

Anaesthesia and minimally invasive surgery

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Abstract

Minimally invasive surgery is commonly performed because of various advantages such as reduced postoperative pain, faster recovery, and reduced postoperative pulmonary complications. However, anaesthesia for laparoscopy can be difficult and potentially hazardous in long, complex surgical procedures and in those with significant comorbidity. Establishment of carbon dioxide (CO₂) pneumoperitoneum produces adverse pathophysiological changes due to increased intra-abdominal pressure and hypercapnia, and these are further altered by postural changes. Laparoscopy is also associated with potential complications such as extraperitoneal gas insufflation and pneumothorax. It is important for the anaesthetist to understand the advantages and potential risks. General anaesthesia is most commonly used but neuraxial anaesthesia is possible, although spontaneous ventilation may be difficult. Endotracheal intubation has been a popular technique but supraglottic airway devices are less traumatic, easier to insert and more modern versions provide a good airway seal as well as gastric drainage, should it be required. This article will focus on the pathophysiological changes caused by CO₂ pneumoperitoneum, the anaesthetic management for patients undergoing laparoscopy, and potential complications.

Keywords Anaesthesia; complications; laparoscopy; minimally invasive surgery; pathophysiological changes; pneumoperitoneum; regional anaesthesia; supraglottic airway device; trendelenburg

Royal College of Anaesthetists CPD Matrix: 2A00, 3A03

Introduction

Minimally invasive surgery involves the use of precise instruments designed to decrease the size of incisions as well as spare surrounding tissue. They are usually performed with endoscopic visualization. Laparoscopy is the most common technique and used for diagnostic and staging procedures, emergency operations, as well as elective surgeries including oesophagectomy, hemicolectomy, liver resection, gastrectomy, nephrectomy, radical prostatectomy, cystectomy, and distal pancreatectomy.^{1,2} In addition, robotic surgery is also becoming

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Learning objectives

After reading this article, you should be able to:

- understand the pathophysiological changes of CO₂ pneumoperitoneum on organ systems
- understand pathophysiological concerns for elderly patients in response to pneumoperitoneum
- give four reasons why CO₂ is the most commonly used gas for pneumoperitoneum
- list four potential complications of laparoscopic surgery

more common. This review will focus primarily on how to manage patients undergoing laparoscopy.

Laparoscopy requires insufflating gas into the peritoneal cavity to provide a surgical view. Usually 2.5–5.0 L of CO₂ is inflated.¹ An intra-abdominal pressure (IAP) of up to 15 mmHg is used for abdominal surgeries. CO₂ is used because it does not support combustion, is cheap, is cleared more rapidly than other gases, and is highly soluble in blood which reduces the risk of gas embolism. The disadvantage is that vascular absorption of CO₂ causes hypercapnia and respiratory acidosis.

Laparoscopic surgery offers several advantages over open surgery. There is a reduction in stress response, postoperative pain, intra-operative bleeding, rate of postoperative wound infection, impairment of respiratory function and pulmonary complications. Recovery time is shorter and cosmetic appearance is improved.^{1,2} Therefore, laparoscopic surgery is an essential component of enhanced recovery after surgery (ERAS) programmes, where multimodal, multidisciplinary perioperative pathways are implemented to shorten recovery, reduce morbidity and improve outcomes. In ERAS programs for colorectal surgery, laparoscopic surgery was associated with significantly reduced hospital stay, enhanced recovery, reduced complication rates, and mortality compared with open surgery.³

Laparoscopic surgery is usually performed under general anaesthesia. Endotracheal intubation is common but supraglottic airway devices, particularly those with the facility for gastric drainage, are becoming more popular.^{1,4,5} Neuraxial anaesthesia has also been used.^{1,6,7}

Physiological effects of pneumoperitoneum

Pneumoperitoneum with CO₂ insufflation produces adverse pathophysiological effects via increased IAP and hypercapnia. While well tolerated in healthy individuals, these can be harmful in patients with cardiopulmonary disease.

Respiratory effects (Table 1)

During pneumoperitoneum, delivery of CO₂ to the lungs may increase by up to 50%.⁸ Arterial (PaCO₂), alveolar (PACO₂), and mixed venous PCO₂ levels usually rise by 10 mmHg 5 minutes after insufflation.⁹ This can cause hypercapnia and respiratory acidosis. Increased IAP shifts the diaphragm cephalad and reduces diaphragmatic excursion. This reduces functional residual capacity by up to 20%⁹ and causes atelectasis. Oxygenation is minimally affected with no significant change in alveolar arterial oxygen gradient.^{9,10} At an IAP of 15 mmHg,

Effect of CO₂ pneumoperitoneum on respiratory function

Respiratory factor	Effect
Functional residual capacity	Decrease
Atelectasis	Increase
Peak airway pressure	Increase
Lung compliance	Decrease
Work of breathing	Increase
Alveolar arterial oxygen gradient	Unchanged
PaCO ₂	Increase
Forced expiratory volume in 1 second (FEV1)	Decrease
Peak expiratory flow (PEF)	Decrease
Forced vital capacity	Decrease

Table 1

pulmonary compliance decreases by up to 47% and peak airway pressures can increase by 50%.⁹ Work of breathing is increased and controlled ventilation is prudent in most cases. Postoperative lung function tests show significant reduction in forced expiratory volume in 1 second (FEV1), peak expiratory flow (PEF), and forced vital capacity (FVC) in both open and laparoscopic surgery.⁸ However, atelectasis and impairment of lung function test parameters are significantly less in patients undergoing laparoscopy. Laparoscopy produces adverse intra operative respiratory effects, but results in less postoperative respiratory impairment.

Cardiovascular effects (Table 2)

CO₂ pneumoperitoneum produces significant cardiovascular effects due mostly to increased IAP, but also hypercapnia.

Effects due to increased intra-abdominal pressure: IAP, patient position and intravascular volume all affect haemodynamic function during pneumoperitoneum. At an IAP of 15 mmHg, cardiac output and stroke volume have been shown to decrease by 30% due to reduced venous return and increased afterload.⁸ Reduction in cardiac output is greater with higher IAP. Reduction in cardiac output in the obese appears to be less, probably because they usually have a chronically high IAP of 9–10 mmHg.¹⁰ Cardiac depression is usually transient with cardiac index returning to baseline levels within 10–15 minutes after abdominal insufflation.¹¹

Effect of CO₂ pneumoperitoneum on cardiovascular function

Cardiac factor	Effect
Heart rate	Increase
Stroke volume	Decrease
Cardiac output	Decrease
Systemic vascular resistance	Increase
Mean arterial blood pressure	Increase
Central venous pressure	Increase

Table 2

At an IAP of 15 mmHg, there is an increase in systemic vascular resistance (SVR) and afterload due to compression of the abdominal aorta and increased catecholamine, vasopressin and renin angiotensin activity.² Raised SVR increases mean arterial pressure. Heart rate is also elevated and increased afterload can increase ventricular wall tension. Risk of myocardial ischaemia may, therefore, be increased.⁸

Intense vagal stimulation due to insertion of Veress needle/trocar, peritoneal stretch, CO₂ embolization, or stimulation of fallopian tubes during bipolar electrocauterization can cause sinus bradycardia, nodal bradycardia, atrioventricular dissociation and even asystole.¹ It is unusual and can be treated with atropine and withdrawal of the stimulus.

Effects due to hypercapnia: A PaCO₂ of 45–50 mmHg creates little haemodynamic effect. At a PaCO₂ of 55–70 mmHg, hypercapnia and acidosis have direct and indirect actions. Hypercapnia directly depresses myocardial contractility and causes vasodilation. This is counteracted by central sympathetic stimulation, which enhances heart rate, myocardial contractility and vasoconstriction. Overall, the indirect effect due to sympathetic stimulation is greater.

Renal effects

Increased IAP reduces renal blood flow, glomerular filtration rate, and urine output.⁸ Reduced renal blood flow may be due to a direct pressure effect on renal cortical blood flow and renal vasculature, as well as an increase in antidiuretic hormone, aldosterone and renin. Urinary N-acetyl-B-D-glucosaminidase (UNAG) is a sensitive marker for tubular cell damage. Pneumoperitoneum has no obvious effect on UNAG or serum creatinine levels.⁸ There is no evidence to suggest long-term harmful effects on renal function.

Effects on other systems

Pneumoperitoneum increases intracranial pressure (ICP) and reduces cerebral perfusion pressure which has little clinical significance in healthy individuals.

Increased IAP reduces femoral venous flow, indicating an increase in venous stasis.¹⁰ This is due to increased pressure on the inferior vena cava and iliac veins, which reduces venous blood flow in the lower limbs.

Postoperative C-reactive protein (CRP) levels and interleukin 6 (IL-6) are less elevated after laparoscopic surgeries compared to open surgery, suggesting an attenuation of the surgical inflammatory response.⁸ IL-6 is an important cytokine mediating the acute phase response, and its level increases in proportion to tissue trauma.⁸ CO₂ has been associated with less inflammatory response, as measured with inflammatory biomarkers, when compared with helium, air, and abdominal wall lifting.⁸

Pneumoperitoneum has been shown to reduce portal blood flow by 53%,¹⁰ which may lead to transient elevation of liver enzymes (ALT and AST).

Trendelenburg position

Head down position increases venous return, which tends to increase stroke volume and cardiac output back towards normal. Respiratory function is further impaired because cephalad shift of

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