

Abstract

Minimally invasive surgical procedures aim to minimize the tissue trauma but still achieve a satisfactory therapeutic result. Tissue trauma is significantly less than conventional open procedure. Laparoscopy is the process of inspecting the abdominal cavity through an endoscope. Carbon dioxide is commonly used to insufflate the abdominal cavity to facilitate the view. The surgical advantages of laparoscopic operations are the reduction of postoperative pain, significant cost savings and more rapid return to normal activities. Pathophysiological changes including the alteration of cardiorespiratory function occur after carbon dioxide pneumoperitoneum and extremes of patient positioning. In addition, the sequential effects of anesthesia combine to produce a characteristic hemodynamic response. A thorough understanding of these physiological changes is fundamental for optimal anesthetic care. General anesthesia and controlled ventilation using balanced anesthesia technique including several intravenous and inhalation agents with the use of muscle relaxant shows a rapid recovery and cardiovascular stability. Peripheral nerve blocks, neuraxial anesthesia and local anesthesia infiltration were considered as safe and effective in some laparoscopic operations. This report considers the pathophysiological changes during laparoscopy, preprocedure assessment, patient monitoring, anesthetic techniques, intraoperative complications and postoperative period.

Key Words: Anesthetic management; Complication; Laparoscopic surgery.

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Introduction

Laparoscopic surgery aims to minimize trauma of the interventional process but still achieve a satisfactory therapeutic result. It is commonly performed because of various advantages such as reduced postoperative pain, reduction of intraoperative bleeding, better cosmetic results, faster recovery and more rapid return to normal activities, shorter hospital stay, less postoperative wound infection, reduced metabolic derangement and reduced postoperative pulmonary complications. The operative technique requires inflating gas into the abdominal cavity to provide a surgical procedure. An intra-abdominal pressure (IAP) of 10-15 mmHg is used. Carbon dioxide (CO₂) is commonly used because it does not support combustion, is cleared more rapidly than other gases,

and is highly soluble in blood. However, the disadvantage of CO₂ is that the absorption of CO₂ can cause hypercapnia and respiratory acidosis [1,2].

The physiological effects of intra-abdominal CO₂ insufflation combined with the variations in patient positioning can have a major impact on the cardiorespiratory function. In addition, the sequential effects of anesthesia combine to produce a characteristic hemodynamic response. A thorough understanding of these physiological changes is fundamental for optimal anesthetic care. The risk factors for perioperative complications in patients undergoing laparoscopic surgery can be estimated based on patient's characteristics, clinical findings and the surgeon's experience [3]. The advantages should be balanced with potential adverse effects caused by CO₂ pneumoperitoneum. Several anesthetic techniques can be performed for laparoscopic surgery. Total intravenous anesthesia, regional anesthesia and general anesthesia using balanced anesthetic technique including intravenous drugs, inhalation agents and muscle relaxants are usually used. Short acting drugs such as propofol, atracurium, vecuronium, sevoflurane or desflurane represent the maintenance drugs of choice. Pre-procedure assessment and preparation, appropriate monitoring and a high index of suspicion can result in early diagnosis and treatment of complications.

Pathophysiological Effects During Laparoscopy

Physiological Effects of Pneumoperitoneum

Carbon dioxide was shown to be affected by raising the intra-abdominal pressure (IAP) above the venous pressure which prevents CO₂ resorption leading to hypercapnia. Hypercapnia acti-

vates the sympathetic nervous system leading to an increase in blood pressure, heart rate, arrhythmias and myocardial contractility as well as it also sensitizes myocardium to catecholamines [4]. CO₂ absorption varies widely, both between the patients as well as during a single operation. Increased IAP may compress venous vessels causing an initial increase in preload, followed by a sustained decrease in preload.

Respiratory Effects

The changes in pulmonary function during the laparoscopic surgery include reduction in lung volumes, decrease in pulmonary compliance, and increase in peak airway pressure [1,5]. Increased IAP shifts the diaphragm cephalad and reduces diaphragmatic excursion, resulting in early closure of smaller airways leading to intraoperative atelectasis with a decrease in functional residual capacity. Additionally, the upward displacement of diaphragm leads to preferential ventilation of nondependent parts of lung, which results in ventilation-perfusion (V/Q) mismatch with a higher degree of intrapulmonary shunting. Oxygenation is minimally affected with no significant change in alveolar arterial oxygen gradient. Higher IAP reduces the thoracic compliance and may cause pneumothorax and pneumomediastinum due to the increased in alveolar pressures [5]. However, postoperative impairment of pulmonary function is significantly less after laparoscopy than after laparotomy. Arterial O₂ desaturation is less severe after laparoscopic operations. In addition, the incidence of atelectases and pneumonia is lower after the laparoscopic operations.

Cardiovascular Effects

During laparoscopic surgery, the circulation undergoes typical cardiovascular changes that are the result of complex interactions between anesthesia, patient position, pressure changes in the body cavities, neuroendocrine reactions and the patient factors such as cardiorespiratory status and intravascular volume. Hemodynamic changes include the alterations in arterial blood pressure, arrhythmias and cardiac arrest. The principal responses are an increase in systemic vascular resistance, mean arterial blood pressure and myocardial filling pressures, with little change in heart rate. CO₂ pneumoperitoneum is associated with increased preload and afterload in patients undergoing the laparoscopic surgery. It also decreased heart performance (fractional shortening), but does not affect cardiac output [6].

The patients with normal cardiovascular function are able to well tolerate these hemodynamic changes. At IAP levels greater than 15 mmHg, venous return decreases leading to decreased cardiac output and hypotension. However, these changes are short lived and have no statistical significance at 10 minutes from the time that the patient undergoes pneumoperitoneum [7]. Bradyarrhythmias are attributed to vagal stimulation caused by insertion of the needle or the trocar, peritoneal stretch, stimulation of the fallopian tube during bipolar electrocauterization, or carbon dioxide embolization. These may induce cardiovascular collapse during laparoscopy even in the healthy patients. Increased concentrations of CO₂ and catecholamines can create tachyarrhythmias. Paroxysmal tachycardia and hypertension, followed by ventricular fibrillation, have been reported [8].

Effects of Other Systems

Increased IAP not only influences global hemodynamics but interferes also with the blood flow to individual organs. Increases in

IAP, cardiovascular responses to peritoneal insufflations, changes in patient position and alterations in CO₂ concentration can alter intracranial pressure (ICP) and cerebral perfusion. ICP shows a significant further increase. Cerebral blood flow has been shown to increase significantly during CO₂ insufflation. Pneumoperitoneum reduces renal cortical and medullary blood flow with an associated reduction in glomerular filtration rate (GFR), urinary output and creatinine clearance [1,2]. The reduction of renal blood flow may be due to a direct pressure effect on renal cortical blood flow and renal vascular compression as well as an increase in antidiuretic hormone (ADH), aldosterone and renin. Pretreatment with an ADH antagonist improves urine output and urea excretion despite an unaltered GFR.

Increasing IAP by insufflating CO₂ markedly reduces blood flow in the portal vein, hepatic artery and superior mesenteric artery. The effects of laparoscopy on renal function show that urine output, renal blood flow and creatinine clearance are reduced during pneumoperitoneum [9]. Increased in IAP reduces femoral venous blood flow. This is due to increased pressure on the inferior vena cava and iliac veins, which reduces venous blood flow in the lower extremities. It also has been shown to reduce the portal blood flow, which may lead to transient elevation of liver enzymes. The reduction of tissue trauma with laparoscopic operations is reflected in a reduction of the inflammatory response. The C-reactive protein and interleukin-6 levels are less elevated after laparoscopy compared to the open surgery, suggesting an attenuation of the surgical inflammatory response [10].

Patient positions can further compromise cardiac and respiratory functions, can increase the risk of regurgitation and can result in peripheral nerve injuries. Head-up position reduces venous return, cardiac output, cardiac index and mean arterial blood pressure as well as an increase in peripheral and pulmonary vascular resistance [4]. Head-down position increases volume and cardiac output back towards normal. Respiratory function is impaired because of the cephalad shifting of diaphragm is exaggerated. Intracranial pressure is increased.

Anesthetic Management

Preoperative Assessment

The general health status of each patient must be evaluated. History and physical examinations are generally sufficient techniques. The patients with cardiorespiratory diseases require additional investigation. To aid in assessment risk, the American Society of Anesthesiologists (ASA) has developed a classification system for patients, which categorizes individuals on a general health basis. The patients with compromised pulmonary function and reduced ventilatory reserve such as patients with chronic obstructive pulmonary disease or patients after lung resection are at a higher risk. In this preoperative assessment, there are no differences in a routine practice between the laparoscopy and the open surgery.

Patient Positioning

The patient's position influences the hemodynamics and the respiratory parameters. The position of the patient for laparoscopic surgery depends on the site of surgery. The patient is usually positioned so that gravity causes the abdominal organs to fall away from the operative site to facilitate surgical access. For upper abdomen surgery such as cholecystectomy or gastric surgery, the patient is supine in a head-up position. For lower abdomen surgery

such as gynecological operations or appendectomy, the patient is in a head-down position. For the operations in the thorax, the patient is placed in a lateral decubitus position.

Patient Monitoring

Appropriate patient selection with proper monitoring to detect and reduce complications must be used to ensure optimal anesthesia care during laparoscopic surgery. Standard intra-operative monitoring including noninvasive blood pressure, electrocardiogram, pulse oximeter, airway pressure, end tidal carbon dioxide (ETCO₂) and peripheral nerve stimulation is routinely used. Monitoring body temperature is recommended, since significant hypothermia can occur during the laparoscopic surgery. Invasive hemodynamic monitoring may be appropriate in the patients with hemodynamic unstable or those with compromised cardiopulmonary function [1,2].

ETCO₂ is most commonly used as a noninvasive indicator of PaCO₂ in evaluating the adequacy of ventilation. Careful consideration should be taken for the gradient between PaCO₂ and the tension of CO₂ in expired gas (PECO₂) because of V/Q mismatch. However, in the patients with compromised cardiopulmonary function, the gradient between PaCO₂ and PECO₂ increases to become unpredictable. Direct arterial blood gas analysis may be considered to detect hypercarbia. Generally, the airway pressure monitor is routinely used during intermittent positive pressure ventilation. The high airway pressure can help detection of excessive elevation in IAP.

Premedication

The premedication drug should be chosen that does not cause postoperative drowsiness. Short-acting benzodiazepine such as midazolam is a good choice. The appropriate dose and proper time of application is important to ensure getting the maximum benefit from the premedication. A small dose of intravenous midazolam can give shortly before induction. There are a number of studies which show that the co-induction technique reduces the dose of hypnotic needed to attain the targeted depth of anesthesia [12]. At present, the antisialogogues are no longer considered a mandatory component of the premedication.

Anesthetic Techniques

Various anesthetic techniques can be performed for laparoscopic surgery. However, general anesthesia with endotracheal intubation for controlled ventilation is the most common anesthetic technique. Endotracheal intubation protects the patient's airway and prevents aspiration pneumonia. In short procedures and extraperitoneal procedures such as hernia repair, ventilation using supraglottic airway device can be used as an alternative. General anesthesia without endotracheal intubation can be used safely and effectively with a ProSeal laryngeal mask airway in non-obese patients. The use of laryngeal mask airway results in less sore throat and provide smoother emergence with less post-extubation coughing compared with endotracheal intubation [11]. Double lumen endotracheal tube should be used for thoracoscopic operations in order to facilitate collapse of the lung. This improves surgical access, shortens the operative time and obviates the necessity of gas insufflation with its associated complications.

The optimal anesthetic agent for laparoscopic surgeries is one

that takes advantage of the excellent pharmacokinetics of drugs such as propofol, fentanyl, desflurane, sevoflurane and others with rapid on-off characteristics. This can be a total intravenous anesthetic (TIVA) technique or a balanced anesthetic technique with an opioid and a volatile anesthetic agent, as well as a muscle relaxant drug. Many physicians prefer a TIVA technique with propofol as the hypnotic, because propofol is effective in preventing postoperative nausea and vomiting.

Total Intravenous Anesthesia: In the definition of total intravenous anesthesia (TIVA), the components of anesthesia and analgesia, are achieved solely with intravenous drugs, without using the inhalation agents. The combination of opioid, propofol and midazolam is commonly used for laparoscopic surgery. Generally, the patients are given an oral premedication. Intubation is facilitated with a neuromuscular blocking agent. When the signs of light anesthesia occur, the standard protocol is to increase the dose of the analgesic. If two additional bolus injections of the opioid have no effect, a supplemental dose of the hypnotic is given.

General Anesthesia: General anesthesia using balanced anesthesia technique including inhalation agents, intravenous drugs and muscle relaxant drugs is usually used. Using the combination of these agents not only reduces the recovery time but also reduces the adverse effects associated with the use of high concentrations of volatile anesthetic agents. The uses of rapid and short acting volatile anesthetics such as sevoflurane and desflurane as well as rapid and short acting intravenous drugs such as propofol, etomidate, remifentanyl, fentanyl, atracurium, vecuronium and rocuronium are commonly used and have allowed anesthesiologists to more consistently achieve a recovery profile. Propofol is effective and safe even in children and elderly patients [13-17].

Ventilation should be adjusted to keep ETCO₂ of 30-35 mmHg by adjusting the minute ventilation [1]. In patients with chronic obstructive pulmonary disease and in patients with a history of spontaneous pneumothorax or bullous emphysema, an increase in respiratory rate rather than tidal volume is preferable to avoid increased alveolar inflation and reduce the risk of pneumothorax. Combination of local anesthetic wound infiltration, intraperitoneum local anesthetics, and non-steroidal anti-inflammatory drugs or cyclooxygenase-2-inhibitors provides the most effective pain relief.

Regional Anesthesia: The laparoscopic surgery can be performed by using the regional anesthesia technique including peripheral nerve block, neuraxial block and local anesthetic infiltration. Several advantages of regional anesthesia technique are quicker recovery, decreased postoperative nausea and vomiting, improved patient satisfaction, fewer hemodynamic changes, less postoperative pain, shorter hospital stay, early detection of complications and cost effectiveness [18]. However, this anesthetic technique requires a cooperative patient and gentle surgical technique. There are only few laparoscopic procedures that could be carried out under this anesthetic technique. Regional anesthesia is most useful for short procedures with low-pressure pneumoperitoneum such as laparoscopic tubal ligation, diagnostic procedures and extraperitoneal hernia repair. Generally, the regional anesthesia technique is not recommended for upper abdominal surgery. However, epidural anesthesia is the method of choice for laparoscopic cholecystectomy in patients with severe obstructive lung disease [19], and in patients with pregnancy.

Intraoperative Complications

Laparoscopic operations carry a distinct risk of complications despite their minimal invasiveness. Cardiorespiratory-related complications of laparoscopic operations with relevance to anesthesia are hypotension, hypertension, tachycardia, bradycardia, dysrhythmias, hypercapnia, hypoxemia, atelectasis and barotrauma. Misplacement of the needle can lead to intravascular, subcutaneous tissue, bowel, and omentum. Accidental insertion of the trocar or needle into the major or minor vessels, gastrointestinal tract injuries and urinary tract injuries can occur [20]. Inadvertent insufflation of gas into intravascular vessels, tear of abdominal wall or peritoneal vessels, can produce to gas embolism. Although, it is rare but it is a potentially lethal complication and can result in severe hypotension, cyanosis, arrhythmias and asystole. Subcutaneous emphysema may occur after direct subcutaneous gas insufflations. The majority of subcutaneous emphysema has no specific intervention. It can resolve soon after the abdomen is deflated and nitrous oxide is discontinued to avoid expansion of closed space.

Pneumothorax can occur when the airway pressure is high. The gas traverses into the thorax through the tear of visceral peritoneum, parietal pleura during dissection, or spontaneous rupture of pre-existing emphysematous bulla [1]. Pneumothorax can be asymptomatic or can increase the peak airway pressure, decrease oxygen saturation, hypotension, and even cardiac arrest in severe cases. The treatment is according to the severity of cardiopulmonary compromise [20]. Extension of subcutaneous emphysema into thorax and mediastinum can lead to pneumomediastinum and pneumopericardium. Their managements depend on the severity of the cardiovascular dysfunction.

Postoperative Period

During early postoperative period, the $ETCO_2$ of spontaneous breathing patients is high. The additional CO_2 can lead to hypercapnia. The efficacy of post-anesthesia care units is therefore important to facilitate return to normal functions. The patients with respiratory dysfunction can have problems excreting excessive CO_2 load, which results in more hypercapnia. In addition, the patients with cardiovascular diseases are more prone to hemodynamic changes and instabilities.

Although laparoscopic surgery results in less discomfort compared with the open surgery, postoperative pain still can be considerable. Several medications used intraoperatively for prevention and treatment of postoperative pain are the uses of local anesthesia, opioids, nonsteroidal anti-inflammatory drugs, and multimodal analgesia techniques. Additionally, preprocedure administration of parecoxib is clinically effective [21].

Postoperative nausea and vomiting (PONV) is a common and distressing symptom following laparoscopic surgery. The use of multimodal analgesia regimens and the reduction of opioid doses are likely to reduce the incidence of PONV. Propofol-based anesthesia has been associated with reduced PONV [22]. Ondansetron has been found to provide effective prophylaxis against PONV [23]. Administration of ondansetron at the end of surgery produces a significantly greater anti-emetic effect compared to pre-induction dosing. Reduced preoperative anxiety by providing more information should also relieve postoperative adverse effects in order to promote faster and better postoperative recovery period.

Summary

Laparoscopic surgery has proven to be a major advance in the treatment of patients with various surgical diseases. Several advantages from this procedure are minimal tissue trauma, reduction of postoperative pain, quicker recovery, shortening the hospital stay. Pneumoperitoneum induces intraoperative cardiorespiratory changes. Improved knowledge of pathophysiological changes in the patients allows for successful anesthetic management. Proper patient selection and preparation as well as adequate monitoring should be performed. For prolonged and upper abdominal procedures, general anesthesia and controlled ventilation with balanced anesthesia technique including inhalation agent, intravenous drug and muscle relaxant is commonly used. Regional techniques including peripheral and neuraxial blocks and local anesthetic infiltrations could be used with precautions for pelvic laparoscopy. Intraoperative complications may arise due to physiologic changes associated with patient positioning and pneumoperitoneum. Multimodal analgesic regimen combining opioids, non-steroidal anti-inflammatory drugs, and local anesthetic infiltration is the most effective regimen for postoperative pain management.

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