Laparoscopic abdominal surgery

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Laparoscopic surgery is now widely established. Benefits include reduced postoperative pain, improved cosmetic results and patient satisfaction, and reduced hospital stays. The range of surgical techniques is increasing in complexity and now includes cholecystectomy, adrenalectomy, nephrectomy, fundoplication, hernia repair, bowel resection and gynaecological procedures. There is also an increase in the number of emergency operations performed laparoscopically. Most patients undergoing gynaecological procedures are young and fit. However, patients undergoing gastrointestinal or emergency surgery may be sick and elderly; such patients may have significant associated co-morbidity.

Laparoscopic surgery involves insufflation of a gas (usually carbon dioxide) into the peritoneal cavity producing a pneumoperitoneum. This causes an increase in intra-abdominal pressure (IAP). Carbon dioxide is insufflated into the peritoneal cavity at a rate of 4–6 litre min^{-1} to a pressure of 10–20 mm Hg. The pneumoperitoneum is maintained by a constant gas flow of 200–400 ml min^{-1}. The raised intra-abdominal pressure of the pneumoperitoneum, alteration in the patient's position and effects of carbon dioxide absorption cause changes in physiology, especially within the cardiovascular and respiratory systems. These changes, as well as direct effects of gas insufflation, may have significant effects on the patient, especially if they are elderly or have associated morbidity.

Physiological effects of pneumoperitoneum

Cardiovascular

Increased IAP affects venous return (VR), systemic vascular resistance (SVR) and myocardial function (Table 1). Initially, owing to autotransfusion of pooled blood from the splanchnic circulation, there is an increase in the circulating blood volume, resulting in an increase in venous return and cardiac output. However, further increases in the IAP result in the compression of the inferior vena cava, reduction in venous return and subsequent decrease in cardiac output. The SVR is increased because of direct effects of the IAP, but also because of an increase in the release of circulating catecholamines, especially epinephrine and norepinephrine. This change in SVR is generally greater than the reduction in cardiac output, maintaining or even increasing systemic blood pressure. The increasing SVR, systolic and diastolic blood pressures and tachycardia, result in a large increase in myocardial workload. Consequently, myocardial ischaemia may result. Further increases in IAP may decrease cardiac output with a subsequent fall in blood pressure, an effect more pronounced in patients who are hypovolaemic or have cardiovascular disease.

Table 1 Physiological effects of pneumoperitoneum

Cardiovascular	
IAP < 10 mm Hg	↑ VR ⟶ ↑ CO
IAP 10–20 mm Hg	↑ IAP ⟶ ↓ VR ⟶ ↓ CO ↑ IAP ⟶ ↑ SVR BP = ↓ CO × ↑↑ SVR ↔↑ BP
IAP > 20 mm Hg	↓↓ VR ⟶ ↓↓↓ CO ↓ BP
Respiratory	
Lung volumes esp FRC	↓
Airway resistance	↑
Pulmonary compliance	↓
Airway pressure	↑
Risk of barotrauma	↑
V/Q mismatch	↑
Renal	
Renal function	↓
Gastrointestinal	
Risk of regurgitation	↑
Neurological	
ICP	↔↑
CPP	↔↓

IAP, intra-abdominal pressure; VR, venous return; CO, cardiac output; SVR, systemic vascular resistance; BP, blood pressure; FRC, functional resistance capacity; ICP, intracranial pressure; CPP, cerebral perfusion pressure.

Respiratory

The supine position and general anaesthesia decrease functional residual capacity (FRC). Pneumoperitoneum and the Trendelenburg position cause cephalad shift of the diaphragm,

Key points

Recovery after laparoscopic surgery is faster than with open procedures.

Creation of a pneumoperitoneum has significant effects on cardiovascular and respiratory physiology.

Carbon dioxide is used as the insufflation gas as it is non-flammable, colourless and has a higher blood solubility than air, thus reducing the risk of complications after venous embolism.

Capnography is important; it enables appropriate adjustments to ventilation in order to maintain normocapnia.

Laryngeal mask airways may be used for short procedures if there is no history of reflux or obesity.

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further decreasing FRC, possibly to values less than closing volume; this causes airway collapse, atelectasis, ventilation–perfusion (V/Q) mismatch, potential hypoxaemia and hypercarbia. There is an increase in airway resistance and reduction in compliance which potentiates the risk of barotrauma with positive pressure ventilation.

Renal

Markedly increased IAP reduces renal function and urine output owing to an increase in renal vascular resistance and reduction in glomerular filtration rate (GFR). This is compounded by the reduction in cardiac output.

Gastrointestinal

Increased IAP may cause regurgitation of gastric contents with associated risk of pulmonary aspiration. This is particularly significant in the obese patient.

Neurological

Intracranial pressure (ICP) is increased by the rise in IAP, which may result in a decrease in the cerebral perfusion pressure (CPP), especially if there is a reduction in cardiac output.

Physiological effects of positioning

Patient positioning depends on the operation, for example Trendelenburg position (head down) for gynaecological procedures, reverse Trendelenburg (head up) for upper abdominal surgery (Table 2).

Trendelenburg (head down)

Respiratory effects include further reduction in FRC, more V/Q mismatch and greater risk of atelectasis. Endobronchial intubation, attributable to cephalad movement of the lungs and carina in relation to the fixed endotracheal tube, should be prevented. Cardiovascularly, there is initially an increase in venous return with subsequent increase in cardiac output, but this causes compensatory vasodilatation with overall minimal effects on the cardiovascular system in a patient with no cardiovascular illness. Increased venous return with Trendelenburg position may not be tolerated in patients with compromised myocardial compliance (hypertrophy and/or ischaemia).

Table 2 Physiological effects of positioning

	Trendelenburg	Reverse Trendelenburg
Cardiovascular		
VR	↑	↓
CO	↑	↓
BP	↔	↓
Respiratory		
Lung volumes	↓	↔
V/Q mismatch	↑	↔
Atelectasis	↑	↔

Reverse Trendelenburg (head up)

There are few respiratory effects in the reverse Trendelenburg position but more marked effects on the cardiovascular system. A decrease in venous return results in decreased cardiac output and therefore blood pressure. These effects are more marked in a patient who is hypovolaemic or compromised cardiovascularly.

Physiological effects of gas absorption

Carbon dioxide is the most frequently used gas for insufflation of the abdomen as it is colourless, non-toxic, non-flammable and has the greatest margin of safety in the event of a venous embolus (highly soluble). It is absorbed readily from the peritoneum, causing an increase in Pa_{CO_2}. This has direct, as well as indirect (by raising catecholamine levels), effects on the cardiovascular system. Thus, tachycardia, increased cardiac contractility and reduction in diastolic filling can result in decreased myocardial oxygen supply to demand ratio and greater risk of myocardial ischaemia.

Effects of gas insufflation

Arrhythmias

Nodal rhythm, sinus bradycardia and asystole attributable to vagal stimulation can be initiated by stretching of the peritoneum. Such effects are more pronounced at the beginning of insufflation because of the rapid stretching of the peritoneum.

Subcutaneous emphysema, pneumomediastinum and pneumothorax

Subcutaneous emphysema, pneumomediastinum and pneumothorax may occur because of incorrect positioning of the gas insufflation needle or trocars, anatomical anomalies or by gas dissecting across weak tissue planes attributable to the increased abdominal pressure.

Venous gas embolism

Venous gas embolism is a rare but potentially fatal complication. It may occur if carbon dioxide is insufflated directly into a blood vessel or by gas being drawn into an open vessel by the venturi effect. The physiological effects caused by carbon dioxide are less than that with air because if its greater blood solubility. However, hypotension, desaturation, and a 'mill wheel' murmur may result. Treatment includes rapid deflation of the abdomen and resuscitation of the patient. If severe, the patient may be placed in the left lateral position and the air aspirated via a central line, as recommended for other gas embolisms. The management of this complication has been reviewed recently in this journal (see key references).

Trauma

Introduction of the trocars may cause damage to underlying organs (e.g. liver, spleen, bladder, intestine), which may not be diagnosed immediately at the time of surgery. Damage to blood vessels can also occur and result in massive haemorrhage. An open procedure is likely to be required to curtail haemorrhage in this situation. The risk of organ damage can be reduced if the trocars are introduced under direct vision.

Anaesthetic management

Preoperative assessment

A full preoperative anaesthetic assessment should be carried out. Particular attention to the cardiovascular and respiratory systems is essential because of potential effects of the pneumoperitoneum and patient position. Morbidly obese patients also need careful assessment as they are at increased risk of respiratory failure postoperatively. This is particularly important as it has to be considered that all patients are at risk of their surgery being converted to an open procedure with consequent increased postoperative pain and respiratory problems.

Absolute contraindications to laparoscopy are rare; relative contraindications include severe ischaemic or valvular heart disease, increased intracranial pressure (e.g. hydrocephalus, cerebral tumour, head injury) and hypovolaemia.

Premedication

Premedication is often not required unless the patient is particularly anxious, when a benzodiazepine may be appropriate. H_2-blockers or proton pump inhibitors may be given to patients with an increased risk of aspiration (e.g. hiatus hernia, obesity) as it reduces the incidence of pneumonitis if aspiration occurs. Atropine may decrease vagus-induced bradycardia but it also causes unpleasant side-effects such as dry mouth and tachycardia. We believe that it is preferable to treat bradycardia when it occurs, rather than routinely prescribing of vagolytics preoperatively.

Anaesthetic technique

The choice of anaesthetic depends on the type of operation and patient characteristics. The aims of laparoscopic surgery in the day-case environment, which is predominantly gynaecological, are to achieve rapid recovery with minimal residual effects, good pain control and no nausea or vomiting. Laparoscopic surgery for major abdominal procedures have different priorities as the patients will have undergone more extensive tissue trauma, but will remain in hospital where greater analgesia and monitoring are available. All operations must accommodate surgical requirements as well as considering the effects of physiological changes on the patient. The options for laparoscopic surgery include general, regional or local anaesthesia.

General anaesthesia

General anaesthesia with endotracheal intubation and controlled ventilation is considered the safest technique as it protects the airway, enables control of Pa_{CO_2} and aids surgical exposure; it is highly recommended for long procedures or for patients with a history of gastro-oesophageal reflux. Gastric distension should be avoided during hand ventilation, as this increases the risk of damage by the trocar and impairs the surgical view. A gastric tube may be necessary to decompress the stomach if distension occurs. Minute ventilation can be increased to maintain end-tidal carbon dioxide, which can be achieved by large tidal volumes of 12–15 ml kg^{-1}. This prevents microatelectasis and therefore hypoxaemia but causes an increase in intrathoracic pressure and adverse effects on cardiac function. The use of positive end-expiratory pressure (PEEP) raises intraoperative FRC, reduces hypoxaemia and may also help to reduce postoperative atelectasis. However, PEEP can reduce cardiac output, especially in the presence of a pneumoperitoneum; therefore it should be used with caution.

Spontaneous ventilation with a laryngeal mask airway (LMA) may be used for patients with no history of reflux or obesity who are undergoing short procedures with a low IAP and small degree of head tilt. However, LMA neither protects the airway from aspiration of gastric contents nor allows control of ventilation to maintain the Pa_{CO_2}.

Anaesthetic agents

The induction of anaesthesia should be conducted as indicated by the patient's condition. Maintenance with nitrous oxide is controversial, as it is thought to be associated with bowel distension and therefore altered laparoscopic view. An increase in post operative nausea and vomiting with nitrous oxide anaesthesia probably only occurs after gynaecological laparoscopic procedures but not after other forms of laparoscopic surgery. Propofol infusion may be used for day-case procedures; it is associated with a reduction in nausea and vomiting.

Analgesia

Postoperative analgesic requirements depend on the operation. A combination of simple analgesics, including acetaminophen and non-steroidal anti-inflammatory drugs (NSAIDs) administered preoperatively or intraoperatively, is often adequate for many procedures, especially if augmented by intra/retroperitoneal local anaesthetics (e.g. sterilization, hernia repair). Day case gynaecological procedures are most often treated with short-acting opioids (alfentanil or fentanyl), while more extensive abdominal surgery requires longer acting opioids or major regional blocks.

Intraoperative analgesia is also dictated by the nature of the procedure but, in prolonged surgery, the use of short-acting agents (e.g. remifentanil) allows titration of the response to the pneumoperitoneum.

Monitoring

Standard monitoring, including ECG, non-invasive blood pressure, pulse oximetry, end-tidal carbon dioxide and agent monitoring is essential. Additional monitoring may be required depending on the operation and patient's condition.

Absorption of the insufflated carbon dioxide necessitates close monitoring of end-tidal carbon dioxide to allow adjustment of the minute ventilation and maintenance of normocapnia. With compromised cardiopulmonary function, the difference between end-tidal and Pa_{CO_2} may be large and unpredictable, requiring direct measurement of arterial blood gas. End-tidal carbon dioxide monitoring also helps in the early detection of venous gas embolism. Invasive arterial blood pressure monitoring is used in cardiovascularly compromised patients. It is useful to monitor urine output in these patients. Monitoring of cardiac output and transoesophageal echocardiography may also be useful.

A peripheral nerve stimulator ensures adequate muscle paralysis and prevents unexpected patient movement with risk of accidental injury of viscera.

Regional anaesthesia

This has occasionally been used for day-case gynaecological procedures. Epidural anaesthesia is usually preferred to allow for prolonged surgery and extension of the block, if required. Advantages include a more rapid recovery, decreased incidence of post operative nausea and vomiting, avoidance of effects associated with general anaesthesia (e.g. sore throat, airway trauma) and less need for opioids. Disadvantages include the requirement for a very high (T2–T4) and widespread block, with consequent myocardial depression, bradycardia and reduced venous return. A regional block does not relieve patient discomfort from shoulder tip pain which is caused by diaphragmatic irritation.

Local anaesthesia

This is a useful method for a diagnostic laparoscopic procedure, liver biopsy or staging of metastatic disease. Advantages are similar to regional anaesthesia but disadvantages include increased patient anxiety and pain. Sedation may be required, which in itself can lead to complications including respiratory depression. Nitrous oxide may be used instead of carbon dioxide as the insufflation gas to minimize the amount of peritoneal irritation; however, it is flammable and diathermy cannot be used.

Postoperative recovery

Recovery after laparoscopic procedures is generally more rapid than after open procedures. Pulmonary function is better preserved, with only a slight reduction in forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1), with less atelectasis and therefore better gas exchange. Pain is also significantly reduced as wounds are smaller and muscle trauma less. Some patients find that shoulder-tip pain causes the most discomfort; however this is short-lived. There is also a reduction in the incidence of postoperative ileus and quicker mobilization. All these factors lead to a shorter hospital stay and earlier return to work.

Monitoring should be continued in recovery as the cardiovascular effects caused by the pneumoperitoneum may continue after its release. Prevention and treatment of minor complications is important to prevent unnecessary admissions to hospital.

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See multiple choice questions 84–86.