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SURGICAL ENDOSCOPY
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Laparoscopic surgery

Pitfalls due to anesthesia, positioning, and pneumoperitoneum

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Abstract
Background: Laparoscopic procedures are increasing in number and extensiveness. Many patients undergoing laparoscopic surgery have coexisting disease. Especially in patients with cardiopulmonary comorbidity, pneumoperitoneum and positioning can be deleterious. This article reviews possible pitfalls related to the combination of anesthesia, positioning of the patient, and the influence of pneumoperitoneum in the course of laparoscopic interventions.
Methods: A literature search using Medline's MESH terms was used to identify recent key articles. Cross-references from these articles were used as well.
Results: Patient positioning and pneumoperitoneum can induce hemodynamic, pulmonary, renal, splanchnic, and endocrine pathophysiological changes, which will affect the entire perioperative period of patients undergoing laparoscopic procedures.
Conclusion: Perioperative management for the estimation and reduction of risk of morbidity and mortality due to surgery and anesthesia in laparoscopic procedures must be based on knowledge of the pathophysiological disturbances induced by the combination of general anesthesia, pneumoperitoneum, and positioning of the patient.

Key words: Surgery — Laparoscopy — Anesthesia — Pneumoperitoneum — Artificial

Although endoscopy of the abdominal cavity was performed as early as 1911, it was not until the past few decades that laparoscopic surgery became common clinical practice [1]. Initially, the use of laparoscopic procedures was confined to small and rapid gynecological interventions such as sterilization and short diagnostic procedures. It was generally carried out in young and healthy women and often performed in a day-care setting. Recovery from anesthesia had to be rapid and with a minimum of residual effects. Therefore, laparoscopic procedures became a challenge to anesthesiologists.

New intraabdominal laparoscopic surgical techniques have since been developed and performed and are advocated for children and older patients also. In contrast to the young and healthy female, children may suffer from previously undiagnosed conditions such as congenital heart disease or an abnormal airway, whereas the older patients may have coexisting cardiac and/or pulmonary disease. Therefore, a careful preoperative evaluation and optimization of these patients should take place in order to decrease perioperative morbidity and mortality. Because these new procedures may involve extreme changes in patient position, extensive periods of intraabdominal carbon dioxide (CO_2) insufflation, unexpected visceral injury, and difficulty in evaluating the amount of blood loss, anesthesia for laparoscopy can be considered a potentially high-risk rocedure.

Since the early 1990s elaborate and timely laparoscopic procedures have been performed. Almost every abdominal organ now seems to be amenable to laparoscopic surgery [2–6]. All these laparoscopic procedures may induce major pathophysiological disturbances. Therefore, the anesthesiologist must choose an appropriate anesthetic management technique, apply adequate monitoring, and be aware of possible complications. In addition special attention must be given to the position of the patient on the operating table and to perioperative fluid management. Early detection and reduction of possible intraoperative problems may then be achieved. Finally, during the early postoperative period special attention must be paid to cardiovascular and pulmonary problems, postoperative nausea and vomiting, and pain management.

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Table 1. ASA classification of physical status and the associated mortality rates

ASA rating	Description of patient	Morbidity rate (%)	Mortality rate (%)
Class I	A normally healthy individual	4	0.1
Class II	A patient with mild systemic disease	8	0.2
Class III	A patient with severe systemic disease that is not incapacitating	14	1.8
Class IV	A patient with incapacitating systemic disease that is a constant threat to life	34	7.8
Class V	A moribund patient who is not expected to survive 24 h with or without operation	ND	9.4
Class VI	A declared brain-dead patient whose organs are being removed for donor purposes	NA	NA
Class E	Added as a suffix for emergency operation		

ND, No data; NA, not appropriate

Table 2. Clinical examination relevant to the anaesthesiologist according to Baxendale and Smith [8]

System	Features of interest
General	Nutritional state; fluid balance; condition of the skin and mucous membranes (e.g., anemia, perfusion, jaundice); body temperature
Cardiovascular	Peripheral pulse (i.e., rate, rhythm, volume); jugular venous pressure and pulsation; arterial pressure; heart sounds; carotid bruits; dependent edema
Respiratory	Central vs peripheral cyanosis; observation of dyspnea; auscultation of lung fields
Airway	Mouth opening; neck movements; thyromental distance; dentition
Nervous	Any dysfunction of the special senses, other cranial nerves, or peripheral motor and sensory nerves

Table 3. Patient characteristics for selected preoperative testing according to ASA Task Force [9]

Preoperative test	Patient characteristic
ECG	Advanced age; cardiocirculatory disease; respiratory disease
Other cardiac evaluation	Cardiovascular compromise
Chest x-ray	COPD; cardiac disease; recent upper respiratory infection; smoking
Pulmonary function tests	COPD; reactive airway disease; scoliosis
Office spirometry	Reactive airway disease; COPD; scoliosis
Hemoglobin/hematocrit	Anemia; bleeding disorders; other hematological disorders; advanced age; very young age
Coagulation studies	Bleeding disorders; anticoagulants; liver dysfunction; renal dysfunction
Serum chemistry (i.e., Na, K, CO_2, Cl, glucose)	Renal dysfunction; endocrine disorders; medications
Pregnancy test	History suggestive of current pregnancy; uncertain pregnancy history

ECG, Electrocardiography; COPD, chronic obstructive pulmonary disease; Na, plasma sodium; K, plasma potassium; CO_2, arterial partial pressure of carbon dioxide; Cl, plasma chloride

Preoperative evaluation

The main goal of preoperative medical assessment is the estimation and possible reduction of risk of morbidity and mortality due to surgery and anesthesia. Further aims are to increase the quality of peroperative care, to restore the patient to the desired level of function, and to obtain the patient's informed consent for the anesthetic procedure [7]. The American Society of Anesthesiologists (ASA) classification score (Table 1) provides a simple description of the physical state and is one of the few prospective descriptions of the patient that correlates with the risks of anesthesia and surgery.

An ASA Task Force on "Practice Advisory for Preanesthesia Evaluation" recommends preoperative evaluation to include (1) readily accessible medical records, (2) patient interview, (3) a directed preanesthesia examination (Table 2, [8]), (4) preoperative tests when indicated (Table 3), and (5) other consultations when appropriate [9]. A directed preanesthetic physical examination should at least include an assessment of the airway, lungs, and heart [9].

Thus, the presence of coexisting medical disease must be identified, together with its extent and association with limiting normal daily activity in the patient. With respect to infants and children, preoperative examination must also identify previously undiagnosed conditions such as congenital heart disease [10].

All conventional complications and concerns of laparoscopy are applicable. In general pneumoperitoneum (PP) and laparoscopy are contraindicated in patients with increased cranial pressure, ventriculoperitoneal shunt, peritoneojugular shunt, hypovolemia, and congestive heart failure [11].

Intraoperative management

Anesthetic technique

Common side effects of laparoscopic procedures are irritation of the diaphragm due to the carbon dioxide insufflation for maintaining PP, significant nausea and vomiting, and referred pain in the distribution of the

Table 4. Methods for basic monitoring standards

Essential	Oxygenation	Ventilation	Circulation	Temperature
	Inspired gas monitoring	Expired gas volume	ECG	Body temperature
	Pulse oximetry	Disconnection detector	HR	
	Clinical observation	Expired carbon dioxide	Blood pressure	Clinical observation
If applied	Muscle relaxant use		Volatile anesthetic use	
	Nerve stimulator		Inspiratory anesthetic concentration	
			Expiratory anesthetic concentration	

ECG, Electrocardiography; HR, heart rate

phrenic nerve. Although regional anesthesia has been applied successfully for laparoscopic cholecystectomy [12], general anesthesia is thought to be the technique of choice for laparoscopic procedures [13].

The combination of a generally uncomfortable position on the operating table together with a long-lasting procedure makes a state of wakefulness during laparoscopic surgery not very acceptable for patients. When regional anesthesia is combined with sedation, airway protection cannot be ensured, and respiratory depression with further induction of hypercapnia can be expected. The general anesthetic technique provides a secure airway, enables controlled mechanical ventilation with proper handling of the CO_2 absorption that is induced by the PP, and facilitates management of muscle relaxation necessary to optimize the surgical view. In conclusion, general anesthesia is preferred over a regional technique for extensive laparoscopic procedures.

In children, anesthesia can be induced by inhalation of volatile anesthetics as well as with intravenous techniques [10]. Because of an increased intraabdominal pressure (IAP) due to the PP, i.v. access is preferred to ensure immediate onset of medication [10]. Furthermore, it seems better to intubate children < 6 years of age with a *cuffed* endotracheal tube (this is usually avoided in this age group because of the small diameter of the trachea) to prevent ventilation difficulties due to the IAP increase [10].

Monitoring of patients

Cardiac events are the leading cause of death during and immediately after surgical procedures [14–16]. Perioperative morbidity also is associated with pulmonary complications and moderate hypothermia [17]. However, the rate of complications directly related to anesthesia is low [18].

Although guidelines and recommendations for monitoring standards are usually defined by the national societies of anesthesia, some *basic* aspects should be monitored in every patient regardless of the choice of anesthetic technique, type of surgery, or condition of the individual patient [19, 20]. Table 4 gives methods for the application of these basic monitoring standards.

Advanced monitoring consists of the measurement of cardiac filling pressure, cardiac output, and mixed venous oxygen saturation. The conventional monitoring of cardiac filling pressures requires central venous cannulation. Although complications due to cannulation are infrequent, they may result in severe morbidity [21]. Since laparoscopic procedures are also performed in the elderly, often cardiovascularly disabled ASA III or IV patients, such advanced monitoring may be necessary. However, when the cardiac function is impaired the relation between central venous pressure and cardiac preload is altered and the cardiac filling pressure measurements may not be reliable [22], In such cases insertion of a pulmonary artery catheter should be considered.

Transesophageal echocardiography (TEE) is a semiinvasive method of measuring cardiac performance and ventricular filling. The use of TEE in laparoscopic procedures is recommended for early detection of gasembolism and examination of a possible patent foramen ovale (PFO) [23]. The estimation of the prevalence of PFO in postmortem studies is 25% to 35% [24]. The clinical significance increases from 5–10% at basal in vivo conditions to 18–22% after sudden release of intrathoracic pressure, a situation that might be expected during laparoscopy [25]. Although the effect of regular TEE use on outcome is unknown, when used by experienced staff the complication rate of the technique is low [26]. Therefore, its use is recommended in subsets of patients, such as those having a known cause of hemodynamic instability [19].

Fluid management

Fluid management in laparoscopic surgery can be a dilemma for the anesthesiologist. Usually, patients enter the operating room after a time of fasting, most often at least 6 h. The patients' circulatory status is therefore relatively hypovolemic, and anesthesia, whether general or regional, further increases the fluid debt.

Depending on the positioning of the patient in combination with PP, on the one hand a restrictive fluid regimen may be advantageous whereas on the other hand vital organ perfusion requires intravenous fluid loading.

The Trendelenburg, "head-down" position in itself causes increased venous return [27]. In combination with PP, this venous return may be even further increased due to compression of the splanchnic vasculature. In cardiovascularly compromised patients these sudden hemodynamic changes may lead to congestive heart failure and/or acute myocardial infarction.

The Trendelenburg position, especially the long-lasting extreme head-down position, can raise the intracranial and intraocular pressures. Cerebral edema and retinal detachment may occur. Because of venous stagnation, cyanosis and edema in the face and neck may be expected. On the other hand hypotension can be induced when high intraabdominal pressure (IAP) is applied in combination with intermittent positive pressure ventilation (IPPV) due to compression of the inferior vena cava in combination with an elevated intrathoracic pressure. The latter is especially seen in relatively hypovolemic patients. Furthermore, high IAP may reduce renal perfusion and consequently urine production [28]. The best method for maintaining renal perfusion is the preservation of an adequate intravascular volume.

The reverse Trendelenburg, "head-up" position reduces venous return, which may lead to a fall in cardiac output and arterial pressure. If the patient has an adequate intravascular volume, PP will compensate for this decrease by increasing the venous return.

The lithotomy "legs up" position will induce "autotransfusion" by redistributing blood from the vessels of the lower extremities into the central body compartment, which thus will increase the preload of the heart. Subsequent PP will further increase venous return, the effect of which on the cardiac output (CO) will depend on the patient's circulatory filling status.

The lateral decubitus position used for nephrectomy can cause direct compression of the inferior vena cava resulting in a decreased venous return and subsequent hypotension.

In conclusion, because of a combination of anesthesia, positioning, and PP, impressive fluid shifts may take place. Therefore, it is recommended that patients be adequately intravenously fluid loaded to maintain a normal CO. However, ASA class III and IV patients then may need advanced cardiac monitoring. It should be stressed that because of positioning and intra-thoracic pressure, central venous pressure monitoring does not reliably reflect the patient's filling status.

Intraoperative complications

Apart from the common side effects of laparoscopy and usual reported morbidity and mortality around all surgical procedures, specific complications during laparoscopic surgery may occur. These complications are basically due to the carbon dioxide PP and/or patient positioning.

Pneumoperitoneum will induce hemodynamic, pulmonary, renal, splanchnic, and endocrine pathophysiological changes. However, most of these changes are clinically insignificant if appropriate anesthetic care is provided.

Pulmonary changes

Carbon dioxide is a highly soluble gas that is rapidly absorbed through the peritoneum into the circulation inducing hypercapnia and acidosis. During PP, the end-tidal CO_2 concentrations increase progressively with time, reaching maximum value after 40 min of CO_2 insufflation if ventilation is kept constant [29]. Thereafter, CO_2 begins to accumulate in the body reservoir; up to 120 L CO_2 can be stored. The absorption of CO_2 is especially increased during prolonged surgery in combination with high IAP. Although a persistent elevation in the pCO_2 is known to stimulate renal H^+ secretion resulting in the addition of bicarbonate to the extracellular fluid, the renal response takes time to develop, and the net effect is that after 3 to 5 days, a new steady state is attained [30]. So, during laparoscopic procedures CO_2 is almost only excreted through the lungs, and thus, hypercapnia must be decreased by compensatory hyperventilation. This hyperventilation may best be accomplished by increasing the tidal volume of ventilation in anesthetized patients. Nevertheless, respiratory acidosis and increased CO_2 output last for at least up to 1 h postoperatively [31]. Carbon dioxide exhaustion is reduced when cardiopulmonary function is compromised [32].

Intraabdominal pressure plays a major role in the cause of hypercapnia as it increases the absorption and decreases the exhaustion of CO_2. Elevated IAP and abdominal expansion shifts the diaphragm cephalad. This causes an increase in intrathoracic pressure; the abdominal part of the chest wall stiffens, thus restricting expansion of the lungs. During general anesthesia alone the functional residual capacity of the lung is reduced by ~20% [33]. During increased IAP the pulmonary dynamic compliance is significantly decreased up to 50%, whereas peak and plateau pressures are increased [34–36].

Ventilation perfusion mismatch and intrapulmonary shunting may become increased. In patients with a normal preoperative pulmonary function this will not lead to hypoxemia. In contrast, patients with compromised cardiopulmonary function such as emphysema or chronic obstructive pulmonary disease (COPD) will be at risk for developing hypoxemia.

To avoid hypercapnia and respiratory acidosis during PP the minute volume of ventilation should be increased, perhaps even to ~12–15 ml/kg. However, the anesthesiologist will consider the disadvantages of hypercapnia and acidosis vs the increases in inspiratory peak and plateau pressures that may induce ventilator induced lung injury (VILI). Although positive end-expiratory pressure (PEEP) improves the pulmonary gas exchange during PP [37], it should be realized that PEEP in combination with increased IAP increases the intrathoracic pressure, thus causing a reduction in CO [38]. Because of these pulmonary changes, insufflation with other gases such as argon, xenon, helium, and room air was investigated [39–44]. Although argon PP was not associated with significant changes in cardiorespiratory functions, argon embolism seemed to be more deleterious than CO_2 embolism and might thus carry a higher risk in case of accidental gas embolism [39]. Helium insufflation was found to be superior in comparison to CO_2 insufflation with respect to acidosis, hypercarbia, base excess changes, and influence on intracranial pressure [41, 43, 44], but was found to cause a greater impairment of hepatic blood flow [42]. Both helium and xenon were also investigated in laparoscopy because of a possible antitumor effect [40]. Further studies with these gases are still being performed.

Pulmonary complication

Pulmonary complications that may occur during laparoscopic surgery are barotrauma, pulmonary edema, atelectasis, gas embolism, subcutaneous emphysema, pneumothorax, pneumomediastinum, and pneumopericardium.

Hypoxemia may develop in patients with cardiopulmonary comorbidity such as emphysema and COPD. In most cases adequate ventilation and oxygenation will reverse hypoxemia. If not, conversion to open surgery may be required. The combination of increased mean airway pressure and decreased lung compliance is associated with barotrauma, which may result in acute pneumothorax [45]. Although pulmonary changes are of concern in infants undergoing laparoscopic surgical procedures, laparoscopy can safely be performed if proper attention is maintained during the procedure [46].

Carbon dioxide embolism is a very serious but rare complication of PP; mortality rates of up to 28% have been described [47]. The major cause of CO_2 embolism is known to be misplacement of the Veress needle, either directly into a vessel or into a parenchymal organ. Carbon dioxide bubbles can enter the circulation through an opening in any injured vessel due to the raised IAP. With respect to the occurrence of gas emboli during the initial institution of PP, the Hasson technique seems safer than the Veress needle technique [48].

The intravascular presence of small amounts of CO_2 frequently occurs, usually without any clinical consequence. Studies with TEE revealed 68% of asymptomatic patients to have CO_2 bubbles in the right ventricle during laparoscopic cholecystectomy [49]. Since CO_2 is very soluble in blood, a large amount of it must rapidly enter the circulation in order to be clinically relevant. A known risk factor is hypovolemia. If serious gas embolism is suspected during the course of laparoscopic surgery rigorous measures must be taken. Gas embolism may present as profound hypotension, cyanosis, arrhythmias, and/or asystole. A grinding murmur can be found by auscultation of the heart. End-tidal CO_2 concentration suddenly increases, followed by an acute decrease due to cardiovascular collapse. Upon suspicion of embolism the following measures must be taken at once [50, 51]:

- Immediate deflation of PP
- Placement of the patient in a left lateral head-down position to enable the gas embolus to move into the right ventricular apex, thereby preventing its entry into the pulmonary artery
- Increase of minute ventilation and administration of 100% in-tidal O_2 to help eliminate CO_2
- Placement of a central venous catheter to enable aspiration of the gas
- Cardiopulmonary resuscitation must be performed in case of asystole
- Hyperbaric oxygen therapy may be used if available

Subcutaneous emphysema may be caused by gas passing through a disruption of the peritoneum into the subcutaneous tissue and into the retroperitoneal space. Its occurrence has been estimated at 0.3–3.0% [49]. From the intraabdominal and retroperitoneal spaces, the insufflated CO_2 can escape through the soft tissues around the vena cava and aorta into the mediastinum. In addition CO_2 may escape into the intrapleural space through congenital defects of the diaphragm or through accidental diaphragmatic injuries. The latter has been described during laparoscopic adrenalectomy and fundoplications [52].

Pneumothorax may occur during laparoscopy because of increased mean airway pressures and should be differentiated from "capnothorax" caused by CO_2 diffusion into the intrapleural space. The presence of subcutaneous emphysema should lead to the suspicion of capnothorax. End-tidal CO_2 concentration increases in both subcutaneous emphysema and capnothorax. Clinically significant capnothorax should be suspected when the mean airway pressure increases and SpO_2 declines. A chest x-ray then is required for diagnostic purposes. In contrast to a pneumothorax, the capnothorax generally does not require insertion of a chest drain because CO_2 is rapidly reabsorbed once PP is released.

Hemodynamic changes

Cardiovascular changes occur due to a combination of anesthesia, PP, and patient positioning. Many clinical studies of laparoscopic surgical procedures have characterized the influence of the different modalities on patient hemodynamics [45, 53–60]. Most studies reported increased systemic (SVR) and pulmonary vascular resistances (PVR) and a reduction of cardiac output when laparoscopy was performed with maximum IAP set at 15 mmHg or more in combination with reversed Trendelenburg position. Significant increases were also noted in mean arterial pressure (MAP), right atrial pressure (RAP), and pulmonary capillary wedge pressure (PCWP). At lower IAP the foregoing parameters change to a lesser extent. Interestingly, all measured variables usually return to preinsufflation values 30 min after the start of PP. Also, in healthy infants it was found that these same cardiovascular impairments completely reversed after peritoneal exsufflation without any clinically deleterious effect [61].

Hemodynamic changes during PP with the accompanying position of the patient are caused by a number of mechanisms. A quick rise in blood pressure, which is often seen at the start of PP, is mainly caused by an increased preload due to an increased venous return from blood compressed out of the splanchnic vasculature. Neurohumoral changes during PP may increase the SVR, which can lead to an increase in MAP. Induction of CO_2-PP also may lead to an increased plasma renin activity and increased antidiuretic hormone (ADH) production, which, in combination with the influence on the sympathetic system, may induce SVR elevation [53].

Hypotension is a rare complication that may occur during laparoscopic interventions. Generally this is induced by a high IAP in combination with IPPV. It should be remembered that high IAP in combination with the reversed Trendelenburg position reduces cardiac filling even further.

Insufflating the abdomen can provoke arrhythmias. Differentiation must be made between more innocent arrhythmias due to release of catecholamines, such as sinus tachycardia and ventricular extrasystoles, and more dangerous bradyarrhythmias such as bradycardia, nodal rhythm, atrioventricular dissociation, and asystole. These latter arrhythmias are generally caused by a vagal nerve–mediated cardiovascular response due to acute stretching of the peritoneum [47]. Carbon dioxide also may induce arrhythmias as it causes irritability of the heart. Most arrhythmias respond to a reduction in IAP and increase of minute ventilation with FiO_2 set at 1.0. Cardiac arrest associated with laparoscopy is caused either by a vasovagal response to rapid CO_2 insufflation into the intraperitoneal cavity or by gas embolism.

Since some of the pathophysiological mechanisms underlying a number of cardiopulmonary complications are well known, preventive measures can be taken. Preoperative volume loading (10–12 ml/kg) may prevent a decrease in CO that is induced by the IAP in combination with a reversed Trendelenburg position of the patient. Invasive hemodynamic monitoring or TEE may be necessary in ASA III and IV patients. Slow CO_2 insufflation will reduce gas embolism and avoids vasovagal response leading to collapse, cardiac arrest, and arrhythmias. Finally, it is recommended to apply the lowest possible IAP for each particular procedure. Extreme positioning should be avoided as it could influence cardiac function and ventilation and could cause peripheral nerve damage.

Renal physiology is influenced by PP, which may induce renal complications such as oliguria [62]. The following underlying mechanisms are considered: (1) compression of renal vasculature and parenchyma [63], (2) an increase of antidiuretic hormone release [64], (3) activation of the renin–angiotensin-aldosterone system (RAAS), and (4) a decrease of CO.

An inverse correlation exists between IAP and both renal perfusion and urine production [65–67]. Pneumoperitoneum with cool, room-temperature CO_2 has been shown to decrease not only core temperature, but urine output as well [68]. Warm (body-temperature) insufflation probably causes local renal vasodilatation and may be beneficial to patients with borderline renal function [68]. In conclusion, PP especially with high IAP may impair renal function. The best method for maintaining renal perfusion is preservation of an adequate intravascular volume load, before as well as during laparoscopy, with concomitant insufflation of warmed CO_2 for maintenance of PP.

The splanchnic circulation also may become compromised when high IAP is applied during laparoscopy. In healthy patients, increase in IAP from 10 mmHg to 15 mmHg significantly decreases blood flow, to the stomach by 54%, the jejunum by 32%, the colon by 4%, the liver by 39%, the parietal peritoneum by 60%, and the duodenum by 11%. Splanchnic blood flow decreases along with insufflation time [69]. The direct mechanical compression of the superior mesenteric artery and hepatic portal vein is the mechanism suggested in literature [69]. To prevent this possible complication, IAP should not exceed 8–10 mmHg.

Recovery period

Surgical injury induces a stress response characterised by profound endocrine-metabolic changes with hypermetabolism and catabolism, as well as an inflammatory response with activation of humoral cascade systems leading to malaise, hyperthermia, and immunosuppression [70]. Modern anesthetic and surgical care aims to reduce surgical stress responses, although the best way to modify such a natural evolutionary response is unclear [70, 71]. Various techniques are described for reduction of surgical stress responses, such as high inspired oxygen fraction postoperatively, application of peripheral nerve blocks, and prevention of hypothermia [72].

Routine postoperative care should consist of adequate monitoring of vital organ functions. This includes continuous monitoring of peripheral oxygen saturation, respiratory rate, ECG, and heart rate and rhythm. Intermittent measurements of blood pressure and urinary output are obligatory.

Advanced postoperative monitoring may be required in cardiovascularly debilitated ASA III and IV patients. If appropriate, this may include measurements of right atrial (RAP), pulmonary artery pressures (PAP), and cardiac index (CI) by means of a pulmonary artery catheter [55].

Monitoring of end-tidal CO_2 is important when prolonged laparoscopic procedures are performed, when high IAP is applied, or when extensive subcutaneous emphysema is present. Since up to 120 L of CO_2 can be stored in the human body during PP, prolonged postoperative mechanical ventilation may sometimes be needed until all extra CO_2 has been eliminated [73]. When extensive subcutaneous emphysema is present or when either capnothorax or pneumothorax is suspected, a chest x-ray should be taken. Since prolonged PP, especially at higher IAP levels, may cause oliguria, urine output must be followed carefully, the filling status of the patient monitored, and variables of kidney function measured. This is specifically important in patients with a borderline renal function.

The gut clearly plays a role in postoperative recovery. Laparoscopy has been shown to blunt the response in serum interleukin (IL-6), with no change in gut mucosal IL-6, as compared with open laparotomy [74]. Laparoscopy causes less trauma to the peritoneal environment by decreasing the inflammatory response of the gut as compared with open laparotomy. This different response may partially explain the more rapidly restored intestinal function following laparoscopy as compared to laparotomy [74].

Postoperative nausea and vomiting (PONV) is common after laparoscopic surgery. At present, the etiological mechanism is not quite clear. Among the possible causes are mechanical pressure to gut and stomach and stretching of vagal nerve endings in the peritoneum. Carbon dioxide may induce vasodilatation of the cerebral vessels, consequently raising the intracranial pressure (ICP). A raised ICP is a well-known cause of nausea and vomiting [75]. In many centers, prophylactic administration of antiemetics is routine. The safest or least expensive drug should be used first, with multiple interventions being reserved for high-risk patients [76].

Pain after laparoscopic surgery is multifactorial and may be quite intense. Many patients require opioid analgesia [77]. A number of measures can be considered for the management of postoperative pain. Among them are local anesthetic infiltration of port sites, avoiding IAP peaks and prolonged PP with high IAP, evacuating residual gas, and using preemptive analgesia.

Early postoperative complications, which should be recognized rapidly, are intraabdominal and/or retroperitoneal hemorrhage, capnothorax, capnopericardium, and pneumothorax. When extensive subcutaneous emphysema is present and extended to the neck area, respiration must be carefully monitored.

Conclusions and recommendations

Pathophysiological changes that may occur during and after laparoscopy are hemodynamic, pulmonary, renal, splanchnic, and endocrine in nature. These changes are basically caused by CO_2 pneumoperitoneum, anesthesia, and/or patient positioning. Pulmonary complications that may occur during laparoscopic surgery are barotrauma, pulmonary edema, atelectasis, gas embolism, subcutaneous emphysema, pneumothorax, pneumomediastinum, and pneumopericardium, whereas hemodynamic complications consist of changes in cardiac output, systemic and pulmonary resistance, and arrhythmias. Hypovolemia in combination with high intraabdominal pressure may lead to restrictive flow to vital organs such as kidney and the splanchnic area.

Good preassessment and anesthetic practice and adequate monitoring in combination with optimal communication between surgeon and anesthesiologist will see most patients through the extended laparoscopic procedure without complications. The elderly ASA III and IV patients, especially those with moderate to severe cardiopulmonary comorbidity, should be considered for invasive monitoring or monitoring by means of transesophageal echocardiography.

Postoperative care should be focused upon the specific complications connected with laparoscopic interventions, and the treatment of pain and PONV.

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