdominis plane blocks can be used to reduce opioid requirements (Ortiz and Rajagopalan, 2014). The use of local anaesthetics at the port sites and intraperitoneally also improves postoperative analgesic requirements (Ortiz and Rajagopalan, 2014).

#### Anti-emetic

Insufflation of the abdomen can predispose many patients to postoperative nausea and vomiting. Multimodal techniques, such as through the use of cyclizine, dexamethasone and ondansetron, alongside opiate-sparing techniques can provide a more effective way of preventing postoperative nausea and vomiting.

#### Physiotherapy

Occasionally chest physiotherapy and short-term continuous positive pressure techniques may be required to improve the atelectasis caused by the pneumoperitoneum and changes in position in at-risk patients with significant respiratory disease.

#### Other complications

Trochar insertion is generally under direct camera vision following the insertion of the camera port. However, blind trochar insertion can cause direct trauma to blood vessels,

**Table 3. Physiological effects of pneumoperitoneum**

|                  |   |        |
|------------------|---|--------|
| Cardiovascular   | Cardiac output                            | ↓      |
|                  | Systemic vascular resistance              | ↑      |
|                  | Blood pressure                            | ↑ or ↓ |
| Respiratory      | Functional residual capacity              | ↓      |
|                  | Compliance                                | ↓      |
|                  | Airway pressure                           | ↑      |
|                  | Perfusion/ventilation (V/Q) mismatch      | ↑      |
|                  | Pulmonary vascular resistance             | ↑      |
| Gastrointestinal | Gut blood flow                            | ↓      |
|                  | Risk of regurgitation of gastric contents | ↑      |
| Renal            | Glomerular filtration rate                | ↓      |
| Cerebral         | Intracranial pressure                     | ↑      |

## KEY POINTS

- Laparoscopic surgery involves the introduction of laparoscopic instruments into the abdomen after insufflation with carbon dioxide to create a pneumoperitoneum and has become a common surgical technique.
- The benefits of laparoscopic over open surgery include less postoperative pain, reduced incidence of wound infections which leads to reduced perioperative morbidity, and a shorter hospital stay.
- The pneumoperitoneum created to facilitate laparoscopic surgery generates an intra-abdominal pressure of 10–20 mmHg that may result in undesirable physiological changes. Patients need to be fit enough to cope with these physiological stresses.
- A number of patient positions may be adopted for laparoscopic surgery. It is important that the patient is appropriately secured with his/her eyes taped and all pressure points protected.
- A supraglottic device can be used for airway management but an endotracheal tube is preferable.
- Neuromuscular blockade and pressure-controlled ventilation have demonstrated optimal control of ventilation and oxygenation, with lower airway pressures and improved compliance.
- Complications of laparoscopic surgery are mainly the result of the pneumoperitoneum, patient positioning or the surgical instruments.
- Laparoscopic surgery has become a common surgical technique and has allowed major surgery to be performed in groups of patients not deemed fit for open procedures.

**Table 4. Complications of laparoscopic surgery**

|  |
|--|
| Damage to surrounding viscera (bowel, bladder, other organs) |
| Damage to vessels  |
| Venous gas embolism  |
| Lung atelectasis   |
| Acute kidney injury  |
| Complications associated with extremes of positioning        |
| Well leg compartment syndrome (not common)                   |
| Postoperative shoulder tip pain                              |

bowel, bladder and other organs. The complications are summarized in *Table 4*.

## Conclusions

Laparoscopic surgery has revolutionized intra-abdominal surgery and allowed major surgery to be performed in groups of patients not deemed fit for open procedures. Certain patients with poor cardiorespiratory reserve may still not be able to tolerate the physiological changes associated with the pneumoperitoneum. In certain patients the benefits of laparoscopic techniques need to be closely weighed against their risks. An open operation avoids the intraoperative haemodynamic issues but could have detrimental consequences postoperatively, while a laparoscopic procedure avoids excessive tissue

trauma and the problems associated with a large painful incision. Through careful assessment and diligence in the conduct of general anaesthesia, vulnerable patient groups can now benefit from the reduction in morbidity that they would not otherwise encounter with open surgical techniques. **BJHM**

*Conflict of interest: none.*

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