Chapter 3

Anesthetic Management for Laparoscopic Cholecystectomy

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Additional information is available at the end of the chapter

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1. 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, faster recovery and more rapid return to normal activities, shorter hospital stay, 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 (CO_2) 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 CO_2 is that the absorption of CO_2 can cause hypercapnia and respiratory acidosis [1].

Laparoscopic cholecystectomy (LC) procedure offers several advantages such as a reduction in stress response, postoperative pain, postoperative wound infection rate, intraoperative bleeding, impairment of respiratory function and pulmonary complications, short recovery time, and cosmetic appearance [1,2]. LC reduces hospital stay but has no overall effect on postoperative mortality [3]. The risk factors for perioperative complications in patients undergoing LC can be estimated based on patient characteristics, clinical findings and the surgeon's experience [4]. The advantages should to be balanced with potential adverse effects caused by CO_2 pneumoperitoneum.

The physiological effects of intra-abdominal CO_2 insufflation combined with the variations in patient positioning can have a major impact on 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. Several anesthetic techniques can be performed for LC. General anesthesia using balanced anesthetic technique including intravenous drugs, inhalation agents and muscle relaxants is usually used. Short acting drugs such as propofol, atracurirm, vecuronium, sevoflurane or desflurane represent the maintenance drugs of choice. Preprocedure assessment and preparation, appropriate monitoring and a high index of suspicion can result in early diagnosis and treatment of complications.

2. Pathophysiological effects during laparoscopic cholecystectomy

2.1. Physiological effects of pneumoperitoneum

Carbon dioxide was shown to be affected by raising the intra-abdominal pressure (IAP) above the venous pressure which prevents CO_2 resorption leading to hypercapnia. Hypercapnia activates 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 [5]. Increased IAP may compress venous vessels causing an initial increase in preload, followed by a sustained decrease in preload.

2.2. Respiratory effects

The changes in pulmonary function during LC include reduction in lung volumes, decrease in pulmonary compliance, and increase in peak airway pressure [6]. 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 [7]. Higher IAP reduces the thoracic compliance and may cause pneumothorax and pneumomediastinum due to the increased in alveolar pressures [6].

2.3. Cardiovascular effects

Hemodynamic changes include the alterations in arterial blood pressure, arrhythmias and cardiac arrest. These cardiovascular changes depend on the interaction of several factors including patient positioning, neurohumoral response and the patient factors such as cardiorespiratory status and intravascular volume. The principal responses are an increase in systemic vascular resistance, mean arterial blood pressure and myocardial filling pressures, with little change in heart rate [2]. CO_2 pneumoperitoneum is associated with increased preload and afterload in patients undergoing LC. It also decreased heart performance (fractional shortening), but does not affect cardiac output [8]. 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 [9]. However, these changes are short lived and have no statistical significance at 10 minutes from the time that the patient undergoes pneumoperitoneum [10].

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 [11]. These may induce cardiovascular collapse during laparoscopy even in the healthy patients. Increased concentrations of CO_2 and catecholamines can create tachyarrhythmias. Paroxysmal tachycardia and hypertension, followed by ventricular fibrillation, have been reported [12].

2.4. Effects of other systems

Increases in IAP, cardiovascular responses to peritoneal insufflations, changes in patient position and alterations in CO_2 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 CO_2 insufflation.

Pneumoperitoneum reduces renal cortical and medullary blood flow with an associated reduction in glomerular filtration rate (GFR), urinary output and creatinine clearance [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.

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 extremetries. It also has been shown to reduce the portal blood flow, which may lead to transient elevation of liver enzymes.

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 [13].

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 [5,14]. 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.

3. Anesthetic management

3.1. 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. In this preoperative assessment, there are no differences in a routine practice between the laparoscopy and the open surgery.

3.2. Patient monitoring

Appropriate patient selection with proper monitoring to detect and reduce complications must be used to ensure optimal anesthesia care during LC. Standard intraoperative monitoring including noninvasive blood pressure, electrocardiogram, pulse oximeter, airway pressure, end tidal carbon dioxide ($ETCO_2$), body temperature and peripheral nerve stimulation is routinely used. Invasive hemodynamic monitoring may be appropriate in the patients with hemodynamic unstable or those with compromised cardiopulmonary function [1].

$ETCO_2$ is most commonly used as a noninvasive indicator of $PaCO_2$ in evaluating the adequacy of ventilation. Careful consideration should be taken for the gradient between $PaCO_2$ and the tension of CO_2 in expired gas ($PECO_2$) because of V/Q mismatch. However, in the patients with compromised cardiopulmonary function, the gradient between $PaCO_2$ and $PECO_2$ 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.

3.3. Anesthetic techniques

Various anesthetic techniques can be performed for LC. However, general anesthesia with endotracheal intubation for controlled ventilation is the most common anesthetic technique. In short procedures and in certain patients, 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 [15]. The use of laryngeal mask airway results in less sore throat and provide smoother emergence with less post-extubation coughing compared with endotracheal intubation [16].

3.3.1. General anesthesia

General anesthesia using balanced anesthesia technique including inhalation agents, intravenous drugs and muscle relaxant drugs is usually used. 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, remifentanil, 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 [17-21].

Ventilation should be adjusted to keep $ETCO_2$ of around 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 [22].

Furthermore, the use of an auditory evoked potential or Bispectral index monitor to titrate the volatile anesthetics leads to a significant reduction in the anesthetic requirement, resulting in a shorter postanesthesia care stay and an improved quality of recovery from the patient's perspective [23].

Combination of local anesthetic wound infiltration, intraperitoneum spray of local anesthetic, paracetamol and non-steroidal anti-inflammatory drugs or cyclooxygenase 2 inhibitors provides the most effective pain relief, which can be supplemented with small doses of opioids.

3.3.2. Regional anesthesia

Several advantages of regional anesthesia technique are quicker recovery, decreased postoperative nausea and vomiting, fewer hemodynamic changes, less postoperative pain, shorter hospital stay, early diagnosis of complications, improved patient satisfaction and cost effectiveness [24]. This anesthetic technique requires a cooperative patient, low IAP to reduce pain and ventilation disturbances, gentle surgical technique and a supportive operating room staff. However, regional anesthesia technique is not commonly used for LC. This technique should be performed in combination with other anesthetic techniques. Local anesthetic infiltration at the trocar site combined with general anesthesia significantly reduces postoperative pain and decreases medication usage costs [25]. Additionally, subcostal transversusabdominis block provides superior postoperative analgesia, improves theater efficiency by reducing time to discharge from the recovery unit and reduces opioid requirement following LC [26]. Bilateral paravertebral blockade at T5-6 level combined with general anesthesia can be used for LC [27].

Mehta and college had been conducted a prospective, randomized, controlled trial to compare spinal anesthesia with the gold standard general anesthesia for elective LC in the healthy patients. Their study demonstrated that spinal anesthesia was adequate and safe for LC in otherwise healthy patients and offered better postoperative pain control than general anesthesia without limiting the recovery [28]. The interim analysis of a controlled randomized trial is also confirmed [29]. Thoracic epidural anesthesia with 0.75% ropivacaine and fentanyl for elective LC is also efficacious and has preserved ventilation and hemodynamic changes within physiological limits during pneumoperitoneum with minimal treatable side effects [30]. In addition, epidural anesthesia might be applicable for LC. However, the incidence rate of intraoperative referred pain is high, and so careful patient recruitment and management of shoulder pain should be considered [31].

4. Intraoperative complications

Misplacement of the needle can lead to intravascular, subcutaneous tissue, preperitoneal space, bowel, and omentum. 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 ovoid 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 [32].

Extension of subcutaneous emphysema into thorax and mediastinum can lead to pneumomediastinum. Pneumopericardium can occur when the gas is forced through the inferior vena cava into the mediastinum and pericardium. Their managements depend on the severity of the cardiovascular dysfunction.

The other complications can be presented. Accidental insertion of the trocar or needle into the major or minor vessels, gastrointestinal tract injuries and urinary tract injuries can occur [32].

5. Postoperative period

The efficacy of post-anesthesia care units is therefore important to facilitate return to normal functions. In the early postoperative period, respiratory rate and $ETC0_2$ of laparoscopic patients breathing spontaneously are higher as compared with open surgery. So, the ventilation requirement is increased. The patients with respiratory dysfunction can have problems excreting excessive CO_2 load, which results in more hypercapnia. Additionally, the patients with cardiovascular diseases are more prone to hemodynamic changes and instabilities.

Although LC 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 [33].

Postoperative nausea and vomiting (PONV) is a common and distressing symptom following LC. 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 [34]. Ondansetron has been found to provide effective prophylaxis against PONV [35]. 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.

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6. Summary

Laparoscopic cholecystectomy has proven to be a major advance in the treatment of patients with symptomatic gall bladder 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. Arterial CO_2 increases because of CO_2 absorption from the pneumoperitoneum. 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. General anesthesia and controlled ventilation comprise the accepted anesthetic technique. Balanced anesthesia technique including inhalation agent, intravenous drug and muscle relaxant is commonly used. 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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