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Risks Associated with Laparoscopic Surgery

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1. Introduction

Laparoscopic surgical (LS) procedures aim to achieve a satisfactory therapeutic result while minimizing the traumatic and metabolic stress of the intervention. Tissue trauma is significantly less than that with conventional open procedures, thus results in the additional benefit of reduced post-operative pain. Other advantages of LS procedures include smaller incisional sites, lower risks of wound complications, reduced postoperative pain and complications, shorter hospital stay, more rapid return to normal activities, and cost savings (Carther, 2011; Nicholsen, 2011; Leonard & Cunningham, 2002).

Despite these advantages, laparoscopic surgery may result in serious complications due to the important physiologic changes which occur during the procedure. In complicated surgical cases of extended duration, the prolonged steep head-down position and carbon dioxide insufflation results in a pneumoperitoneum which often has adverse haemodynamic and respiratory consequences (Russoa et al., 2009). Negative aspects of laparoscopic surgery in terms of the surgical procedure itself include poor visualization and traumatic injuries to viscera and blood vessels associated with blind trocar insertion.

The physiologic changes associated with laparoscopy include those associated with tilting the patient to facilitate instrumentation and surgical exposure, the pressure effects of instilled gas into a closed cavity, and the systemic effects of the gas, almost universally CO_2, that is instilled (and absorbed or embolized).

Initially performed in healthy patients, laparoscopy is now used for complicated gastrointestinal (eg. distal gastrectomy for gastric cancer patients with comorbid diseases, laparoscopic hepatic resection for colorectal cancer liver metastases, and laparoscopic resection or debulking of presacral and retrorectal space tumors) and genitourinary procedures. (Russoa et al., 2009).

2. Physiologic changes and complications related to patient positioning

During laparoscopy, the patient is placed in a variety of positions in order to maximise the surgical visual field and facilitate instrumentation. The head-down (Trendelenburg) positioning is commonly used in gynecological operations, prostatectomy, and colorectal procedures, and usually is combined with lithotomy. The steep head-down tilt is frequently used for laparoscopic gynecologic and urologic procedures. The head-up position (reverse Trendelenburg) is used for cholecystectomy, invasive urological surgery, and gastric bypass surgery, whereas the lateral decubitus position is used for nephrectomy. The tilting of a patient during laparoscopy results in important physiologic responses and potential serious

complications. During laparoscopy, it is difficult to clearly separate the effects of anesthesia, position, and pneumoperitoneum. Because abdominal insufflation adds to the deleterious physiologic effects of the head-down tilt position, special attention by the anesthesiologist must be given to patients undergoing laparoscopic surgery in this position.

2.1 Hemodynamic effects of positioning during laparoscopy

In a study of hemodynamic changes using transthoracic echocardiography in patients undergoing gynaecological laparoscopic operations, the Trendelenburg position increased central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP) and pulmonary arterial pressures (PAP) and decreased cardiac output (CO) (Russo et al, 2009). Pneumoperitoneum increased these pressures further, mostly at the beginning of the laparoscopy, and cardiac output decreased towards the end of the laparoscopy. In recent years, gynaecological laparoscopic operations of longer duration with an even steeper head-down position are being performed.

In the study by Meininger et al, ASA I-III patients undergoing total endoscopic radical prostatectomy with 4 hours of pneumoperitoneum in the Trendelenburg position experienced no significant hemodynamic compromise. Placing the patient in the Trendelenburg position caused a significant increase in CVP (from 9.9 ± 3.4 to 15.1 ± 2.3 mm Hg), whereas all other hemodynamic parameters [cardiac index (CI), heart rate (HR), mean arterial pressure (MAP), systemic vascular resistance index (SVRI), and intrathoracic blood volume] remained nearly unaffected, as measured with a continuous cardiac output monitoring (PiCCO) system via a femoral artery catheter (Meininger et al., 2008). Similarly, in the steep (40°) Trendelenburg position during robotic prostatectomy, HR, MAP, CVP, oxygen saturation via pulse oximeter (SpO$_2$), and end-tidal carbon dioxide (EtCO$_2$) remained within a clinically acceptable range (Kalmar et al., 2010).

The Trendelenburg position changes hemodynamic parameters and moves intraabdominal organs cephalad due to gravity. The head-down position causes an increase in central blood volume in adult patients, with a resulting increase in cardiac output and systolic blood pressure. However, an immediate systemic vasodilatation secondary to reflex barostimulation also occurs, which leads to decreased stroke volume, reduced cardiac output, and diminished perfusion of vital organs. The physiology of a patient in the lithotomy position includes the physiologic consequences of leg elevation on central blood volume and a decrease in tissue perfusion in the elevated legs due to gravity. The lithotomy position and pneumoperitoneum during laparoscopic surgery increase preload, probably as a result of blood shifting from the abdomen to the thorax by compression of splanchnic vessels caused by the pneumoperitoneum (Joris, 2005).

The increased intra-abdominal pressure created in the head-up tilt position would be expected to decrease venous return to the heart. In patients undergoing laparoscopic surgery in the head-up tilt (15-20°) position, as measured with a pulmonary artery catheter, HR, CI, stroke index (SI), CVP, and PCWP decreased, systemic vascular resistance increased, and MAP did not change (Hirvonen et al., 2000). Likewise, Alishlai et al., (2000) found that both cardiac output and stroke volume fell, whereas HR, systolic BP, and diastolic BP did not change in ASA I-III patients undergoing laparoscopic surgery (cholecystectomy, fundoplication, liver thermal ablation) during pneumoperitoneum in the 30° head-up tilt position.

The lateral decubitus position has minimal effects on major organ function when the patient is carefully positioned. In the elderly, hypovolemic, and hypertensive patients, blood

pressure may not remain stable. The right lateral decubitus position appears to have greater propensity for caval compression and reduced venous return because of the closer proximity of the vena cava to the right flank. In the lateral flexed position, venous return may fall significantly, resulting in low cardiac output and hypotension. The physiological effects of positioning on cardiorespiratory function, particularly in elderly patients with co-morbidities (obesity, COPD, hypertension, coronary artery disease, etc.) may be catastrophic (Gottumukkala et al., 2008).

Cardiovascular
- Decreased left ventricular function
- Decreased cardiac output
- Decreased mean arterial pressure
- Increased systemic vascular resistance
- Increased central venous pressure
- Increased pulmonary artery pressure
- Increased pulmonary capillary wedge pressure

Respiratory
- Reduced vital capacity
- Decreased respiratory plateau pressure
- Decreased compliance
- Hypoxemia

Central nervous system
- Increased intracranial pressure
- Decreased cerebral perfusion pressure

Table 1. Physiologic changes due to Trendelenburg positioning

2.2 Respiratory and ventilatory effects of positioning

The steep head-down position in an anesthetized patient results in atelectasis and sometimes hypoxemia due to decreased functional residual capacity (FRC). With induction of anesthesia, the increased central blood volume, cephalad displacement of the diaphragm, and the weight of the abdominal contents impeding diaphragmatic excursion reduces pulmonary vital capacity. As a result of these changes, impedance of the chest wall and lung increases, an effect which is more pronounced in elderly and obese patients. Inhibition of lung expansion can occur, as well as right mainstem bronchial intubation, both of which are possible causes of hypoxemia in patients placed in the steep head-down position (Kalmar et al., 2010).

During laparoscopy in the Trendelenburg lithotomy position, compared with young patients, elderly patients had an higher $P(a-ET)CO_2$ in the setting of mechanical ventilation based on the value of $EtCO_2$. $PaCO_2$ increased progressively in both groups. Increasing the tidal volume to keep $P_{ET}CO_2$ within 20% of the pre-insufflation value may not prevent the increase in $P(a-ET)CO_2$; thus all patients, especially elderly ones, should be followed with caution while in the Trendelenburg lithotomy position (Takahata et al., 2007). Overweight patients (BMI of 25–29.9 kg/m^2) who underwent totally endoscopic robot-assisted radical prostatectomy under general anesthesia in Trendelenburg position had a significantly lower PaO_2 and higher the alveolar–arterial PO_2 difference compared with normal weight patients (Meininger et al., 2006). Similarly, SpO_2, $EtCO_2$, tidal volume, compliance, and minute

ventilation remained within a clinically acceptable range in normal weight patients with steep (40°) Trendelenburg positioning during robotic prostatectomy (Kalmar et al., 2010).

2.3 Cerebral effects of positioning

Trendelenburg positioning causes an increase in intracranial pressure (ICP) due to increased venous pressure, which hinders cerebral venous drainage with a consequential increase in the cerebral blood volume (Mavrocordatos et al., 2000). Only a limited number of studies focus on the relationship between Trendelenburg positioning and regional cerebral oxygen saturation (rSO_2). Harrison et al (Harrison et al., 2001) found no difference in rSO_2 when comparing values at the beginning and end of abdominal surgery performed with patients in the Trendelenburg position.

Regional cerebral oxygen saturation did not change in patients undergoing robot-assisted laparoscopic radical prostatectomy in a 30° Trendelenburg position (Park et al., 2009). However, in a study of gynaecologic laparoscopic surgery patients (Lee et al., 2006), the mean rSO_2 was found to fall from 65.5±5.4% (baseline before surgery) to 60.8±5.6% when the patients were initially placed in the Trendelenburg position.

2.4 Patient position and lower extremity hypoperfusion

While in the lithotomy position, particularly when a head-down position is used, general hypoperfusion of the lower extremities may be exacerbated. Lithotomy positions (low, standard, high, and exaggerated) differ primarily from one another by the degree of hip angulation and height of leg placement. The hydrostatic gradient of arterial blood pressure between the ankle and the heart in these positions may decrease lower extremity blood pressure and contribute to lower extremity hypoperfusion. Lower-extremity systolic pressures may be reduced significantly in some patients, so much so that the lower extremities may be at risk for ischemia (Halliwill et al., 1998). Prolonged ischemia during surgical procedures performed on patients in lithotomy positions probably increases the risk of compartment syndrome. Long operation time (466 min), obesity (body mass index (BMI) 29.0 kg/m²), and hypothermia during the operation (body temperature 34.2°C) also seemed to be risk factors that could have contributed to the symptoms observed in a case of lithotomy position-related compartment syndrome (Ikeya et al., 2006). To minimize the risk of compartment syndrome, surgeons should perform appropriate positioning and repositioning during surgery.

3. Pneumoperitoneum during laparoscopy

3.1 Hemodynamic changes due to pneumoperitoneum

Pneumoperitoneum is associated with altered cardiac and pulmonary physiology which may cause significant complications. The hemodynamic changes due to position are most significant at the initiation of pneumoperitoneum and near the end of the laparoscopic surgery. The adverse effects of pneumoperitoneum on cardiac performance are due to decreased venous return (cardiac preload), increased systemic vascular resistance (afterload), or both. (Alishlai et al., 2001).

The hemodynamic changes associated with pneumoperitoneum depend on a number of factors, including the mean intraabdominal pressure, amount of CO_2 absorbed, the patient's level of hydration, the type of ventilation, and the nature of the surgery. Investigators have found significant interpatient variability regarding the reduction of

cardiac output and stroke volume associated with pnuemoperitoneum (Alishlai, 2001; Haxby, 1994). These differences could be at least be partially due to varying postures, arterial CO_2 partial pressures, anesthetic techniques, measurement techniques, and intraoperative fluid regimens.

A variety of patients undergo laparoscopic cholecystectomy, hernia repair, urogenital surgery, and cancer surgery, ranging from young healthy patients to older patients with cardiopulmonary disease. Morbidly obese patients who undergo gastric bypass surgery often have significant comorbid conditions such as coronary artery disease, diabetes mellitus, cerebral vascular disease, restrictive lung disease, sleep apnea, and hypertension. Invasive hemodynamic monitoring may benefit high-risk patients undergoing laparoscopic surgery (Hironen, 2000; Koivusalo, 2008). Extending the scope of laparoscopic techniques to older patients at higher risk of cardiovascular complications requires reappraisal of hemodynamic monitoring during anaesthesia.

During laparoscopy, to evaluate cardiac function, most investigators have used pulmonary artery catheterization which is both invasive and not routine in clinical practice (Hironen et al., 2000). Usually, invasive haemodynamic monitoring is used only in patients undergoing laparoscopic surgery who have pre-existing cardiovascular disease (Artuso, 2005; Koivusalo, 2008). This technique permits more precise calculation of left ventricular preload, afterload, and oxygen delivery. However, these advantages must be weighed against a low but appreciable risk of morbidity, which may not be acceptable in many patients. Noninvasive monitoring of patients at risk for acute hemodynamic changes that may not be readily revealed by conventional intraoperative monitoring techniques is often recommended, usually transoesophageal echocardiography (Alishahi, 2001; Fahy, 1999; Haxby, 1997; Russoa, 2009; Rist, 2001).

Haxby et al (Haxby et al., 1997) measured aortic flow velocity using oesephageal Doppler before, during, and after induction of carbon dioxide pneumoperitoneum in head-down position patients undergoing laparoscopic hernia repair. They found that the insufflation of the abdomen with the carbon dioxide (at 13 mmHg; a relatively low intraabdominal pressure) produced significant effects on the cardiovascular system, but the clinical significance of these changes was uncertain. Likewise, during laparoscopic surgery of the lower abdomen in the head-up tilt position CO was found to fall after abdominal insufflation (peak intra-abdominal pressure: 13-15 mmHg). The CO fell more (30%) in patients with high surgical risk than in patients with low risk (25%), when patients were classified according to ASA physical status classification (Rist et al., 2001).

Patients in the head-down tilt position during laparoscopic hysterectomy were found to have a significant reduction in stroke volume, cardiac output and left ventricular end-diastolic volume and increase in afterload with pneumopericardium, as measured with cardiac apical Doppler echocardiography. The augmented preload resulted in an increase in stroke volume, cardiac output and left ventricular end-diastolic volume in both laparoscopic hysterectomy and conventional open hysterectomy groups. Branche et al (Branche et al., 1998) investigated the effect of intraperitoneal insufflation of carbon dioxide and head up (10°) tilt position on left ventricular afterload by using transaesophageal echocardiography in patients undergoing laparoscopic cholecystectomy. They found that systolic arterial pressure increased at the beginning of the pneumoperitoneum and subsequently decreased gradually during pneumoperitoneum. Significant variation in HR and regional wall motion were not observed, but left ventricular afterload and left ventricular end-systolic wall stress increased.

In morbidly obese laparoscopic gastric bypass surgery patients (Artuso et al., 2005), upon insufflation of the abdomen, systemic blood pressure, pulmonary artery pressure, central venous pressure, and pulmonary artery capillary wedge pressure increased significantly from baseline values, but CI and SVR did not change significantly. These changes were attenuated when the patient was placed in the reverse Trendelenburg position and almost completely corrected when the abdomen was deflated at the completion of the procedure. Laparoscopic gastric bypass surgery candidates who often have significant cardiorespiratory comorbidities, like other high-risk patients undergoing laparoscopic surgery, may benefit from invasive hemodynamic monitoring. Likewise, the head-up position in patients undergoing laparoscopic cholecystectomy, SI decreased, but CI did not change significantly because of the compensatory increase in heart rate (Hirvonen et al., 2000). CO_2 insufflation at the start of laparoscopy increased CVP and PCWP as well as mean systemic and mean pulmonary arterial pressures without significantly changing CI or SI. Toward the end of the laparoscopy, CI decreased by 15%. The hemodynamic values returned to nearly pre-laparoscopic levels after deflation of the gas, and CI increased during the recovery period, whereas systemic vascular resistance was 15% lower in the recovery room compared to preinsufflation values.

Laparoscopy in the lateral flexed position may significantly decrease venous return, causing low cardiac output and hypotension. This condition can be prevented by fluid loading and promptly reversed by deflation and table deflection.

Fahy et al, (Fahy et al., 1999) detected a high incidence of regurgitation in healthy donors in the lateral decubitus position at the mitral, tricuspid, pulmonic, and aortic valves with trans oesephageal echocardiogram (TEE) after CO_2 insufflation during laparoscopic nephrectomy. The consequences of these challenges in patients with preexisting valvular or cardiac disease would be more serious. Patients with cardiovascular disease have responses to laparoscopy that are affected by the extent of cardiac reserve, baseline medications, level of hydration, and their response to the anesthesia medications used (Slodzinski & Merritt, 2008).

For abdominal laparoscopic procedures, IAP is usually not allowed to exceed 15 mm Hg, but during pelvic procedures a higher IAP (approximately 25 mm Hg) is used. An IAP of less than 15 mm Hg is required during laparoscopic cholecystectomy, in so far as it reduces the risks associated with high pressures (Catani et al., 2004). Cardiovascular variables usually return to preinsufflation values after a pneumoperitoneum of short duration.

When a pneumoperitoneum is created for laparoscopic surgery in patients with no known cardiac disease, a decrease in left ventricular function and CO, and an increase in CVP (from redistribution of abdominal blood volume), systemic vascular resistance, and mean arterial pressure occurs, as measured by noninvasive methods (Critchley, 1993; Girardis, 1996; Westerband, 1992), thermodilution catheter (Hirvonen et al, 2000), transoesophageal echocardiography (Gannedahl, 1996; Harris, 1996; Haxby, 1997; Rist, 2001), and transthoracic echocardiography (Russoa et al., 2009).

Cases of sudden intraoperative cardiovascular collapse or severe pulmonary edema requiring ventilation after uneventful laparoscopic cholecystectomy have been reported (Giaquinto et al., 2003). The adverse effects on cardiac performance produced by pneumoperitoneum may increase the risk of cardiac complications in patients with underlying cardiac and pulmonary disease. In addition to the central changes, pneumoperitoneum results in reduced peripheral venous flow (Alishahi, 2001; Schwenk, 1998) and diminished perfusion of intraabdominal organs (Jakimowicz et al., 1998).

Blood flow falls significantly in the renal, hepatic, gastric, and mesenteric beds during laparoscopic surgery with pneumoperitoneum (Ishizaki et al., 1993; Jakimowicz et al., 1998);

resulting in impaired renal function in some patients. In nephrectomy patients with preexisting renal disease, laparoscopy may create additional kidney injury as a result of elevated intraabdominal pressure and kidney manipulation (Crane et al., 2008). In patients undergoing laparoscopic surgery (cholecystectomy, fundoplication, liver thermal ablation) in the reverse Trendelenburg position, common femoral venous flow falls significantly. The application of intermittent sequential pneumatic compression (ISPC) of the lower limbs during laparoscopic surgery reversed that effect, returning peak systolic velocity to normal (Millard, 1993; Alishahiet, 2001).

3.2 Respiratory and ventilatory effects of pneumoperitonium during laparoscopy

The changes with pneumoperitoneum in the mechanical properties of the respiratory system are related to two main factors: shifting of blood flow to the pulmonary circulation and compression of the lung bases by raising the dome of the diaphragm. Increased pressure within the abdomen increases the intrathoracic pressure by pushing the diaphragm upward, thus decreasing respiratory system compliance, which in turn results in reduced lung volumes and increased airway pressures (Hirvonen, 1995; Odeberg, 1994). These changes predispose patients to airway closure and collapse of dependent lung regions (atelectasis) (Andersson, 2005; El-Dawlatly, 2005; Nguyen, 2005). Atelectasis can be prevented by positive end-expiratory pressure or treated by inflation maneuvers (Strang et al., 2009).

Obese patients have a greater risk of atelectasis than non-obese patients. Preventing atelectasis is important for all patients, but is especially important when caring for obese patients.The use of high positive end-expiratory pressure (10 cm H_2O) in patients undergo laparoscopic bariatric surgery resulted in improved respiratory function and oxygenation in obese patients (Talab et al., 2009). When compared to preinsufflation values, abdominal insufflation to 2.26 kPa caused a significant (31%) decrease in respiratory system compliance, a significant (17%) increase in peak and plateau (32%) airway pressures at constant tidal volume with significant hypercapnia, but no change in arterial O_2 saturation in obese patients undergoing laparoscopic gastroplasty. Respiratory system compliance and pulmonary insufflation pressures returned to baseline values after abdominal deflation (Dumont et al., 1997).

Positive end expiratory pressure (PEEP) prevents the upward shift of the diaphragm during laparoscopy, limits the deliterious effects of surgery on respiratory mechanics, and improves oxygenation. However, no consensus has been reached regarding the ideal level of PEEP during laparoscopic surgery. A PEEP of 10 cm H_2O had better oxygenation both intraoperatively and postoperatively in the PACU, lower atelectasis score on chest computed tomographic scan, and less postoperative pulmonary complications than a PEEP of 0 cm H_2O (ZEEP) and 5 cm H_2O in patients undergo undergo laparoscopic bariatric surgery (Talab et al., 2009.) Likewise, a PEEP of 10 cm H_2O produced beneficial effects in the elasticity, as well as in the resistance, of the respiratory system in patients undergoing cholecystectomy video-laparoscopy procedures (Maracaja-Neto et al., 2009).

The use of a recruitment maneuver (RM) re-expanded atelectasis and improved oxygenation in obese patients undergoing laparoscopic procedures (Almarakbi, 2009; Chalhoub, 2007; Whalen, 2006). RMs and PEEP were both required to prevent rapid reoccurrence of atelectasis, especially when a high-inspired oxygen fraction was used. Oxygenation may be a poor indicator of the extent of lung collapse as oxygenation has not been found to correlate with atelectasis formation during pneumoperitoneum (Andersson, 2005; Strang, 2009).

End-expiratory lung volumes are commonly used in clinical practice to denote functional residual capacity during mechanical ventilation. Futierae et al (Futierae et al., 2010) investigated the effects of RM after application of PEEP on changes in end expiratory lung volume (EELV), respiratory mechanics, and oxygenation in healthy weight and obese patients undergoing laparoscopic surgery. They found that pneumoperitoneum worsened the reduction in EELV and respiratory mechanics produced by anesthesia induction, with no major effect on oxygenation. A PEEP of 10 cm H_2O combined with RM induced sustained improvements in EELV, gas exchange, and respiratory mechanics, and may be useful in counteracting the detrimental effects of pneumoperitoneum, especially on lung volume reduction in healthy weight and obese patients (Futier et al., 2010). Both conventional volume-controlled ventilation and pressure-controlled ventilation (PCV) were found to be equally suited for patients undergoing laparoscopic gynaecologic surgery. However, a higher lung compliance and lower peak airway pressures, plateau pressures, and airway resistance were observed with PCV in laparoscopic gynaecologic surgery patients (Oğurlu et al., 2010).

Patients with pulmonary dysfunction are at high risk for complications; pre-op screening with pulmonary function tests is of the utmost importance for these patients. In morbidly obese patients, compared with open gastric bypass procedure (GBP), laparoscopic gastric bypass resulted in higher $EtCO_2$, peak inspiratory pressure, total exhaled CO_2 per minute, and a lower respiratory compliance. Arterial blood gas analysis demonstrated higher $PaCO_2$ and lower pH during laparoscopic GBP than during open. Laparoscopic GBP alters intraoperative pulmonary mechanics and acid-base balance but does not significantly affect pulmonary oxygen exchange. Changes in pulmonary mechanics are well tolerated in morbidly obese patients when proper ventilator adjustments are maintained (Nguyen et al., 2004). Sprung et al (Sprung et al., 2003) showed that arterial oxygenation during laparoscopy could not be improved by increasing either the tidal volume or respiratory rate. In morbidly obese patients with chronic obstructive pulmonary disease and hypertension, the 20° reverse Trendelenburg position during laparoscopic gastric banding surgery improved respiratory mechanics (respiratory compliance, airway resistance and peak inspiratory pressure) and oxygenation without any apparent adverse effects on haemodynamics (Salihoglu et al., 2003). On the other hand, PaO_2 was significantly lower and the alveolar-arterial oxygen difference (A-aDO_2) was higher in overweight (BMI 25–29.9 kg/m²) and normal weight (BMI 18.5–24.9 kg/m²) patients who underwent totally endoscopic robot-assisted radical prostatectomy in the Trendelenburg position (Meininger et al., 2006). Whereas pneumoperitoneum did not have any significant effect in normal weight patients, A-aDO_2 decreased to below baselines values in overweight patients after prolonged (1.5 hours) pneumoperitoneum.

The kidney position can lower the vital capacity by another 5–10%. Most of this decrease is thought to result from reduced movement of the ribs and diaphragm. Although vital capacity and FRC are reduced in the lateral decubitus position, better ventilation–perfusion matching results from increased perfusion in the dependent lung and corresponding increase in ventilation from the stretched dependent hemidiaphragm. However, general anesthesia in the lateral decubitus position causes an increased mismatch in ventilation–perfusion ratios compared to that in awake subjects. Complications from the lateral decubitus position include pressure injuries (ischemic), muscular and ligamentous strain, whiplash-like injury to the cervical spine, neurologic injuries, and ocular complications (corneal abrasions, pressure effects, dependent edema, and blindness) (Gottumukkala, 2008).

3.3 Hypercarbia-induced pneumoperitonium

Laparoscopic procedures use carbon dioxide, a highly diffusable gas, for insufflation. CO_2 insufflated during laparoscopy is soluble in blood, and after transperitoneal absorption is presented to the lungs for excretion. The high solubility of CO_2 in the blood stream minimizes the risk of gas emboli. $ETCO_2$ increases from 0–30% when minute ventilation is held constant, but increasing respiratory rate, tidal volume, or both by as much as 30% may be necessary to keep the $ETCO_2$ in the mid-30s (mm Hg) range. This almost always means general anesthesia with endotracheal intubation to maintain adequate ventilation, which tends to be impaired by surgical positioning and abdominal distension. Higher intraabdominal pressures are associated with faster CO_2 absorption and gas embolism. These effects are further influenced by the intraoperative position of the patient and duration of procedure, and whether the patients have pre-existing cardiovascular disease. (Slodzinski & Merritt, 2008).

Patients with preoperative cardiopulmonary disease demonstrated significantly higher Pa CO_2 levels and lower pH during carbon dioxide insufflation compared to patients without underlying disease. During laparoscopic cholecystectomy, patients with chronic cardiopulmonary disease may require careful intraoperative arterial blood gas monitoring of absorbed carbon dioxide (Catherine et al., 1991). The physiological effects of intraperitoneal carbon dioxide insufflation on cardiorespiratory function, particularly in elderly patients with co-morbidities (obesity, COPD, hypertension, coronary artery disease, etc.), may be catastrophic.

Carbon dioxide levels are easily measured at the end of exhalation and the anesthesiologist should constantly measure these levels and adjust the ventilator to prevent hypercarbia and acidosis. Patients who have pulmonary airway disease compromising the ability to exhale CO_2 might require surgery via another technique. Because pulmonary compliance is decreased and functional residual capacity is impaired by pneumoperitoneum and patient positioning, minute volume may need to be increased in order to correct the ventilation-perfusion mismatch to avoid hypercarbia and acidosis. The retroperitoneal approach for laparoscopic surgery has a greater risk of hypercarbia than the transperitoneal approach.

3.4 Effects of pneumoperitoneum on the central nervous system

Pneumoperitoneum during laparoscopic surgery also has the potential to increase cerebral blood flow (CBF), intracranial pressure, and intraocular pressure due to the increased $PaCO_2$ caused by absorption of CO_2 from the peritoneal cavity. The creation of pneumoperitoneum during laparoscopic surgery elevates ICP because increased the abdominal pressure obstructs venous return from the lumbar venous plexus (Halverson et al., 1998). Pneumoperitoneum also increases cerebral blood flow due to an increase in $PaCO_2$ and an increase in catecholamine release independent of $PaCO_2$. The rate of cerebral blood flow changes proportionally to the change in $PaCO_2$ within the range of 2.7–8.0 kPa (Huettemann, 2002; Fujii, 1999).

Regional cerebral oxygen saturation (rSO_2), as measured by near-infrared spectroscopy cerebral oximetry which allows for continuous and noninvasive monitoring of rSO_2, decreased when cerebral perfusion pressure declined as a result of increased ICP (Dunham, 2002; Lee, 2006). Lee et al (Lee et al., 2006) also reported that rSO_2 decreased significantly in the Trendelenburg position. They reported that although no additional effect was seen with pneumoperitoneum, the rSO_2 was further decreased in the setting of hypercapnea, which increased the blood volume with a consequential increase in ICP. In contrast, Park et al

(Park et al., 2009) during robot-assisted laparoscopic radical prostatectomy, in patients in the Trendelenburg position, found that cerebral oxygenation, as assessed by rSO$_2$, increased slightly, which suggested that the procedure itself did not induce cerebral ischemia. While in the steep (40°) Trendelenburg position, regional cerebral oxygenation was well preserved and CPP remained within the normal limits of cerebral autoregulation, as measured by near-infrared spectroscopy (Kalmar et al., 2010).

Respiratory changes
- Decreased total volume of the lungs
- Decreased pulmonary compliance
- Hypoxemia (secondary to a ventilation-perfusion mismatch and intrapulmonary shunting)
- Hypercapnia and acidosis (secondary to CO_2 absorption)
- Increased PaCO$_2$ and EtCO$_2$

Cardiovascular changes
- Decreased stroke index, cardiac index
- Decreased peripheral venous flow
- Direct and indirect sympatho-adrenal stimulation (caused by hypercarbia)
  - Myocardial depression
  - Direct vasodilation
- Increased SVR, PVR

Renal changes
- Oliguria, decreased renal blood flow
- Increased ADH, renin, and aldosterone
- Intraoperative increase in serum creatinine

Abdominal changes
- Increased intra-abdominal pressure
- Decreased perfusion of intraabdominal organs (kidney, liver, stomach, mesentery) and spinal cord

Table 2. Pathophysiologic changes during pneumoperitoneum

Cerebral blood flow–carbon dioxide (CBF–CO$_2$) reactivity is one marker of the ability of the cerebral vasculature to respond to cerebral metabolic demands. CBF–CO$_2$ reactivity did not change significantly in one study of patients undergoing robot-assisted laparoscopic radical prostatectomy (with pneumoperitoneum) while in the Trendelenburg position (Choi et al., 2009). During pneumoperitoneum in the head-down position, the resulting changes in venous pressures, together with hypercapnia, can lead to significant increases in intracranial pressure. These changes can result in brain injury in selected patients, causing postoperative neurological deficits (Fujii, 1994; Huettemann, 2002). Laparoscopic procedures in the head-down position are to be avoided in patients with space-occupying intracranial lesions because of the excessive increase in ICP (Alishahi, 2001; Dunham, 2002).

3.5 Other complications of induced pneumoperitonium
Venous CO_2 embolism may occur intraoperatively and in the early postoperative period. Abnormal gastroesophageal junction competence from high intraabdominal pressure may lead to pneumomediastinum, subcutaneous emphysema, pneumothorax, and retroperitoneal CO_2.

In hand-assisted laparoscopic donor nephrectomy patients, ocular complications and corneal abrasions were reported. These may result from increased fluid intake, flank positioning, and potential increased venous compression resulting from the effects of the pneumoperitoneum. The fact that the dependent eye was involved in all patients suggests conjunctival edema as a potential common pathway (Koning et al., 2011).

Rhabdomyolysis after prolonged laparoscopic nephrectomy in the lateral decubitus position has been reported, but is thought to be rare. Its myoglobinuria may result in kidney dysfunction (Kuang et al., 2002).

4. Intraoperative anesthesia management

Laparoscopy patients should undergo a preoperative evaluation identical to that for patients undergoing the equivalent open procedure. Depending on the surgeon's experience with these procedures, the anesthetic plan should anticipate the possibilities of significant bleeding and conversion to an open procedure. Routine intraoperative monitoring (EtCO$_2$, pulse oximetry, BP, airway pressure) should be adequate for the expected physiologic changes encountered in most patients. The anesthesiologist should continually monitor the insufflating pressure being used and should be alerted if an unusual amount of CO$_2$ is required.

Noninvasive methods of assessing changes in partial arterial pressures of carbon dioxide (eg. EtCO$_2$ measured with mass spectrography) may be misleading because changes in partial arterial pressures of carbon dioxide are typically much smaller than changes in arterial blood levels and, unlike arterial gas measurements, do not indicate the true level of arterial hypercarbia. During laparoscopic cholecystectomy, patients with chronic cardiopulmonary disease may require careful intraoperative arterial blood gas monitoring of absorbed carbon dioxide (Wittgen et al., 1991). With extended periods of insufflation and higher pressures, faster CO$_2$ absorption occurs and arterial carbon dioxide levels may reach harmful levels. Measurement of EtCO$_2$ allows the physician to manipulate ventilation as needed (Nguyen & Wolfe, 2005).

Cardiovascular monitoring should be appropriate for the planned procedure, based on the patient's clinical status. Central venous and pulmonary arterial wedge pressure measurements are biased during laparoscopy because of transmission of intraabdominal pressure to the mediastinal space. Use of TEE in high-risk patients allows for more accurate assessment of cardiac volumes. TEE for hemodynamic monitoring may be useful in the prevention and recognition of cardiovascular complications. Femoral venous flow augmentation with intermittent sequential pneumatic compression reverses perioperative cardiac depression and overcompensates for the state of peripheral venous stasis induced by pneumoperitoneum during laparoscopic surgery in the head-up tilt position (Alishahi, 2001; Schwenk, 1998).

When laparoscopic procedures are performed in an ambulatory setting, the choice of induction and maintenance anesthetic agents reflects the need for prompt awakening and rapid recovery. The anesthetic management of laparoscopic surgery includes minimizing hemodynamic changes which may occur due to the pneumoperitoneum and patient's position (Colombo et al., 2001). In laparoscopic surgery, nitrous oxide (N$_2$O) is often avoided, to prevent bowel distension if the procedure becomes prolonged. Nitrous oxide accumulates in the CO$_2$ pneumoperitoneum during laparoscopy when N$_2$O is used as an adjuvant for inhaled anesthesia. Accumulated N$_2$O in a CO$_2$ atmosphere may be dangerous because it can lead to excessive dilatation of the bowel.

The risk of CO_2 and N_2O gas embolism is also a concern because the consequences of such embolization may differ from those with the same volume of CO_2 alone. N_2O diffuses into the abdominal cavity and will diffuse into CO_2 bubbles and emboli, increasing their size and potential for an obstructive event. (Diemunsch et al., 2002). Adequate muscle relaxation is required during laparoscopy so that spontaneous respiratory efforts do not impair the surgical procedure or increase the gradient for embolic gas to enter the central circulation. Despite the limited surgical incision(s) of laparoscopic procedures, postoperative muscle pain remains a problem. These problems have not been eliminated by avoiding succinylcholine or by using other anesthetic regimens.

$PaCO_2$ should be maintained within its normal range during pneumoperitoneum in the Trendelenburg position. For example, rSO_2 increased in conjunction with the increase in $PaCO_2$ during pneumoperitoneum in a steep Trendelenburg position in patients undergoing daVinci robot-assisted laparoscopic prostatectomy (Park et al., 2009).

Watanabe et al. found that remifentanil (0.2 µg/kg/min) may suppress the cardiovascular changes caused by pneumoperitoneum in laparoscopic cholecystectomy patients. Through an epidural catheter placed between T_{10-12}, 0.2% ropivacaine was infused continuously at 6 mL/hr. With a pneumoperitoneum, as opposed to an epidural anesthetic, remifentanil significantly suppressed the tachycardia, but not the hypertension caused by the pneumoperitoneum (Watanabe et al., 2009). Esmolol infusion can also be used to provide hemodynamic stability during laparoscopy (Coloma, 2001; Junghans, 2006).

No ventilation technique for laparoscopic surgery has proved to be clinically superior to any other. Both conventional volume-controlled ventilation and pressure-controlled ventilation were found to be equally suited for use in patients undergoing laparoscopic gynaecologic surgery (Oğurlu et al., 2010).

Stationary positioning of the patient over long periods of time during laparoscıpic surgery may place the patient at risk for neuropraxia, rhabdomyolysis, compartment syndrome, and pressure ulcers. Neuromuscular and pressure injury becomes more likely with increasing surgical duration, hence the need for appropriate padding and support, especially during laparoscopic nephrectomies (Elsamra & Pareek, 2010).

> Hypotension, decreased cardiac output
> Hemorrhage
> Acidosis
> Pneumothorax
> Pneumomediastinum
> Endobronchial intubation
> Subcutaneous emphysema
> Airway obstruction
> Retroperitoneal CO_2
> Venous stasis
> Venous CO_2 embolism
> Increased sympathetic activity secondary to increased CO_2
> Bradycardia, increased vagal tone
> Cardiac arrest
> Regurgitation and aspiration

Table 3. Complications during laparoscopy

5. Intraoperative surgical complications.

During laparoscopy, positional changes may significantly decrease venous return, causing low cardiac output and hypotension. This condition can be prevented by fluid loading and promptly reversed by deflation and table deflection. The changes listed above may lead to myocardial ischemia in patients at risk. In the rare event of catastrophic hemodynamic collapse during laparoscopy, several possible causes should be considered: bleeding, subcutaneous emphysema, pneumothorax, pneumomediastinum, diaphragmatic tears, and gas embolism. Although the use of CO_2 for pneumoperitoneum reduces the probability of a massive pulmonary embolism, it is a potentially fatal complication and should be considered in case of intraoperative hemodynamic deterioration (Slodzinski & Merritt, 2008).

Initial therapy during a catastrophic event includes releasing the pressurized pneumoperitoneum (i.e., conversion to an open procedure). For pneumothorax, a thoracentesis should be performed. If massive embolization occurs, N_2O, if employed, should be discontinued immediately and cardiopulmonary resuscitation should be performed. The patient should be placed in the left lateral position. Attempts at embolus retrieval should be made through central venous access, if available. If these measures are not sufficient, cardiopulmonary bypass may be necessary (Joris, 2005; Leonard, 2002).

During laparoscopy, hemorrhage can be obvious or occult (e.g., retroperitoneal), and may be encountered intra-operatively or in the postoperative period. Bleeding complications are an important subset of 'non-biliary' injuries, and can cause death on the operating table if not recognized and treated in time. Bleeding complications are the most frequent cause of procedure-related mortality in laparoscopic cholecystectomy (after anaesthesia-related deaths) (Buttenschoen, 2007; Phillips, 2001).

Intra-operative bleeding usually falls into one of the following four patterns: vessel injury, slippage of clips/ligatures of the cystic artery, liver bed bleeding, and miscellaneous. Vessel injuries are usually the most dramatic and occur either during insertion of the first trocar or during dissection/retraction, and were rarely seen before the advent of laparoscopic surgery. The insertion of the pneumoperitoneum needle and the first trocar is considered by many to be the most dangerous step in laparoscopic cholecystectomy, as it is essentially a 'blind' step. As this initial step is common to all laparoscopic operations, it has been reviewed extensively by various authors. As mentioned earlier, the majority of bleeding complications occur in this phase of the operation. Although the most commonly injured vessels are the epigastric vessels, injury can also occur to the major intra-abdominal vessels (aorta, vena cava, iliac vessels), in 0.04% to 0.18% of patients (Geraci et al., 2006). None of the "no entry" techniques for laparoscopy (trocar entry after creation of pneumoperitoneum, trocar entry without prior insufflation, or various modifications of the open technique of port placement) are free from the risk of complications (Kaushik et al., 2010).

Bleeding complications are divided into major and minor depending on the need for conversion, additional surgical procedures, or blood transfusions. Thus, any bleeding that requires a laparotomy is considered major, irrespective of the vessel injured or the timing (intra-operative or postoperative). Similarly, any bleeding that needs an additional surgical procedure (wound exploration and ligation of bleeder) or blood transfusion is also considered to be major, whereas bleeds controllable by pressure or packing, or abdominal wall haematomas that do not require any additional manoeuvres, can be classified as minor bleeds (Kaushik et al., 2010).

Major and minor complication rates for laparoscopic renal surgery have ranged from 1-6% and 6-17%, respectively. Vascular, bowel, and ureteral injuries are reported as the most

commonly encountered intraoperative complications. A key component to decreasing the incidence of surgical complications is proper patient selection and identification of preoperative risk factors. Potential preoperative risk factors, such as prior operations, increased age, increased body mass index, poor renal function, and anomalies in renal vasculature, are of crucial importance to proper preoperative risk stratification. Also, the urologist must be facile with current laparoscopic techniques in order to minimize complications (Elsamra & Pareek, 2010). In a study (Colombo et al., 2008) of patients who underwent laparoscopic nephrectomy, nephroureterectomy, laparoscopic partial nephrectomy, and adrenalectomy, age greater than 65 years predicted a longer hospital stay, but was not an independent risk factor for complications. In addition, patients with baseline elevated creatinine were at higher risk of postoperative renal deficiency. Recently, in patients with a BMI less than 25 kg/m^2 and greater than 40 kg/m^2 who underwent laparoscopic radical nephrectomy or laparoscopic partial nephrectomy, no statistically significant difference was found for estimated blood loss, operative time, hospital stay, number of open conversions, or complications. However, a trend toward increased operative time and intra-operative complications (not statistically significant) was noted in patients with increased BMI (Gong et al., 2007). Surgical experience appears to be directly related to the complication rate, with at least 50 laparoscopic cases required to achieve proficiency (Vallancien et al., 2002). In addition, 80% of all major complications of laparoscopic surgery occurred among the surgeon's first 100 cases. Short intensive courses may increase the surgeon's experience, confidence, and competency in advanced laparoscopic procedures (Pareek et al., 2005).

6. Postoperative risks

Postoperative nausea and vomiting (PONV) occurs in 40–70% of patients undergoing laparoscopic cholecystectomy. Female patients have a 1.5-3 times greater incidence of PONV than males, due to increased plasma progesterone levels during their menstrual cycles. Antiemetics used to prevent PONV after laparoscopic cholecystectomy include antihistamines (dimenhydrinate), phenothiazines (perphenazine), butyrophenones (droperidol), benzamides (metoclopramide), dexamethasone, and serotonin-receptor antagonists (ondansetron, granisetron, tropisetron, dolasetron, and ramosetron). Knowledge regarding prophylactic antiemetic therapy is necessary to effectively manage PONV in female patients (Fujii 2005; 2009 and 2010).

In laparoscopic cholecystectomy, before or following induction of anesthesia, dexamethasone alone or in combination with a serotonergic antagonist (granisetron, ondansetron) to prevent nausea and vomiting is well established (Dabbous, 2010; Fujii, 2010; Erhan, 2008). Dexamethasone alone was found as effective as 4 mg ondansetron and 3 mg granisetron (Erhan et al., 2008). Dexamethasone, in combination with a serotonergic antagonist, significantly reduced the incidence of PONV more than promethazine and granisetron monotherapy (Dabbous, 2010; Fujii, 2010). In women undergoing ambulatory gynaecological laparoscopy, prophylactic low-dose granisetron and promethazine together were more effective in reducing PONV than promethazine or granisetron alone (Gan et al., 2009) Risk factors for postoperative PONV after laparoscopic cholecystectomy include pain, dizziness, ambulation, oral intake, and analgesics (opioids). Avoiding these risk factors would result in less PONV for patients undergoing LC (Fujii et al., 2010).

In recent years, mini-laparoscopic cholecystectomy (trocar incision <25 mm) has been increasingly advocated for the removal of the gallbladder, due to better surgical and postoperative outcomes (e.g., better cosmetic result, reduced pain, shorter hospital stay, and quicker return to activity). Although mini-laparoscopy is feasibile and safe, it does require a longer surgical time and has a reasonably high risk for conversion to standard laparoscopic cholecystectomy. Furthermore, mini-laparoscopy has not been found to have any additional clinical benefit compared to standard laparoscopic cholecystectomy (Huang, 2003; McCloy, 2008).

To manage the pain associated with increasingly complex surgical procedures on an ambulatory or short-stay basis, anesthesiologists and surgeons should prescribe multimodal analgesic regimens that use non-opioid analgesics (eg. local anesthetics, nonsteroidal antiinflammatory drugs, cyclooxygenase inhibitors, acetaminophen, ketamine, alpha 2-agonists) to supplement opioid analgesics. The opioid-sparing effects of these compounds may lead to reduced nausea, vomiting, constipation, urinary retention, respiratory depression and sedation. Therefore, use of non-opioid analgesic techniques can lead to an improved quality of recovery for surgical patients (White, 2008). Tramadol and paracetamol cause no respiratory depression while providing analgesia and sedation after operative procedures. Oral tramadol (1 mg.kg^{-1}) with IV paracetamol (1 g) decreased the incidence of side effects of tramadol alone without reducing its analgesic efficacy in a day-care laparoscopic surgery setting (Ali & Khan, 2009).

IV tramadol after insufflation of the pneumoperitoneum and again before removal of the trocars was used provided superior postoperative analgesia to IP tramadol in the early postoperative period after laparoscopic cholecystectomy (Akıncı et al., 2008). Epidural analgesia with a bupivacaine/fentanyl combination provided significant improvement in postoperative pain control compared with IV fentanyl during the first 24 hours following laparoscopic cholecystectomy (Erol et al., 2008).

In patients undergoing laparoscopic cholecystectomy, the combination of 0.25% IP bupivacaine and IV morphine was more effective than IP morphine plus IP 0.25% bupivacaine for reducing postoperative analgesic requirements (Hernández-Palazón et al., 2003). Another study in LC patients found pre-operative 50 mg/kg magnesium sulphate IV to be more effective in reducing post-operative pain than saline (Menteş et al., 2008).

Intraoperative and postoperative analgesia usually is performed with a combination of opioids and NSAIDs. While IV or epidural opioids remain the mainstay for postoperative analgesia, their use can be associated with adverse effects, such as ileus, which can prolong hospital stay, especially after colorectal surgery. Thoracic epidural analgesia provides better postoperative analgesia than intraoperative and postoperative IV lidocaine infusion (Wongyingsinn et al., 2011), and spinal anaesthesia using intrathecal morphine in addition to local anaesthetic, and the use of nonsteroidal anti-inflammatory agents (Levy et al., 2010). But thoracic epidural analgesia patients had similar length of hospital stay, time to tolerate a normal diet, and bowel function parameters compared to others under general anesthesia after laparoscopic colorectal surgery (Levy, 2010; Wongyingsinn, 2011). In contrast, when a traditional perioperative care program is used for laparoscopic colectomy, thoracic epidural analgesia is superior to PCA in accelerating the return of bowel function and dietary intake, while providing better pain relief compared to PCA morphine (Taqi et al., 2007).

In patients undergoing ambulatory totally extra-peritoneal laparoscopic inguinal hernioplasty under local anaesthesia, pain and analgesic consumption was less and recovery of daily life activities more rapid compared to those patients undergoing ambulatory

Lichtenstein hernioplasty with local anaesthesia (Planells et al., 2011). Additionally, for patients with recurrent inguinal hernia, or bilateral inguinal hernia, laparoscopic repair offers significant advantages over open techniques with regard to recurrence risk, pain, and recovery (Carter & Duh., 2011). Donors undergoing laparoscopic nephrectomy reported less bodily pain postdonation; this was associated with an improved mental health component of quality of life compared with open nephrectomy patients (Nicholson et al., 2011).

When respiratory functions of patients after open and laparoscopic cholecystectomy were compared, pulmonary function tests were better in patients subjected to LC (Osman et al., 2009). On the first post-operative day, FEV_1, FVC and FEV_1/FVC values in the open cholecystectomy group were significantly lower than those in the laparoscopic cholecystectomy group. The respiratory function tests returned to normal by the 6th postoperative day in both groups. LC resulted in an overall better postoperative respiratory function than open cholecystectomy (Bablekos, 2003; Hendolin, 2000).

Perioperative neurologic complications related to prolonged surgery in the steep head-down position include neurological deterioration after extubation, probably due to cerebral edema. The duration and positioning should be optimized for such prolonged surgery in the steep head-down position to minimize complications (Pandey et al., 2010). Bilateral upper extremity paresis caused by overstretching of the neck with the head was reported in two patients undergoing laparoscopic colectomy in a combined lithotomy and Trendelenburg position with arms abducted to 80° and flexed slightly on padded armboards (Imamura et al., 2010). They developed bilateral numbness of the first, second, and third digits, and the radial side of fourth digit in one patient's right hand, which subsided gradually over three days after physical training in both patients. In a report by Mizuno et al (Mizuno et al., 2008), right median nerve injury was caused by compression and stretching of the brachial plexus after laparoscopic sigmoidectomy in a patient who was operated upon while in the head-down position, with right lateral tilt table, use of shoulder brace, abduction of the upper arm, and extension of the elbow. His findings disappeared completely within one week. In laparoscopic operations in the head-down position, a shoulder brace should not be used to minimize the risk of brachial plexus injury. The arms should be placed at the patient's side, and the elbows should be gently flexed to unload the median nerve and relieve tension on the brachial plexus. Irreversible femoral nerve injury caused by trocar insertion was reported after gynaecologic laparoscopy by Porzionato et al (Porzionato et al, 2008). The patient complained of left thigh weakness and paresthesias, from the site of the left trocar insertion to the anteromedial aspect of the thigh and medial aspect of the leg and foot. Peritoneal adhesions and inadequate pneumoperitoneum may increase the risk of nerve injury. Physicians should be aware of the possibility of this complication, and should avoid too caudal a trocar insertion in the iliac fossa.

7. Conclusion

Laparoscopic surgical procedures aim to minimize the trauma of the interventional process. Advantages of these procedures include smaller incisional sites, lower risks of wound complications, reduced postoperative pain and complications, improved recovery, shorter hospital stays, more rapid return to normal activities, and significant cost savings.

Cardiorespiratory changes associated with laparoscopy include those associated with tilting the patient to facilitate instrumentation and surgical exposure, and pressure effects of the instilled gas into peritoneum. Endoscopic surgery also involves complications,

especially when extended periods of carbon dioxide insufflation are used, and especially with the patient in the steep head-down position. In such circumstances, adverse haemodynamic and respiratory effects are more prone to occur. Traumatic injuries associated with blind trocar insertion may injury viscera and blood vessels, leading to severe hemorrhage and morbidity.

Depending on the surgeon's experience, the anesthesiologist should anticipate the possibility of significant bleeding and/or conversion to an open procedure. Laparoscopy patients should undergo a preoperative evaluation identical to that of patients undergoing the comparable open procedure.

When laparoscopic procedures are performed in an ambulatory setting, the choice of induction and maintenance anesthetic agents reflects the need for prompt awakening and rapid recovery. In the anesthetic management of laparoscopic surgery, hemodynamic changes may occur due to the pneumoperitoneum and/or patient's position. In laparoscopic surgery, N_2O is often avoided, to prevent bowel distension if the procedure becomes prolonged. A continuous infusion of bupivicaine via epidural catheter or IV remifentanil or esmolol may suppress the cardiovascular changes caused by the pneumoperitoneum during laparoscopic surgery.

In laparoscopic surgery, no ventilation technique has proved to be clinically superior to any other. Both conventional volume-controlled ventilation and pressure-controlled ventilation have been found to be equally suited for use in patients undergoing laparoscopic gynaecologic surgery. Prophylactic antiemetics should be used to prevent PONV after LC, especially in female patients.

The death rate during operative laparoscopy is 0.1 to 1 per 1000 cases and the incidence of hemorrhage and visceral injury (the most lethal complications of laparoscopic surgery) is 2 to 5 per 1000 cases. Good surgical technique and early recognition and management of such cases are keys to prevent complications due to laparoscopy. Experience and skill of the anaesthesia and surgical teams continue to be key factors to ensure optimal results.

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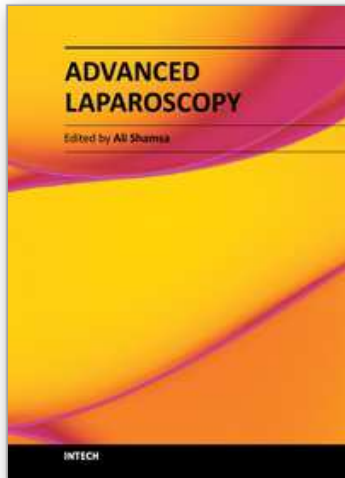
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