Anaesthesia for Laparoscopic Surgery in Urology

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1. Introduction

Laparoscopic surgery is well established in urology. It is used for radical and partial nephrectomy, living donor nephrectomy, nephroureterectomy, pyeloplasty, radical prostatectomy, pelvic lymph node dissection, varicocelectomy and total cystectomy with ileal conduit formation. Advantages include reduced tissue trauma during surgical exposure, less postoperative pain, better cosmetic results and shorter hospital stays. Urological patients undergoing laparoscopic surgery are likely to be older than women undergoing laparoscopic gynaecological surgery and have significant co-morbidity. Furthermore, because of the multiple benefits associated with laparoscopy this approach tends to be readily proposed for the less fit patient.

Table 1.

Laparoscopic surgery involves insufflation of a gas (usually carbon dioxide) into the peritoneal cavity producing a pneumoperitoneum which causes an increase in intra-abdominal pressure, which is usually limited automatically. Carbon dioxide is insufflated into the peritoneal cavity at an initial rate of 4–6 litre per minute to a pressure of 10–15 mm Hg. The pneumoperitoneum is maintained by a constant gas flow of 200–400 ml per minute. Carbon dioxide is used most frequently for insufflation as it is colourless, non-toxic and non-flammable thus allowing the use of diathermy and laser. It also has the greatest margin of safety in the event of a venous embolus as it is highly soluble.
The raised intra abdominal pressure due to the pneumoperitoneum, alteration of the patient's position and the effects of carbon dioxide absorption all cause changes in physiology especially in the cardiovascular and respiratory systems. It is important to be aware of these, and minimise or respond adequately to these changes.

1.1. Physiological effects of pneumoperitoneum

1.1.1. Cardiovascular

Increased intra abdominal pressure affects venous return, systemic vascular resistance, and myocardial function. Initially autotransfusion of pooled blood from the splanchnic circulation increases circulating blood volume, resulting in increased venous return and cardiac output. Further increases in the intra abdominal pressure result in compression of the inferior vena cava, reduction in venous return and decrease in cardiac output. The systemic vascular resistance is increased because of direct effects of the intra abdominal pressure, but also because of release of circulating catecholamines, especially noradrenaline and adrenaline. The increase in systemic vascular resistance is generally greater than the reduction in cardiac output, maintaining or even increasing systemic blood pressure. The increasing systemic vascular resistance, blood pressure and tachycardia result in an increase in myocardial workload. Further increases in intra abdominal pressure may decrease cardiac output with subsequent fall in blood pressure, an effect more pronounced in patients who are hypovolaemic or have cardiovascular disease.

1.1.2. Respiratory

The supine position and general anaesthesia decrease functional residual capacity (FRC). Pneumoperitoneum and the Trendelenburg position cause cephalad shift of the diaphragm further decreasing FRC, possibly to values less than closing volume; this causes airway collapse, atelectasis, ventilation perfusion (V/Q) mismatch and potential hypoxaemia and hypercarbia. There is an increase in airway resistance and reduction in compliance.

1.1.3. Renal

Increased perirenal pressure exerted by the insufflating gas reduces renal function and urine output. Renal cortex and medullary blood flow, glomerular filtration and creatinine clearance fall and urine production decreases [1]. Handling the kidney increases plasma renin and antidiuretic hormone release.

2. Physiological effects of positioning

Some urological procedures require use of Trendelenburg (head down) position. In particular, laparoscopic radical prostatectomy or cystectomy via the transperitoneal approach where a tilt of 20–30 degrees is required for surgical access. Respiratory effects include further reduction in FRC, more V/Q mismatch and an increased risk of atelectasis. There is initially an increase in venous return with a subsequent increase in cardiac output. This leads to compensatory vasodilatation with overall minimal effects on the cardiovascular system in the patient whose cardiovascular system is normal. However, increased venous return may not be well tolerated in patients with reduced myocardial compliance.

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

3. Physiological effects of gas absorption

Carbon dioxide is readily absorbed from the peritoneum, causing an increase in PaCO₂ and respiratory acidosis. This has marked effects on the cardiovascular system causing tachycardia and increased cardiac contractility. Diffusion of carbon dioxide into the body depends on the site of insufflation. Retroperitoneal insufflation of carbon dioxide is used for several urological procedures and may potentially cause carbon dioxide accumulation because the retroperitoneal space provides a greater

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potential for carbon dioxide absorption than the peritoneum. This is because the retroperitoneal space is very vascular, contains adipose tissue and is not as limited as the peritoneum. Carbon dioxide absorption may also persist after the end of surgery [2].

4. Effects of gas insufflation

4.1. CO₂ subcutaneous emphysema

This can develop as a complication of accidental extraperitoneal insufflation [3] but may be an unavoidable side effect of certain laparoscopic procedures that require intentional extraperitoneal insufflation, such as pelvic lymphadenectomy and radical prostatectomy via the extraperitoneal route.

4.2. Pneumothorax/pneumomediastinum/pneumopericardium

Movement of gas during the creation of a pneumoperitoneum can produce pneumomediastinum, pneumothorax and pneumopericardium [4–6]. Embryonic remnants constitute potential channels of communication between the peritoneal cavity and the pleural and pericardial sacs which can open when intraperitoneal pressure rises.

4.3. Venous gas embolism

Although rare, gas embolism is the most feared and dangerous complication of laparoscopy. Intravascular injection of gas may follow direct needle or trocar placement into a vessel or by gas being drawn into an open vessel by the venturi effect or it may occur as a consequence of gas insufflation into an abdominal organ. This complication develops principally during the induction of a pneumoperitoneum particularly in patients who have had previous abdominal surgery. Therefore peritoneal insufflation must be started slowly i.e. at a rate not exceeding 1 L/min. The rapid insufflation of gas under high pressure during laparoscopy causes a “gas lock” in the vena cava and right atrium leading to obstruction to venous return and fall in cardiac output or even circulatory collapse. The physiological effects caused by carbon dioxide embolism are less than with air embolism because it has a higher solubility than air. Hypotension, desaturation and a “mill wheel” murmur may be heard. Carbon dioxide embolism is treated by immediate cessation of insufflation and release of the pneumoperitoneum.

The patient is placed in a steep head down and left lateral decubitus position as this will reduce the advancement of gas through the right heart to the pulmonary circulation.

4.4. Anaesthetic management

4.4.1. Preoperative assessment

A full preoperative assessment should be carried out (ideally in an anaesthetic preassessment clinic). Careful attention should be paid to the cardiovascular and respiratory systems because of potential deleterious effects of patient position and pneumoperitoneum. Over the years patients with more and more severe cardiac disease have been subjected to laparoscopic surgery. Patients with severe congestive cardiac failure and valvular insufficiency are more prone to develop cardiac complications than patients with ischaemic heart disease. For these patients the postoperative benefits must be balanced against the intraoperative risks when the choice of surgical approach is discussed. Preoperative evaluation of these patients should include exercise stress test and echocardiography.

In patients with respiratory disease the postoperative benefits usually outweigh the risk of pneumothorax during pneumoperitoneum and V/Q mismatch. However, it has to be remembered that all patients are at risk if their surgery is converted to an open procedure.

Full blood count, assessment of renal function and crossmatching (or group and screen with the facility for rapid conversion to crossmatch) is required.

Pneumoperitoneum is undesirable in patients with increased intracranial pressure (tumour, hydrocephalus) and in patients with ventriculoperitoneal shunts [7]. Glaucoma is a contraindication to laparoscopic pelvic procedures (prostatectomy and cystectomy) due to the rise in intraocular pressure associated with the pneumoperitoneum and Trendelenburg position [8].

4.4.2. Premedication

If the patient is particularly anxious then premedication with a benzodiazepine may be offered. Sedative premedication is often avoided in elderly patients as it can contribute to post operative confusion. H₂ antagonists (ranitidine) or proton pump inhibitors (omeprazole) may be given to patients at increased risk of aspiration (e.g. hiatus hernia or obesity) as they reduce the incidence of pneumonitis if aspiration occurs. Because of venous stasis in the legs during laparoscopy prophylaxis of deep venous thrombosis should be
initiated before surgery. All patients should wear graduated compression stockings. Unfractionated or low molecular weight heparin should also be considered.

4.5. Conduct of the anaesthetic

Laparoscopic surgery in urology is usually for major procedures. The preferred technique is general anaesthesia with tracheal intubation and controlled ventilation as it protects the airway, enables control of PaCO$_2$ and aids surgical exposure. The principles of anaesthesia in urology and for laparoscopic urological surgery have been described elsewhere [9,10].

Absorption of the insufflated carbon dioxide necessitates close monitoring of the end-tidal carbon dioxide. With insufflation the minute ventilation will need to be increased to maintain the F$_{\text{ET}}$CO$_2$ at about 4 kPa. With compromised cardiorespiratory function, the difference between end tidal and PaCO$_2$ may be large and unpredictable [11]. Urological procedures tend to be lengthy thus allowing sufficient absorption of CO$_2$ to result in acidaemia. This is particularly the case with prostatectomy via an extraperitoneal approach. Positive end-expiratory pressure (PEEP) may be required to raise intraoperative FRC to reduce hypoxaemia and reduce postoperative atelectasis, particularly in obese patients. However, PEEP can reduce cardiac output therefore its effects should be carefully observed. The diaphragm is displaced upwards by the pneumoperitoneum. This results in cephalad movement of the carina and the potential for migration of the tracheal tube down the right main bronchus. This results in a decrease in SpO$_2$ and increase in airway pressure.

Reflex increases in vagal tone may result from sudden stretching of the peritoneum. Bradycardia, cardiac arrhythmias and even asystole can develop. Vagal stimulation can occur if the patient is too light. Atropine or glycopyrronium should be available and may be administered routinely following the induction of anaesthesia.

Much of the operation takes place in low light conditions in order to reduce the amount of light pollution on the VDU’s. It is important that the anaesthetic monitors are clearly visible and an audible signal can be heard from the ECG. Blood loss can be difficult to estimate as suction fluid which is a mixture of saline flush, blood and urine is not a reliable measure.

Mannitol 10% or 20% at 1–2 g/kg may be used to force urine flow. The rationale is to promote urine flow to flush out and maintain urinary tract patency, to preserve renal function, and as a prophylactic against cerebral swelling [10]. However, a recent Cochrane Review failed to demonstrate effectiveness of such interventions in protecting renal function in the perioperative period [12]. In the case of donor nephrectomy, a urine flow of 300–500 ml/hour is sought [13]. Frusemide may be required to maintain this level until the kidney is removed.

4.6. Postoperative recovery

Surgical trauma contributes to pain and postoperative pulmonary dysfunction. Laparoscopy results in a significant reduction in postoperative pain and analgesic consumption. Patients may complain of shoulder tip pain resulting from diaphragmatic irritation from carbonic acid from dissolved carbon dioxide. Careful evacuation of residual carbon dioxide after desufflation can be beneficial as residual carbon dioxide pneumoperitoneum can contribute to postoperative pain [14]. Multimodal analgesia should be employed. Patient controlled analgesia with morphine for 24–48 hours is often required following laparoscopic urological procedures. Intravenous paracetamol should be given regularly. Caution should be exercised with NSAIDs in elderly patients and those with borderline renal function. Antiemetics should also be prescribed [15]. Protracted postoperative nausea and vomiting can be successfully treated with an intravenous dose of dexamethasone [16]. Early mobilisation should be encouraged.

4.7. Summary

Laparoscopic surgery can offer many advantages for the patient requiring a urological procedure. However, insufflation with carbon dioxide has significant effects on cardiovascular and respiratory physiology and it is important for both the anaesthetist and surgeon to be aware of these and manage appropriately.

References


CME questions

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1. Insufflation of carbon dioxide:
   A. causes respiratory alkalosis
   B. causes bradycardia
   C. can cause venous gas embolism
   D. is maintained at a gas flow of 600 ml/min

2. The Trendelenburg position:
   A. is used in laparoscopic radical prostatectomy
   B. causes reduced venous return
   C. causes downward shift of the diaphragm
   D. causes increased functional residual capacity

3. Laparoscopic surgery is contraindicated in:
   A. patients with asthma
   B. patients with raised intracranial pressure
   C. elderly patients
   D. patients with chronic obstructive airways disease

4. Which of the following is true for carbon dioxide?:
   A. it is flammable
   B. it is colourless
   C. it is poorly absorbed from the peritoneum
   D. it is less soluble than air

5. Pneumoperitoneum causes:
   A. reduced circulating catecholamines
   B. reduced intrabdominal pressure
   C. reduction in blood pressure in patients who are hypovolaemic
   D. fall in systemic vascular resistance

6. In the post-operative period:
   A. patients should be kept on bed rest
   B. patient controlled analgesia may be required
   C. NSAIDS should be routinely prescribed
   D. dexamethasone can cause nausea and vomiting