Anesthetic Considerations For Patients Undergoing Laparoscopic Surgery

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Once a technique used primarily for gynecologic surgery, laparoscopy is becoming increasingly popular for the performance of abdominal procedures such as cholecystectomy, bowel resection, splenectomy, adrenalectomy, nephrectomy and inguinal hernia repair. Laparoscopy results in a shorter postoperative hospital stay, less time between surgery and the resumption of full activity, reduced hospital costs, and an earlier return to the work force.[1] By avoiding a large abdominal incision, laparoscopic surgery results in improved cosmetic results and a reduced incidence of postoperative intraabdominal adhesions.[2] Compared to open procedures, postoperative pain is generally considered less after laparoscopic surgery. Finally, respiratory function is less compromising following laparoscopic compared to open surgical procedures.

Laparoscopic surgery of the abdomen necessitates intraoperative intraperitoneal gaseous insufflation. The pneumoperitoneum that is created affects respiratory and cardiac homeostasis and may lead to morbidity including cardiovascular compromise. Laparoscopic procedures are associated with an increased incidence of postoperative emesis. Mediastinoscopy and thoracoscopy are other endoscopic procedures which require special anesthetic consideration.

Preoperative Considerations

There is no difference in preoperative assessment required for the patient undergoing a laparoscopic procedure compared to that needed for a similar procedure performed by laparotomy. Because a wide range of procedures are now performed laparoscopically, patients are varied in regards to age and general health. Many patients scheduled for laparoscopic surgery will arrive in the preoperative area without having been seen by an anesthesiologist. A rapid but complete history and physical must be performed.

Cardiac and pulmonary conditions are of special importance since the type and location of surgery, anesthetic technique, and intraoperative abdominal gaseous insufflation affect cardiac and pulmonary physiology. Chronic medications are usually administered on the day of surgery. Less insulin is administered as the lower caloric intake in the perioperative period reduces insulin requirements for control of blood glucose. Allergies are documented, and previous anesthetic exposure and difficulties ascertained. Airway assessment is essential as it is in the development of any anesthetic plan.

Anesthetic Considerations

Laparoscopic surgery may be performed under local, regional, or general anesthesia. Selected well motivated patients may undergo laparoscopy under local anesthesia. Supplemental sedation to the point of obtundation may be required to enable a patient to tolerate the procedure and surgical conditions are not optimal.[3] In a series of one hundred laparoscopic tubal ligations under epidural anesthesia, patients and surgeons were satisfied with the technique but amount of sedation administered, level of sensory block, and frequency of intraoperative pain were not described.[4] Thoracic epidural anesthesia has been employed but severity of pain, patient satisfaction, and surgical conditions were not addressed.[3] Thoracic epidural anesthesia involving upper thoracic dermatomes may result in significant sympathetic block. This may be acceptable in healthy patients placed in the Trendelenburg position. However, hemodynamic compromise may result from a loss of sympathetic tone in the less healthy patient undergoing a laparoscopic cholecystectomy when the reverse Trendelenburg position is required. The time required for epidural catheter placement and development of surgical anesthesia is greater compared with the use of general anesthesia and may delay a busy operating room schedule unless the surgical suite has locations and personnel to allow preoperative placement of spinal axis anesthesia.

Most commonly, laparoscopic surgery is performed under general anesthesia. The trachea is intubated because of the concern regarding regurgitation of gastric contents and subsequent pulmonary aspiration. Increased intraabdominal pressure with gas insufflation, surgical manipulation of the stomach, and the Trendelenburg position are factors tending to increase gastric pressure and may precipitate regurgitation. Moreover, the outpatient population has been demonstrated to have larger gastric volumes than their inpatient counterparts.[5] Increased gastric volume magnifies the risk of regurgitation as well as the risk of significant pneumonitis if aspiration occurs. In a study using an oral pH monitor, 2 of 93 patients undergoing laparoscopy had evidence of regurgitation.[6] Historically, emergency laparoscopic procedures have a 20% incidence of regurgitation.[7,8] However, in a large study involving 50,000 laparoscopies, 5,000 of whom were not intubated, no cases of aspiration were found.[9] More recently, evidence using an esophageal pH probe failed to reveal reflux in 63 laparoscopy patients.[10] Thus, regurgitation and aspiration in the laparoscopy patient may not be as great a problem as once thought. Stomach decompression by an oro-gastric tube is recommended; it not only improves the surgical field and protects the stomach from instrument injury, but lessens the volume and pressure of gastric contents.

Almost any form of general anesthesia may be utilized. Laparoscopic surgery does not usually require a deep level of anesthesia. They are short procedures, and the time from beginning of closure to completion of surgery is brief. A technique that results in rapid emergence is desirable. Short acting narcotics, benzodiazepines, and muscle relaxants can aid in serving this purpose. Isoflurane has a lower blood/gas solubility than halothane or enflurane, and it is thus more rapidly eliminated, and newer volatile agents such as desflurane and seroflurance that are poorly blood soluble may ultimately have value. The short redistribution half-life of propofol permits rapid emergence. Indeed, propofol anesthesia in laparoscopic surgery provided a more rapid emergence than an isoflurane and nitrous oxide anesthetic.[11] Propofol is rapidly becoming an anesthetic of choice for short procedures such as laparoscopy.

Muscle relaxants are useful in laparoscopy to ensure immobility. The potential for visceral injury exists if the patient moves during laparoscopic instrumentation. Laparoscopic procedures provide less surgical stimulation than their open counterparts and a lighter level of anesthesia may be used in combination with neuromuscular blockade resulting in more rapid emergence from anesthesia. The volume of pneumoperitoneum is important for surgical conditions, but it is intraabdominal pressure which is primarily responsible for cardiovascular and pulmonary compromise. Relaxation of abdominal muscles increases abdominal wall compliance so that a greater volume of gas may be insufflated for a given intraabdominal pressure increase.[12]

Nitrous oxide use during laparoscopic procedures is controversial. The low blood-gas solubility of nitrous oxide allows for rapid uptake and elimination. Nitrous oxide is less soluble in blood than the nitrogen and methane that is present in the intestine. Nitrous oxide therefore diffuses more quickly into the intestine than intestinal gases diffuse out. Expansion of intestinal gas and consequent distended bowel results, possibly worsening surgical conditions. Equilibrium of intestinal gas with inspired nitrous oxide proceeds at a slower pace than with other closed spaces and four hours of inhaling 70% inspired nitrous oxide increases intestinal gas volume 200%.[13] The absolute increase in intestinal volume depends directly on the initial intestinal gas volume. Average intestinal gas content is only 100 ml, but larger initial volumes of air in bowel may result from assisted mask ventilation.[14] In a recent study, surgical conditions in laparoscopic cholecystectomy averaging 72 minutes in length were assessed as a function of the use of nitrous oxide.[15] One group of patients inspired 70% nitrous oxide throughout the duration of the anesthetic and nitrous oxide was not used in the other group. The surgeon was unable to detect a difference in bowel distention, and the study concluded nitrous oxide administration was not detrimental to surgical conditions.

The need for fluid replacement is probably less for laparoscopic surgery than for laparotomy. Evaporative fluid loss is reduced in laparoscopic procedures and blood loss may be less during laparoscopic procedures than for an open surgical procedure.[16] A single peripheral intravenous catheter is sufficient in the majority of laparoscopic procedures. A urinary catheter is placed to ensure that a distended bladder does not interfere with surgical visualization, reduces the likelihood of bladder perforation by trocars, and aids in intravascular volume assessment.

One or both arms may have to be positioned at the patient's side depending on the type of laparoscopy. Brachial plexus stretch and ulnar nerve compression must be avoided. Frequent changing of the operative table position may result in undesirable arm positions. Procedures in the pelvis require the Trendelenburg position so gravity moves the bowel off relevant structures. For a laparoscopic cholecystectomy, the patient is positioned in the reverse Trendelenburg position to move bowel from the operative site.

Physiologic Effects of Peritoneal Gas Insufflation

The peritoneal space is a potential space normally containing a very small quantity of serous fluid. Insufflation of the peritoneal cavity with carbon dioxide increases intraabdominal pressure, and this results in alterations in cardiac and respiratory physiology. The volume of insufflated gas and abdominal compliance determine the magnitude of elevation in intraabdominal pressure. In one study, laparoscopy patients under general anesthesia, ventilated with a constant minute volume, had intraperitoneal insufflation with 1-2 L increments of carbon dioxide and hemodynamic measurements after each gaseous injection.[15,17] Intra-abdominal pressure increased to ~ 20 mm Hg and was accompanied by an increase in central venous pressure (CVP). The rise in CVP exceeded the increase in intrathoracic pressure, resulted in an augmented right sided filling pressure and in supine patients, was associated with increased cardiac output (CO). The CVP increased 3.5 mm Hg and the CO increased 1.1 liter/minute/70 kg at 20 mm Hg. As intraabdominal pressures increased over 20 mm Hg, CVP and CO fell.[15,17,18,19]

The biphasic response of CVP and CO to increases in intraperitoneal pressure has been predicted mathematically and confirmed experimentally.[20] The abdominal venous compartment serves as both a capacitor and resistor depending on the relationship between abdominal pressure and right atrial pressure. When intraabdominal pressure increases but is still less than right atrial pressure, capacitance properties of the abdominal veins predominate. Abdominal venous compliance decreases, with a resultant transfer of blood out of the abdominal compartment increasing central blood volume and venous return.[15,20] Higher intraabdominal pressures cause inferior vena cava (IVC) compression at its exit from the abdomen when it exceeds right atrial pressure. The effective IVC resistance increases, venous return decreases and hypotension may occur. In effect, a starling resistor or vascular waterfall is created. This is different from the supine hypotensive syndrome caused by a gravid uterus, in which the physical compression of the IVC increases venous resistance lowering venous return and cardiac output. The relationship of hemodynamic parameters and increased intraperitoneal pressures has not been studied in the patient with cardio-respiratory disease or in the reverse Trendelenburg position required for laparoscopic cholecystectomy. Hemodynamic compromise in the patient with preexisting cardiac and pulmonary disease may occur with upper abdominal surgery produced by the reverse Trendelenburg position and larger pneumoperitoneum.[21]

The pneumoperitoneum also affects the mechanical properties of the respiratory system. Intraabdominal pressure of 25 mm Hg exerts a force equivalent to 50 Kgs on the diaphragm, elevating the diaphragm and limiting lung expansion.[22] Functional residual capacity falls as does total lung volume. Ventilation ($\dot{V}$)-perfusion ($\dot{Q}$) inequality and atelectasis result.[8] Respiratory compliance is decreased demonstrated by higher peak airway pressures needed to maintain a constant tidal volume during insufflation. Peak inspiratory pressure elevation may be of little physiologic importance in young, healthy patients. The magnitude of the increase in peak airway pressure may be as little as 5-12 cm H_2O.[18,23] Occasionally, patients will require increases in peak airway pressure as much as 20 cm H_2O to compensate for decreased respiratory system compliance.[19]

Carbon dioxide is usually insufflated during laparoscopy and has a blood solubility approximately twenty times that of nitrogen. Gaseous carbon dioxide (CO_2) exchange between the peritoneal cavity and blood occurs with insufflation. The extent of exchange depends upon the gas partial pressure gradient, blood-gas solubility, peritoneal blood flow and the diffusion distance between the gas and blood. When the abdomen is insufflated with CO_2 at one atmosphere, the pressure gradient for CO_2 across the peritoneum is about 660 mm Hg. Calculated intraperitoneal carbon dioxide absorption is only 14 ml/min, an addition of 7% to the normal body carbon dioxide production.[24] The calculated 7% increase in carbon dioxide would increase $PaCO_2$ 3 mm Hg from 35 mm Hg to 38 mm Hg if ventilation was unchanged. This somewhat underestimates the $PaCO_2$ increase actually measured during laparoscopy.

The relation of $PaCO_2$ to carbon dioxide insufflation during brief gynecologic procedures has been extensively studied. In studies of laparoscopic procedures performed on ASA 1 patients with controlled and constant minute ventilation, $PaCO_2$ increased 4.5-10 mm Hg.[8,19,23] Absorbed carbon dioxide is stored in the body and eliminated by the lungs.[25] Arterial carbon dioxide measurement does not reflect total body carbon dioxide content until equilibrium is achieved between carbon dioxide pressures within blood and tissue twenty minutes after a change in carbon dioxide production or elimination.[19] A spontaneously ventilating patient under general anesthesia increases their minute volume during CO_2 insufflation (but not enough to compensate for the increased CO_2) but $PaCO_2$ increases 10 mm Hg reflecting the well-known phenomenon of attenuation of hypercarbia-induced hyperventilation by volatile anesthetics.[19] Patients undergoing laparoscopy with sedation and local anesthesia or with epidural anesthesia maintain their $PaCO_2$ constant.[3,26] Absorbed carbon dioxide from the peritoneum is not of sufficient magnitude to grossly affect respiratory homeostasis in the healthy patient and carbon dioxide can be effectively eliminated with moderate hyperventilation.

The partial pressure of CO_2 in end-tidal gas (capnometry) approximates arterial carbon dioxide pressure. End-tidal CO_2 ($EtCO_2$) is normally slightly less than $PaCO_2$. Dead space gas dilutes alveolar gas which has equilibrated with pulmonary capillary blood carbon dioxide. Increases in dead space result in a larger difference between $PaCO_2$ and $EtCO_2$. Arterial $PaCO_2$ is 1-2 mm Hg higher than $EtCO_2$ in the conscious spontaneously ventilating subject, and is 4-5 mm Hg higher during controlled ventilation under general anesthesia suggesting a minimal effect of pneumoperitoneum on dead space.[8,23,27]

Most studies of effects of pneumoperitoneum on cardiac and respiratory function have examined conditions of short insufflation times in young healthy patients. Newer, more complex, laparoscopic surgical techniques requiring a longer duration of insufflation are now performed on older patients with preexisting medical conditions. The combination of peritoneal carbon dioxide absorption and pneumoperitoneum-induced alterations of pulmonary mechanics during laparoscopy is not tolerated by some patients.[28] In one study, ASA class 3 patients with cardiac or pulmonary disease undergoing laparoscopic cholecystectomy experienced a significant increase in dead space. Capnometry demonstrated no change in end-tidal carbon dioxide but blood gas analysis showed an increase in $PaCO_2$ of 14 mm Hg despite a 20% increase in minute ventilation. In two of the ten patients studied, hypercapnia and acidosis unresponsive to significant ventilatory increases forced conversion to open procedures.[29] Oxygenation is little affected during laparoscopy in healthy patients; no significant change in arterial oxygen pressure (PaO_2) occurs in ASA I patients.[23,29] Most investigators suggest avoiding spontaneous ventilation during laparoscopy in patients with known or suspected pulmonary disease. An arterial catheter may facilitate management in some patients with pulmonary disease during laparoscopy allowing for blood gas analysis and continuous blood pressure monitoring.

Effects of Laparoscopy on Pulmonary Function

Abdominal laparoscopic procedures result in less profound changes in pulmonary function than after open surgical procedures. Following cholecystectomy via a subcostal incision, vital capacity (VC), forced expiratory volume in one second (FEV_1), and peak expiratory flow decrease to approximately 50% of control values. After laparoscopic cholycystectomy, there is a 25% decrease in these parameters.[30,31] Diagnostic laparoscopy is not thought to impair diaphragmatic function. However, laparoscopic cholecystectomy does decrease diaphragmatic function while laparoscopic herniorraphy does not impair diaphragm function.[32] The internal site of surgery appears to be the critical variable with regard to the development of diaphragmatic dysfunction. Further studies are necessary to determine if laparoscopic surgery results in fewer postoperative pulmonary complications such as atelectasis or pneumonia.

Complications (Table 1)

Cardiac arrest occurs rarely during laparoscopy. The risk of death associated with laparoscopic tubal ligations is approximately 4/100,000 procedures.[33] A retrospective review of 5,018 laparoscopic sterilizations found two cases of cardiac arrest and both of these occurred during the induction of anesthesia.[34] Patients undergoing laparoscopy are at risk for a number of potentially life threatening complications. These include venous air embolism, hemodynamic compromise secondary to increased intraabdominal pressure or unrecognized hemorrhage, cardiac dysrhythmia, and pneumothorax.

Venous carbon dioxide embolism is a potentially catastrophic complication of laparoscopy. Carbon dioxide is used for insufflation because it is highly soluble in blood and is rapidly excreted via the lungs. Should carbon dioxide enter the circulation as a bubble or embolus, it rapidly dissolves in blood resulting in reduction in size or complete elimination of the bubble embolus and subsequent excretion by pulmonary ventilation. A hemodynamically significant carbon dioxide venous embolism will produce a characteristic millwheel cardiac murmur.[35] Use of a precordial or esophageal stethoscope may allow early detection of such an event and aid in the differential diagnosis of cardiovascular collapse. Capnometry, now a standard of anesthesia monitoring, is also monitored during laparoscopy. A CO_2 embolism will cause a decrease in $EtCO_2$ as gas bubbles prevent lung perfusion to embolized lung regions and result in increased dead space ventilation. Treatment of venous gas embolism includes immediate intraperitoneal gas evacuation, 100% oxygen administration, vasopressor support as indicated, and hyperventilation to aid elimination of carbon dioxide. As in other forms of pulmonary embolism, cardiovascular collapse is a result of obstruction to blood flow from the right ventricular outlet. The patient may be turned to the left lateral position for treatment of air embolism.[36] This position displace the gas embolism from the right ventricular pulmonary outflow tract into the right ventricle and traps other bubbles in the right atrium, thus relieving or preventing outflow tract obstruction and allowing unimpeded forward blood flow.

Excessive intraabdominal pressure may acutely cause hemodynamic compromise by decreasing venous return and can usually be avoided by maintaining intraabdominal pressure less than 20 mm Hg.[19,20,37] Releasing the pneumoperitoneum usually normalizes hemodynamic parameters. Additionally, hemorrhage as a cause of cardiovascular collapse may be unrecognized by both anesthesia and surgical personnel and must be considered in the differential diagnosis of unexplained hypotension.

COMPLICATIONS OF LAPAROSCOPY

Event	Etiology	Treatment
Venous air embolism	Gas insufflation into a vessel or vascular structure	Remove pneumoperitoneum Hyperventilate Left side down Vasopressors as indicated
Cardiac arrhythmia	Hypercarbia Vagal stimulation (from peritoneal traction)	Hyperventilate Lidocaine (PVC's, ventricular tachycardia) atropine (bradycardia)
Pneumothorax	Gas leak from diaphragmatic defect Positive pressure ventilation (barotrauma)	100% oxygen Thoracentesis, chest tube
Hemorrhage	Unrecognized vessel injury	Intravenous fluid and blood replacement
Decreased venous return	Excessive pneumoperitoneum Reverse Trendelenburg position	Evacuate peritoneum Level operating room table

Table 1.

Significant bradycardia and asystole may occur during laparoscopy. Peritoneal traction caused by insufflation or traction on abdominal viscera can elicit significant reflex vagal stimulation.[38,39,40] A sudden decrease in venous return caused by an increase in intraabdominal pressure may lead to bradycardia via the Bainbridge reflex. Bradycardia may be more prevalent when anticholinergic drugs and nonvagolytic muscle relaxants are not administered. Mobitz type 1 block during laparoscopy, a rare rhythm in the anesthetized patient, has been reported with a propofol-, fentanyl-, and vecuronium-based anesthetic.[41] An anticholinergic premedication with the above drug combination may be useful.

Hypercarbia in combination with a light level of anesthesia increases catecholamine levels and this combination can precipitate ventricular arrhythmias. Halothane is perhaps best avoided as it increases susceptibility to dysrhythmias, including supraventricular tachycardia, premature ventricular contractions and ventricular bigeminy, when circulating levels of catecholamine are elevated. The incidence of arrhythmias during laparoscopy using halothane may approach 30%.[22,42] These arrhythmias may also occur when using other volatile anesthetic gases.

Pneumothorax is a known complication of positive pressure ventilation, often associated with underlying lung pathology or high peak airway pressures. Pneumothorax is also a complication of laparoscopic induced pneumoperitoneum.[43] Carbon dioxide can enter the pleural space through a diaphragmatic defect and produce a pneumothorax. Mediastinal emphysema also may occur. Subcutaneous emphysema may accompany a pneumothorax, and, if found, gas should be removed from the abdomen and the possibility of a pneumothorax considered. Subcutaneous gas exclusive of pneumothorax during laparoscopy is most likely due to direct carbon dioxide insufflation into subcutaneous tissue with initial needle puncture or gaseous dissection into a subcutaneous tissue plane after successful establishment of the pneumoperitoneum.

Postoperative Pain and Analgesia (Table 2)

It is generally believed that a major benefit of laparoscopic surgery is diminished postoperative pain compared to open laparotomy.[2,30] Pain after laparoscopy is multifactorial. Incisional pain is avoided, but pain results from inflammation, and tissue trauma at the surgical site. The nature of the surgical procedure influences the degree of pain that will be experienced. Postoperative pain is greater after laparoscopic sterilization than after diagnostic laparoscopy.[44] Using clips or bands rather than electrocoagulation for tubal ligations increases pain after surgery.[45] Other laparoscopic procedure pain comparisons have not been made. However, it would appear that the internal site of manipulation and the degree and invasiveness of manipulation are correlated with the amount of pain a patient experiences.

Carbon dioxide is usually used as the insufflating gas but nitrous oxide insufflation may decrease the pain of the procedure. Diagnostic laparoscopy under local anesthesia results in less pain when nitrous oxide as an insufflating gas is used compared to carbon dioxide.[46,47] The systemic anesthetic effects of absorbed nitrous oxide was assumed negligible in these studies. Carbon dioxide may cause peritoneal irritation as a function of hydrogen ion mediated vasodilation.[47] Nitrous oxide supports combustion and *therefore is not to be insufflated in laparoscopic procedures requiring electrocautery.* Furthermore, nitrous oxide does not have the favorable solubility characteristics of carbon dioxide and, overall, its use is not recommended.

A small pneumoperitoneum usually persists at the end of surgery. Despite efforts to evacuate all gas, a small amount of residual insufflated gas remains which is absorbed into the peritoneum. Subdiaphragmatic free gas has been demonstrated three days post-operatively in a large number of patients.[48] Carbon dioxide-induced irritation of the diaphragm and phrenic nerve is the probable etiology of shoulder pain in 35% to 65% of patients after laparoscopy and of upper abdominal pain in pelvic procedures.[48,49] A sustained valsalva maneuver during gas expulsion will increase intraabdominal pressure and create a pressure gradient for gas release. Using a drain in the umbilical incision can decrease the incidence of postoperative pain by venting residual gas.[50]

Upright posture tends to exacerbate shoulder pain by allowing intraperitoneal free air to rise to the diaphragm. There is a significant decrease in pain during the first postoperative night for inpatients

ANALGESIC DRUGS FOR LAPAROSCOPY

Class of Drug	Side Effect	Comment
Narcotics	Respiratory depression Sedation Nausea Pruritus Urinary retention	Low doses recommended laparoscopy is not particularly painful High doses may slow anesthetic emergence
Nonsteroidal antiinflammatory agents	Gastric ulceration Bronchospasm Impairment of renal function Decreased platelet function	Narcotic sparing effect Ketorolac administered via IM or IV route Ketorolac provides analgesia equivalent to narcotic Ketorolac equal or superior to other nonsteroidal antiinflammatory agents in efficacy possible increased post-op bleeding
Intraperitoneally applied local anesthetic	Local anesthetic toxicity (CNS irritability, cardiac irritability) with large doses	Few side effects if administered in approximate doses Aid in controlling early postoperative pain Underutilized

Table 2.

after diagnostic and sterilization laparoscopies but pain worsens when the patient returns home and resumes normal activities.[48] Some patients have their pain relieved in the sitting position suggesting that while supine, blood in the peritoneal cavity may irritate the diaphragm. In the sitting position irritating fluid flows away from contact with sensitive interperitoneal surfaces.[51]

Topically applied local anesthetics are effective in reducing postoperative pain after certain laparoscopic procedures. Local anesthetics diminish postoperative pain when applied to fallopian tubes during a laparoscopic tubal ligation. Three cc of 0.5% Bupivacaine applied to the fallopian tubes during sterilization procedures decreased pain scores in the first hour post procedure but after five hours both control and local treatment groups experienced similar pain.[45] In another study, application of 5 ml of 1% Etidocaine topically applied to the banded portion of each fallopian tube decreased postoperative pain at 2 and 6 hours.[52,53] Intraperitoneal installation of local anesthetic can also be used for postoperative pain control. Twenty cc of 0.5% Lidocaine instilled intraperitoneally provided 5 hours of significant pain reduction compared to a control group.[54] The peak in plasma level after administration of 12 ml of 2% lidocaine occurs 30 minutes after intraperitoneal administration; the level was less than that obtained with epidural or brachial plexus blocks. Twenty ml of 0.5% bupivacaine results in a peak plasma level at 60 minutes which was lower than that following epidural or brachial plexus block.[55] All of the plasma local anesthetic levels were well below those considered toxic.

Postoperative pain is often managed with narcotics which may cause respiratory depression, sedation, nausea, and decreased gastrointestinal motility. Nonsteroidal antiinflammatory agents can supplement or replace opioids in the perioperative period. A parentally administered cyclooxygenase inhibitor, ketorolac, can be used in patients unable to take medications by mouth. Ketorolac demonstrates equivalent or superior analgesic efficacy compared to various other nonsteroidal antiinflammatory drugs.[56,59] A recent study compared Ketorolac and morphine with respect to efficacy of postoperative pain relief. Ketorolac, 30-90 mg IM, provides equal or superior analgesia to morphine 6-12 mg, IM.[56] Intramuscular ketorolac and morphine have similar temporal onsets of action.[60] Because nonsteroidal antiinflammatory agents decrease prostaglandin mediated pain in dysmenorrhea, pain following gynecologic surgery may be particularly amenable to nonsteroidal therapy.[61] Other antiinflammatory agents have proven themselves useful in post-laparoscopic analgesia. Ibuprofen administered orally (800 mg) prior to diagnostic laparoscopy provides equal or greater analgesia of a greater duration than 75 mcg of fentanyl given intravenously and the ibuprofen group experienced significantly less nausea and vomiting.[61] Adverse effects of cyclooxygenase inhibitors include gastric ulceration, bronchospasm, impairment of renal function and decreased platelet function. The last is of particular concern in the surgical patient. Skin bleeding times do increase after ketorolac administration but do not increase the bleeding time above the upper limit of normal.[62-64] Operative blood loss in abdominal procedures is not increased with administration of ketorolac.[62] Anecdotal reports of excessive bleeding after certain surgical procedures in association with these agents, however, serve to temper enthusiasm for routine use of cyclooxygenase inhibitors.

Postoperative Nausea (Table 3)

Postoperative emesis occurs commonly after anesthesia and surgery.[65] Nausea and vomiting prolong recovery room time, delay patient discharge and increase hospital costs.[66] Postoperative emesis occurs most frequently in women undergoing laparoscopic ovum retrieval (54%) followed by other types of laparoscopic surgery (35%).[67] Anxiety contributes to an increased incidence of postoperative nausea and vomiting, possibly related to higher serum catecholamine levels.[68] Risk factors associated with postoperative emesis include: obesity, a previous episode of postoperative emesis, history of motion sickness, and the female gender. For similar surgical procedures, females are twice as likely to suffer postoperative emesis than males.[69] The highest rate of nausea and vomiting following laparoscopy occurs when the procedure is performed during menses and is less if performed during the remainder of the menstrual cycle.[70] Women in the third and fourth weeks of their menstrual cycle have rates of emesis equal to males undergoing similar procedures.[71] Few studies have controlled for day of menstrual cycle and this may contribute to variations in reported emesis treatment efficacy.

ANTIEMETIC DRUGS

Class	Example	Site of Action	Side Effects
Phenothiazine	Chlorpromazine	Dopamine receptor blockade	Lethargy, sedation Extrapyramidal symptoms
Butyrophenone	Droperidol	Dopamine receptor blockade	Lethargy, sedation Extrapyramidal symptoms
Benzamides	Metoclopramide	Dopamine receptor blockade	Lethargy, sedation Extrapyramidal symptoms
Anticholinergic	Scopolamine	Cholinergic receptor blockade	Sedation Dry mouth Amblyopia Difficulty urinating Exacerbation of narrow angle glaucoma
Antihistamines	Diphenhydramine	Histamine receptor blockade	Sedation
Serotonin Antagonist	Ondansetron	Serotonin receptor blockade	Mild sedation

Table 3.

The role of nitrous oxide in emesis following laparoscopy is controversial. Nitrous oxide increases sympathetic tone, alters middle ear pressure, and causes abdominal distension, and these may be responsible for postoperative emesis.[65] There have been conflicting reports of the association of nitrous oxide with postoperative nausea and vomiting.[72-75] Halothane, enflurane, and isoflurane, are all thought to be equivalent in regard to the development of postoperative nausea.[65] A narcotic based anesthetic is associated with a higher incidence of postoperative nausea than an inhalation based anesthetic. Isoflurane, 1-2%, combined with nitrous oxide, is superior to 300 μg fentanyl and nitrous oxide with respect to the incidence of post-laparoscopy emesis.[76] Ketorolac may be a useful alternative or supplement to narcotics during laparoscopic procedures as it does not contribute to nausea. Propofol is associated with a very low incidence of nausea after gynecologic surgery (1-3%) and may have antiemetic qualities.[77] There is a decreased incidence of nausea or vomiting with epidural anesthesia compared to general anesthesia.[78] Intraoperative gastric emptying has not been shown to influence emesis rate. Muscarinic receptor stimulation by agents used to antagonize neuromuscular blockade may also increase postoperative vomiting.[79]

Antiemetic administration is not indicated as a routine postoperative medication as the risk of postoperative emesis does not warrant the potential side effects of antiemetic drugs. Patients undergoing laparoscopy, however, with its increased risk for postoperative vomiting are candidates for prophylactic antiemetic therapy. Although central efferent vagal activity leads to vomiting, multiple afferent receptor mediated stimuli initiate nausea and vomiting. Four distinct substances: dopamine, histamine, acetylcholine, and serotonin are known to stimulate emesis at the vomiting center, and specific receptor blockers are in use as antiemetic agents.

Phenothiazines and butyrophenones exert antiemetic effects by antagonism of the dopaminergic receptor. These drugs cause sedation, lethargy and may result in extrapyramidal symptoms. Droperidol at a dose of 20 μg/kg is an effective antiemetic in female patients undergoing outpatient laparoscopy. A dose of 10 μg/kg is less effective with a slightly higher rate of emesis. Its use does not delay discharge from the recovery room because of sedation.[80]

Metoclopramide also acts via inhibition of dopamine receptors but it inconsistently demonstrates antiemetic properties when given in doses of 0.1-0.2 mg/kg. The short duration of action and the increased antiemetic efficacy in males compared to females may account for differences between studies.[65] Ten mg of metoclopramide administered by mouth 30 minutes prior to laparoscopy has no significant effect on postoperative emesis.[80] Metoclopramide may be more effective in larger doses but this also increases the incidence of sedation and undesirable extra-pyramidal reactions.

Scopolamine, an anticholinergic, uniquely can be administered by a transdermal route. The scopolamine patch delivers an initial bolus dose to rapidly achieve an effective serum concentration and then provides slow continuous release of drug to maintain constant plasma levels. Nausea and vomiting following laparoscopy is decreased with transdermal scopolamine prior to surgery.[81] Side effects include: sedation, dry mouth, amblyopia, dysphoria, and mental status changes. Scopolamine is relatively contraindicated in patients with narrow angle glaucoma and urinary tract obstruction. Antihistamines are another class of antiemetics. Sedation is the principle side effect. Their role in laparoscopic procedures has not been studied.

Serotonin antagonists are a new class of antiemetic drugs. The prototype, Ondansetron, has been demonstrated to decrease emetic symptoms after laparoscopy.[82] Preoperative administration of ondansetron is superior to droperidol and metoclopramide in prevention of postoperative emesis.[83] An advantage of serotonin antagonists is that they lack significant side effects.

There are few studies comparing the efficacy of different antiemetics, and for this reason it is not possible to recommend one antiemetic over another. Depending on the situation, the cause of emesis may be varied and different antiemetics will be appropriate depending on the circumstances. Combining antiemetics with different mechanisms of action may provide synergistic relief of symptoms.[65]

Special Considerations for Thoracic Endoscopic Procedures

The techniques and benefits derived from laparoscopy in performing laparoscopy below the diaphragm can be applied to surgery of the chest. Mediastinoscopy is a diagnostic procedure. The superior and middle mediastinum are visualized and biopsied as appropriate. Previous mediastinoscopy may result in obliterated tissue planes and is a relative but not absolute contraindication to repeat mediastinoscopy.[84] Radiation therapy of the mediastinum may produce similar fibrotic changes. Another relative contraindication to performing mediastinoscopy includes the superior vena cava syndrome (vessel and tissue engorgement increase the technical difficulty of the procedure and risk of hemorrhage). Tracheal deviation, tracheotomy, or laryngectomy all make mediastinoscopy more difficult.[85]

A mediastinal mass may cause airway compression during general anesthesia and positive pressure ventilation and result in an inability to ventilate despite proper endotracheal tube position.[86] Tracheal deviation may make intubation difficult. Patients with superior vena cava (SVC) compression may require lower extremity intravenous catheters as fluid and drug administration in an upper extremity vein may not reach quickly the central circulation. Prolonged neuromuscular paralysis may occur in the patient with bronchogenic carcinoma and associated Eaton-Lambert syndrome or in patients with previously undiagnosed myasthenias gravis undergoing mediastinoscopy for a mediastinal mass.[87]

Complications of mediastinoscopy in decreasing order of frequency include: hemorrhage, pneumothorax, nerve injury (recurrent laryngeal nerve, phrenic nerve), esophageal damage, chylothorax, air embolism, and transient hemiparesis. The overall complication rate is 1.5-3%.[84,88] In a series of 9,543 mediastinoscopies, nine deaths were reported that were directly attributable to the procedure or anesthetic.[88]

Hemorrhage may be massive and result from arterial or venous injury. If the SVC is lacerated, intravascular volume must be replaced using a lower extremity vein. Immediate thoracotomy or median sternotomy to control bleeding may prove life saving. Pneumothorax may result in decreased oxygen saturation, increased airway peak pressure, or cardiovascular compromise. Recurrent laryngeal nerve injury results from biopsy of lymph nodes, unintentional electrocautery, or compression by adjacent hematoma. The mediastinoscope may compress the innominate artery and compromise blood flow to the right cerebral hemisphere. A right radial arterial catheter or pulse oximetry of a right hand digit can be used to monitor innominate blood flow. Simultaneous left arm blood pressure measurement serves to distinguish innominate compression from cardiovascular collapse.

Mediastinoscopy may be performed under local anesthesia but is rarely employed. General anesthesia offers several advantages. Positive pressure ventilation limits lung collapse in the event of mediastinal pleura laceration. General anesthesia allows for more surgical options including the ability to rapidly perform a median sternotomy or thoracotomy if needed. Mediastinoscopy is a short procedure and the anesthetic technique should be planned accordingly. Intravenous access should be adequate to provide for the possibility of rapid blood loss. Invasive arterial blood pressure may be monitored depending on the patient's medical history. A nonkinking endotracheal tube will better resist tracheal compression caused by the mediastinoscope and may be used if tracheomalacia is a concern preoperatively but this is rarely used.[85]

Thoracoscopy permits direct inspection of the pleura and lung parenchyma. Therapeutic uses of thoracoscopic surgery include: pleurodesis, ablation of spontaneous pneumothoraces, pericardiectomy, and peripheral lung resection. A pneumothorax is created in order to permit adequate visualization. With positive pressure ventilation the lung on the operative side will still inflate and obscure the surgeon's view; a double lumen endotracheal tube allows for single lung ventilation and maintains intrapleural air. Gas insufflated into the pleural cavity enlarges and maintains the pneumothorax and thus aids visualization. As long as this does not result in increased pleural pressure and its associated hemodynamic compromise, a tension pneumothorax does not develop. Gaseous absorption is more rapid in the pleural cavity than in the peritoneal cavity and may lead to increased physiologic alterations.[13] Reported complications include hemorrhage into the pleural space and subcutaneous and mediastinal emphysema.

Regardless of the type of anesthesia chosen, intercostal nerve blocks will provide analgesia during the surgery as well as postoperatively. Consideration should be given to using intratheral morphine or the combination of local anesthetic and narcotic via an epidural catheter for postoperative pain relief. Nitrous oxide administration may be limited by the need to treat hypoxemia related to one - lung ventilation. Additionally, nitrous oxide must be discontinued if pneumomediastinum is suspected. Monitoring is routine; arterial catheter monitoring is useful if one lung ventilation is utilized. STI

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